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“Precision farming e Agricoltura digitale”

Management Zones And Spatial Variability: A Framework For Developing Site-Specific Management Based On Understanding The Causes Of The Field's Variability

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Introduction

Precision Agriculture (PA) is becoming a popular practice in agricultural management with lots of new start-up and research funding moving in this area. Most of the focus has been on the computational/robotic part of PA with the agronomic management treated as the consequences of certain computational algorithms. In addition, most commercial companies use a single map taken by a drone prior to fertilization,, to make recommendations for fertilizer applicaton. However, there is no direct correlation between a spatial map (e.g. NDVI) and the amount of fertilizer to apply. If the spatial and temporal variability (and their stability through time) are not quantified, and the causes that lead to the field's variability are not understood, this approach will be unsuccessful.

In practice, the focus is dangerously shifting on areas that will not benefit the agronomic management. Therefore, the aim of this study is to demonstrate a first step for developing a novel PA framework for proper agronomic management. The main goal is to: translate spatial and temporal information into successful agronomic management. To do so, a systematic sampling of soil and plant for key parameters is required. Therefore, the objectives of this specific work are to:

a. sample soil and plant variables during the growing season to have a data-based evidence of the factors causing such variability.

b. Use this information to design a Support System to aid for Site-Specific Fertilization Management.

Materials and Methods

For this study, a real farm was used. The total size of the farm was 800 ha but only 10 ha were used for this study due to funding and personnel constrains. The farm is located in Coupar Angus (56^0 34' 04'' N; 3^0 10' 06'' W; 48 m a.s.l.) and is mainly growing winter/spring cereals, canola, potatoes, carrots. On the 10 ha, the rotation for the past 6 years was: winter wheat-winter wheat-spring barley-canola-winter wheat-winter wheat, and for the studied growing season (2018) spring barley. Yield maps were available for the last 6 years, as well as remotely sensed images collected by UAV (Unmanned aerial vehicles) using a Sequia 4x sensor with 4 spectral bands in the Green (530-570 nm), Red (640-680 nm), Red Edge (730-740 nm), Near Infrared (770-810). The six years of yield maps were overlayed to generate stable/unstable zones. In addition within the stable zones, a high, mid, and low stability zone was derived. Several approaches for defining those zones have been compared, such as the Fixed threshold, the Standard Deviation, the smoothing as discussed in details in Nawar et al. (2017). Spring barley was sown on 12th of April 2018 at 300 plants m^{-2} cultivar Concerto. One month before sowing an Electromagentic conductivity mapping (EM38) survey was carried out. In each zone a transect of points was traced, for a total of 25 points per zone, where the soil was sampled at 3 depths (0-30; 30-60; 60-90 cm). In addition, a regular grid of 38 points was established where the soil was sampled at only one depth (0-45 cm). For all these points the soil samples collected one month before sowing were analyzed for bulk density, water retention curves (laboratory), texture, nitrate, ammonium, phosphorous, potassium, cation exchange capacity, organic matter, soil moisture (gravimetric). One day before sowing another soil sampling was carried out, to measure soil nitrate, ammonimum and gravimetric soil water content. Fertilization was uniformily distributed after emergence when tractors tracks were visible. Three weeks after the fertilization the UAV was flown to collect the spatial images along with a soil sampling (nitrate, ammonium, soil water content) and a plant sampling (biomass, nitrogen). Future sampling dates planned for the growing season will be at flowering (soil and plant samples), and at harvest (soil and plant samples, plus yield components). A subsequent work will be to build a Decision Support System using an integration of prior information, data collected, and modelling tools.

Results

The farmer was using a private company to advise on the amount of site-specific fertilizer to apply. However, the above-mentioned approach failed to deliver any uniformity or increase in yield. Figure 1a showed what the commercial company proposed, when following the map-based approach using only one single NDVI (Normalized Difference Vegetation Index) map to identify nitrogen fertilization amounts.

Figure 1b shows the map as the results of 6 years of yield maps overlaid to identify the spatially stable/unstable zones. This is the first step, and the more systematic soil and plant sampling will help to understand the causes that lead to that spatial variability in the field.

The failure of the approach proposed by the company is also evident in the two UAV images acquired in the same year (2017) before and after fertilization (they were taken about 2 weeks prior and after fertilization) and the final yield map showing still some degrees of variability (Fig. 2). Where there was less N applied there was higher yield, while where there was more N applied there were lower yields.

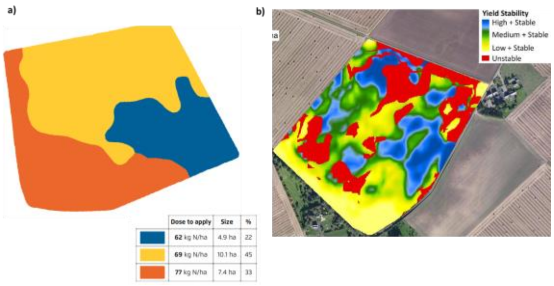

Figure 1. The field which is used in the study and (a) the recommendation map from the private company; and (b) the zoning made using the eabilityxisting information on past yield maps.

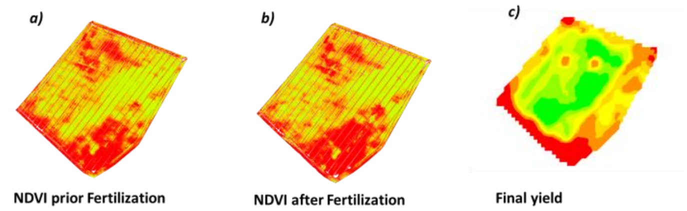

Figure 2. Spatial maps of the (a) Normalized Difference Vegetation Index (NDVI) before site-specific fertilization; (b) NDVI three weeks after site-specific fertilization; (c) grain yield.

Conclusions

A DSS for such production situation should be based on the understanding of the causes of spatial/temporal variability in order to optimize grain yield while minimizing the losses of fertilizer in the environment. But, the site-specific fertilization will only be made if it is economically viable (depending on the spatial/temporal variability). Otherwise, a uniform amount will be given but its total amount will be varied every growing season as the results of the DSS calculations (work planned for next year). In any case, the optimization of fertilizer will also help to minimize the losses of nitrogen in the environment. The use of drones and the development of a DSS based on the causes that lead to the spatial/temporal variability are two innovations that will help to deliver a novel technical innovation that will support a sustainable fertilizer management.

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Integrating Soil And Crop-Based Methods For Maize Variable Nitrogen Fertilisation

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Introduction

Nitrogen (N) is one the most important nutrients determining maize yield. Two main approaches can be used to tailor N supply considering field variability: management zones (MZ) delineation and crop N status monitoring during the growing season. Several studies demonstrated separately the advantages of these approaches on driving variable rate N application (VRA) in maize. This study aimed at verifying if their combination further improves the overall sustainability of maize cropping system.

Materials and Methods

The experiment was carried out in 2014 in three different experimental sites in Colorado (USA), located in Fort Collins, Ault, and Iliff. In each location, the trial compared four different N management strategies on maize cropping system:

- uniform N rate used by the farmer (UR);
- variable rate N management based on MZ (MZ);
- variable rate N management based on crop proximal sensing (PS);
- variable rate N management based on both MZ and crop sensing (MZPS).

Management Zone Analyst free software (Fridgen *et al*., 2004) was used to delineate MZ, isolating areas of similar productivity potential within the field. The UR received the farmer's conventional N amount uniformly distributed. The MZ approach reduced N supply where productivity potential was lower. The PS increased N rates when NDVI values were lower. The MZPS applied different N rates based on NDVI values, but increasing them according to the MZ. Greenseeker (Trimble©, Sunnyvale, California, USA) handheld active optical sensor was used to determine geo-referenced NDVI values. Grain yield was determined at harvest. The QGIS Software (QGIS Development Team, 2015) was used to link each observation to its productivity potential. The R software (R Core Team, 2016) was used for the statistical analysis, performing one-way ANOVA to evaluate significant differences in maize grain yield and PFP_N, determined as a ratio between grain yield and total N supply (Ladha *et al*., 2005).

Results

Table 2 reported grain yield obtained with the different N management practices.

Table 2: Grain yield (Mg ha^{-1}) obtained in the different locations with the four N management strategies

Treatment	Ault		Iliff		Fort Collins	
	Grain yield (Mg ha^{-1})	Mean N rate (kg ha^{-1})	Grain yield (Mg ha^{-1})	Mean N rate (kg ha^{-1})	Grain yield (Mg ha^{-1})	Mean N rate (kg ha^{-1})
UR	8.0 c	106	5.4 a	130	11.8 a	150
PS	10.0 b	71	4.3 b	98	11.6 a	113
MZ	10.9 a	71	4.5 ab	98	11.7 a	113
MZPS	9.7 b	71	5.2 ab	98	11.7 a	113

In Ault, variable rate N management increased grain yield with respect to conventional farmer's practice. Conversely, in Iliff, MZPS and MZ approaches slightly reduced grain yield with respect to UR. Moreover, N supply based on PS led to obtain a lower grain yield. In Fort Collins, maize grain yield was not affected by the different N management. However, in all locations, VRA strategies allowed to reduce mean N supply. Compared to UR, mean N supply was 33% lower in Ault, and 25% lower in Iliff and Fort Collins. Consequently, PF techniques might lead to a potential increase in PFP_N.

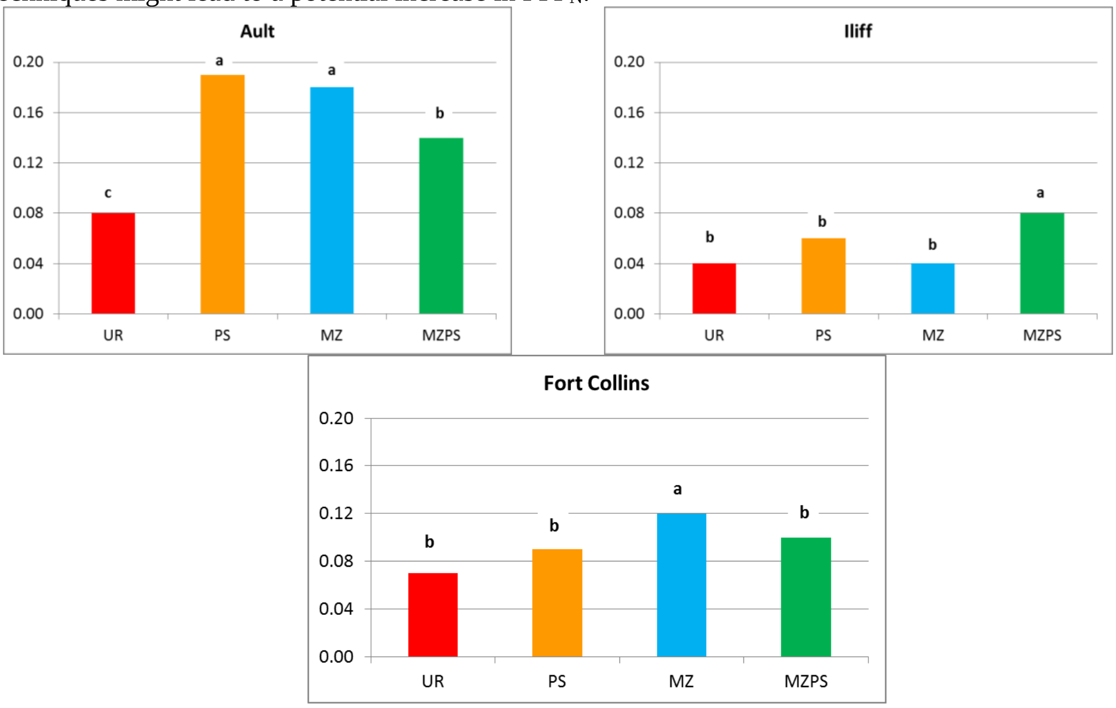

Figure 1: PFPN values for the different treatments, in the different locations

In Ault, VRA techniques increased PFP_N over UR, with PS and MZ approaches showing the highest improvement (+130%) (*Figure 1*). In Iliff, MZPS approach allowed to obtain the highest PFP_N value, that was almost twofold the other N management strategies. In Fort Collins, N supply based on MZ delineation increased PFP_N by 70% over UR.

Conclusions

This study confirmed the advantages of using VRA strategies in a farming contest. However, the best N management varied across the different locations, thus showing the importance of evaluating the best strategy in each agro-environment to increase PFP_N without compromising grain yield. Moreover, the results obtained in Iliff suggest that merging MZ and PS approach should potentially further improve maize fertilisation. Consequently, this approach needs to be tested in different agro-environment, also considering different N levels.

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Application Of A Satellite Based Approach To Monitor Rice Nitrogen Status And To Support Precision Agriculture Techniques

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Introduction

Nitrogen (N) fertilization plays a key role in rice productivity and environmental impact of rice-based cropping systems, as well as on farmers' income, representing one of the main cost items of rice farming. N use efficiency in rice paddies is often very low (about 30%) and operational tools and techniques able to increase N use efficiency can help farmers. Variable rate (VR) fertilization is considered a promising approach to face some of the criticalities involved with N use efficiency (Basso et al., 2016) by providing maps of N to be applied according to crop needs. To perform this action, it is necessary to assess the actual N nutritional status of the crop in relation to the phenological stage. Among the available approaches, Lemaire et al. (2008) proposed the use of N Nutritional Index (NNI) as a valuable indicator of crop condition. NNI is in fact the ratio between actual plant nitrogen content (PNC, %) and critical plant nitrogen concentration (Nc, %) as a function of crop biomass. However, the application of NNI in real case condition can be limited by the need of destructive field data. As a potential solution, it is possible to exploit earth-observation (EO) data for the indirect assessment of the crop variables. This approach is the base of the French system for wheat fertilization support FARMSTAR (Blondlot et al., 2005). Other authors implemented such approach by calibrating Vegetation Indices (VIs) maps, derived from satellite imagery, with field observation in order to create crop parameters maps (Huang et al., 2015). This approach resulted efficient but requires time-consuming field activities. New alternative approach was recently proposed to get field data, needed for NNI computation (LAI and PNC), in a quick and inexpensive way using sensors available on smartphones (Confalonieri et al., 2015). Starting from these experiences, we developed an operational workflow devoted to generate NNI maps by exploiting EO-based smart scouting to drive and optimize field measurements to collect relevant field data with smartphone apps (Nutini et al., 2018). The present contribution describes the fundamental steps of the method and its application in the 2018 rice season as a support for site-specific fertilization in precision farming contexts.

Materials and Methods

The method described in detail in Nutini et al. (2018) was developed in the framework of ERMES project (www.ermes-fp7space.eu) analyzing field and satellite data acquired in 2016. The study was conducted in Italy in Pavia province, in the main European rice district. Field measurements were conducted in four fields (covering an area of about 20 ha), exploiting smartphone apps to collect LAI and PNC data on specific locations previously identified analyzing EO images. VIs values extracted from images in correspondence of field measurements were used to calibrate predictive regression models to map PNC and LAI. From these maps, NNI was then calculated for the monitored rice paddies identifying areas of N deficiency or luxury consumption.

From these achievements, the SATURNO project (progettosaturno.it) was proposed in the framework of Regione Lombardia FEASR - PSR 2014-2020 program (Programma di Sviluppo Rurale Misura 1 - Sottomisura 1.2. - Operazione 1.2.01). Project activities involve the application of the workflow in an operational way for the 2018 crop season. Demonstrations are conducted on six fields (about 32 ha overall) where field data are acquired with apps and automatically integrated with Sentinel-2 imagery in order to produce NNI maps in near real time (NRT). These maps, together with information on soil properties, are analysed by expert agronomist to define site-specific N prescription maps to be used with VRT machinery.

Results

Figure 3 presents the operational workflow tested in 2016 for producing NNI maps using high-resolution satellite images (i.e. Rapid Eye and Sentinel-2) and ground-based LAI and PNC data collected using smartphone apps. The satellite images were acquired in the first week of July in order to match the phenological phase of panicle initiation that is the most important moment for N top cover fertilization. Satellite data analysis was performed to identify within field location with different condition. This information was used to guide a smart scouting (left panel, step one) in order to collect data covering a wide range of crop growing conditions, as showed by the range of LAI and PCN data collected (from 2.13 to 5.14 and 0.1 to 2.5 respectively). This result demonstrate how the procedure is useful in identifying field points with different plant size and nutritional status. The VIs with the highest correlations with ground data were selected to define the empirical models (central panel, step two) for deriving LAI and PNC maps. NNI map are then derived by comparing each field value with those provided by dilution curve (right panel, step three). Most patterns of NNI maps were coherent with the available information on soil texture and performed agro-practices as well as with field observation on crop status; hence, the proposed approach was considered promising for producing time- and cost-effectiveness information for precision farming application.

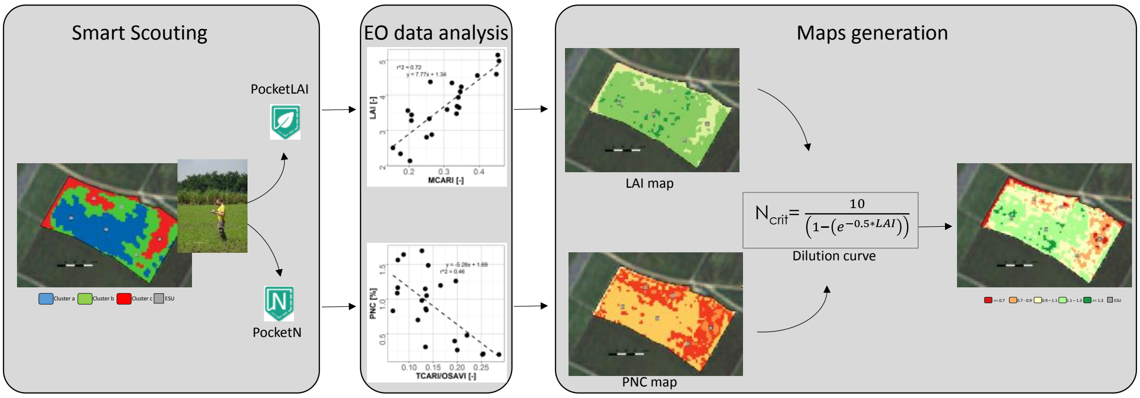

Figure 3- Flowchart of the methodology adopted to estimate NNI. From left to right: Step one - Satellite-aided smart scouting activities to collect representative field data (LAI and PNC), Step two - analysis of satellite data for empirical model development and Step three - computation of NNI maps. Figure shows, as an example, one field out of the four monitored in 2016. Derived from Nutini et al. (2018).

From experiment to operational demonstration

First phase of SATURNO project allowed to define the data-information-action workflow that defined how to *i*) collect field data, *ii*) analyze automatically EO data and *iii*) provide spatial explicit information in NRT to the expert in order to create prescription maps for top cover VR fertilization. Moreover, during winter/spring of 2018 technological WEB tools were implemented to disseminate in NRT crop related information (saturno.get-it.it).

The real case demonstration involves three main steps (Figure 4): *i*) monitoring rice development and status with EO data and crop model *ii*) acquiring field data according to smart scouting procedure and maps generation via regression models to asses NNI and *iii*) analysis of data for prescription map production and VR application. The procedure is planned to be performed few days before every fertilizations (usually at beginning of tillering – about June - and at panicle initiation – about July) in order to supply info on rice N status to farmers and agro-consultant. In detail, phenological estimation from WARM model are disseminated through the project website (saturno.get-it.it/bulletin/) to help farmers of the study area in detecting the best timing for top-dressing fertilization. Satellite data are downloaded and processed providing multitemporal VIs in order to allow spatio-temporal monitoring of rice growing (saturno.get-it.it/maps/185/view). Soil sampling were conducted in January 2018 to provide the fundamental source of information necessary to make fertilization prescriptions. This info, supplied in time to farmers, represent the fundamental support to create site-specific N prescription map to be applied with VR machineries. The project foreseen to collect at the end of the season, yield maps exploiting combine harvester in order to evaluate the effects of the adopted methodology in term of production and economic and environmental sustainability.

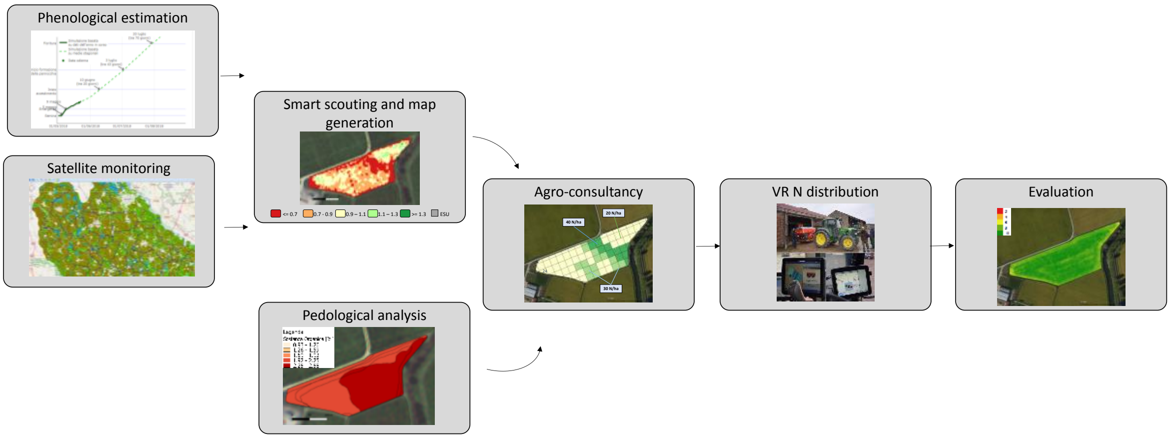

Figure 4- Flowchart of the methodology adopted to use NNI map in precision farming framework.

Conclusions

The study aimed to demonstrate unbiased and cost-effective tools able to support site-specific fertilization. This study revealed the feasibility, under real farming conditions, of a workflow for the production of NNI maps right after satellite image acquisition, using smart scouting techniques and smartphones. NNI maps generated with the above-described method can be used to lead fertilization activities by supporting the determination of N amounts according to actual plant nutritional status.

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Poster

“*Precision farming* e Agricoltura digitale”

Heat And Drought Effects On Barley In The Mediterranean Basin: A Simulation Study

Davide Cammarano[1], Domenico Ronga[1,2], Nicola Pecchioni[2], Enrico Francia[2], Alessandro Tondelli[3], Fulvia Rizza[3], Franz W. Badeck[4], Orazio Li Destri Nicosia[5], Taner Akar[6], Stefania Grando[7], Adnan Al-Yassin[8], Abdelkader Benbelkacem[9], William T.B. Thomas[1], Fred van Eeuwijk[10], Ignacio Romagosa[11], A. Michele Stanca[2]

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Introduction

Barley (*Hordeum vulgare* L.) is a cereal that is globally cultivated, across a multitude of environments and input conditions, growing in areas where other cereals would not. In Southern Europe both wheat and barley yields have stagnated in the recent decade (Dawson et al., 2015). Such effect is likely due to climate change and future projections for the Mediterranean basin indicated an increase of warm and dry periods (Giorgi and Lionello, 2008). Agriculture is very sensitive to both climate change and climate variability especially during key growth stages within the growing season where, depending on crop type, heat and drought can cause negative impacts on crop yields (Cammarano and Tian, 2018).

In this study we aim at understanding the projected impact of heat and drought on barley grown in the Mediterranean basin.

Materials and Methods

A generic barley cultivar was calibrated and evaluated using the published dataset from Francia et al. (2011) where a total of 8 locations from 8 different countries were selected. Of these, 3 of them were considered for model calibration because of the irrigated plots and the remaining for independent model evaluation. The model used was DSSAT v4.7 (Hoogenboom et al., 2010). One year of weather data was available which was integrated with a 30 years of historical weather data from NASA-AgMERRA dataset (Ruane et al., 2015). The choice of one Global Climate Model (GCM) for all the locations was not considered because a site-specific GCM would better suit the aim of the study. Therefore, for each location 40 GCMs were compared respect to the 30-years of historical weather and 3 where chosen (a hotter and dryer, hotter and wetter, and middle). Each GCM was generated using the RCP4.5 and 8.5 with a corresponding level of atmospheric CO_2 of 499 and 571 ppm, respectively. The projections were calculated following the approach of Yin et al. (2013). The GCM runs are not shown in this study but only the results of the baseline run. The crop model was run with the management reported in Francia et al. (2011) but with 8 different sowing dates to cover the barley planting window at each location (starting from the mid of Sept until the mid of Jan; S1 to S8).

Results

The comparison between observed maximum temperature and AgMERA product is showed in Fig. 1.

Overall, there is a good agreement, and this is true also for the other weather parameters used by the model (solar radiation, minimum Temperature and rainfall). The crop model was able to pick the trends of phenology and yield for both the calibration and evaluation dataset (data not shown). The climate variability (historical 30 years of weather data) showed some effects on anthesis date (not shown) and maturity dates (Fig. 2) at each location with later planting showing little variability.

Also, as barley was planted later the days to maturity reduced. Simulation of the soil water content for each growing season showed how in some location and for some year it might not be enough to support an optimal expansive growth causing water stress and yield reduction.

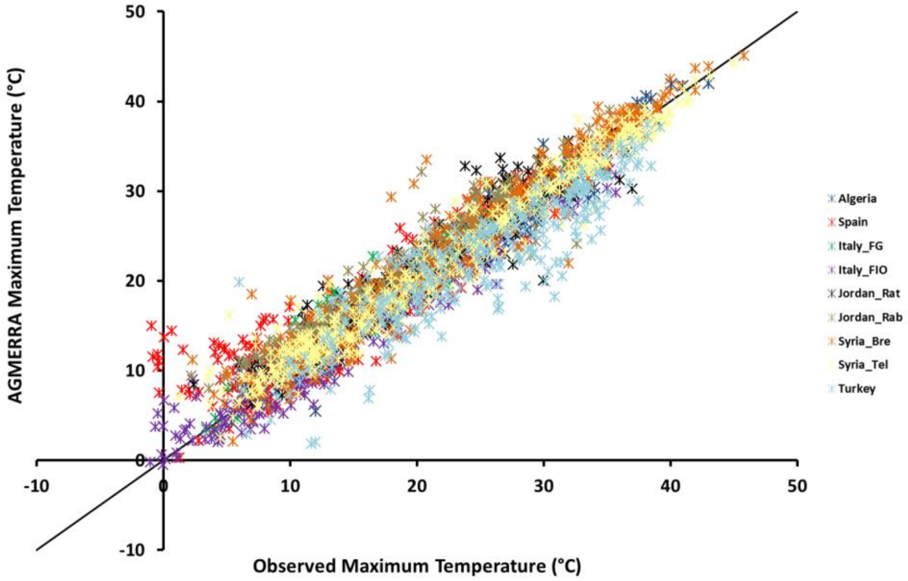
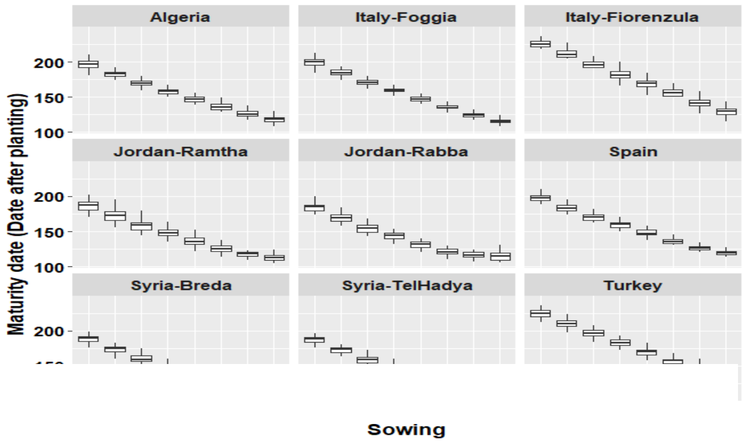


Figure 1. Observed vs. AgMERRA daily maximum Temperature.



Conclusions

These preliminary results show how the simulated data could integrate field research in understanding and quantifying the impacts of heat and drought stresses. Additional runs are scheduled for running the model with climate projections to understand the impact of climate change on the sustainability of barley production in the Mediterranean basin.

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Investigating The Roles, Institutions And Potential Markets For Operationalizing Services To The Irrigation Sector: Opera Project

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Introduction

Agriculture must adapt to the impacts of climate change and improve the resilience of food production systems in order to feed a growing population with less water. Climate change will bring greater variation in weather events, more frequent weather extremes, and new challenges requiring the sector to take mitigation and adaptation actions.Worldwide significant progress has been made to utilize precision irrigation as a means to increase water use efficiency or decrease the water footprint in irrigated agriculture. The progress is mainly restricted to advances at the plot scale and individual systems, such as installations for drip irrigation or central pivots. In this context, innovative ways for efficient use of water in agriculture, including precision irrigation techniques and making use of models, sensors and information and communication tools are needed. Among the main objectives are: a) to identify ways for operationalizing management of water scarcity and drought, b) to identify specific market driven, farmer demands for producing alternative crops and to relate operational services that bring precision irrigation for such crops and production system into practice.

Materials and Methods

One of main activities in OPERA will be the conceptualization of practical service models, through the investigation of roles, institutions and potential markets for operationalizing services to the irrigation sector capable of providing benefits to the user community.

This activity will be led by CREA through the following steps, and starting from Italian case study activities (Fig. 1a and b) :

- Elaboration of a business model by identifying business roles of the system, defining the relationships and building the overall business model framework to establish operative and self-supportive downstream service activities with the user community of irrigation water management.
- Analysis of the importance of technological innovation in the agricultural water management, using choice experiments (CE) for identifying preferences of the farmers, and the analysis of marginal willingness to pay for the service.
- Socio-economic assessment of service scenarios. It includes cost-benefit analysis for a range of users, economic valuation and an assessment of socio-economic impacts.
- Framework for socio-economic assessment and business development. This includes the definition of an overall methodology for socio-economic assessment of irrigation schemes applicable to different contexts/situations.

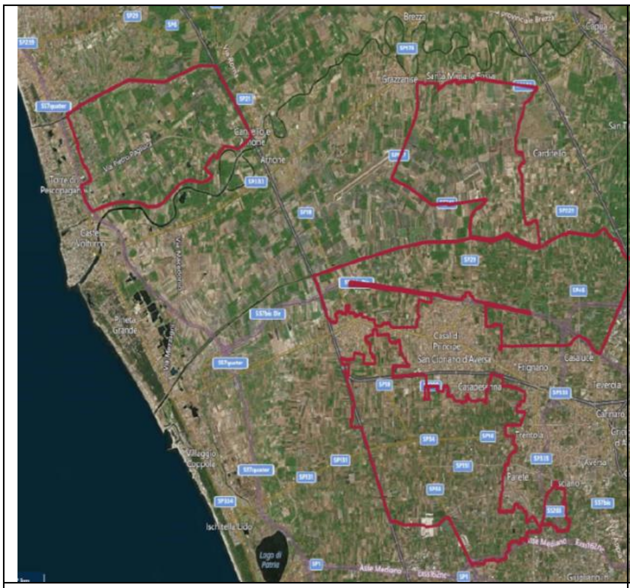

Fig. 1a. Italian case study – Campania region

Fig. 1b. Pilot area OPERA – Campania Region

Conclusions

Overall the strive of OPERA is to elaborate a practical concept that can support future service providers in delivering more robust decision making support, particularly under the anticipation of climate variability and critical moments of water scarcity. On a larger scale, this information can be used to support drought management decisions.

The mid term and long term benefits will result mainly from realizing a better advisory service in the agricultural sector that can lead to a better water demand management, to avoid harvest losses, needless over-irrigation and to a more healthy socio-economic development in the rural farming areas in times of water scarcity and drought.

Acknowledgements

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The Use Of Unmanned Aerial Vehicles In Agricultural And Forestry Studies: A Bibliometric Analysis

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Introduction

The origins of the Unmanned Aerial Vehicles (UAV) or Remotely Piloted Aircraft System (RPAS), commonly known as drones, can be attributed to military research; the multiplicity and diversification of uses have obviously influenced the forms, the technical characteristics and the typology of devices on board (Sayler, 2015). As for non-military uses, drones can be classified as "fixed wing", "rotary wing" and "hybrid" vehicles, with take-off mass (MTOM) ranging from a few tens of grams up to 25 kg and over. Also the progress made in the field of sensors, in particular regarding the miniaturization of devices finalised to reduce the load weigh to be transported (i.e. payload), has allowed to equip the UAV with various sensors: high resolution digital cameras, multi-spectral cameras, LIDAR, sensors for air quality monitoring, as well as devices for transporting and distributing agricultural products, sanitary facilities, commercial products, etc. The advanced technology of modern UAVs also contribute to makes easier and safer the remotely control which today get advantages by the satellite Global Positioning System (GPS), as well as by intelligent anti-collision systems able to automatically avoid any obstacles on the route. In this perspective, the aim of this work is to explore the role of UAVs in agricultural and forestry studies by means of a bibliometric analysis.

Materials and Methods

Data were collected from the Elsevier Scopus database, based on articles published in English language, from 1995 to 2017, and on the subject area of Agricultural and Biological Sciences, and Environmental Science. The main terms of search were “uav” and “uas”; we excluded terms, subject areas and journals about military, medical, engineer, archaeology, marine, hazard, chemistry, architecture, veterinary, zoology and entertainment topics. We derived 414 documents. A first analysis was performed according to the Scopus statistics on all the publications retrieved from 1995 to 2017. A second analysis was performed on the most used keywords and scientific concepts in UAV-based agriculture and forestry studies. To this aim, we used a science mapping approach and focused only on years with more than 40 publications, i.e. from 2013 to 2017. Science mapping is a key research topic in the field of bibliometrics (Van Eck & Waltman, 2010), the workflow is divided into several phases: data recovery, pre-processing, network extraction, normalization, mapping, analysis and visualization (Börner, et al. 2003). For the science mapping, we used the VOSviewer software (www.vosviewer.com). To analyze keywords, we used a Co-occurrence analysis with a threshold of 10, that is how many times a keyword have to occur in a given dataset to be used in the analysis. By running the network analysis, a relevance score will be calculated for all keywords, then the clustering technique will identify groups of related keywords (Waltman, et al., 2010).

Results

In the period analyzed (1995-2017), Scopus search identified 414 scientific publications, with a gradual increase in the number of UAV-based scientific articles from the 2003. The Countries of origin of authors for which at least one publication related to UAV research was produced are 56: USA published most articles (37%), followed by China (11.34%), Spain and Italy (11% each one). The top 5 journals about UAV-based agriculture and forestry research, from 1995 to 2017 were: SAE Technical Papers (17.9%), GIM International (7.8%), Remote Sensing of Environment (5%), Computers and Electronics in Agriculture (3.8%), Precision Agriculture (2.8%). Results highlighted that the various scientific organizations do not cooperate with each other, except for: University of Rome La Sapienza (Italy), Clarkson University (USA), Politecnico di Torino (Italy) and RMIT University (Australia). Figure 1 shows the keywords mapping network which provided 3 clusters. The “agriculture” cluster is characterized by the terms: agriculture, cost effectiveness, crops, data acquisition, GPS, image classification, multispectral, precision agriculture, sensors, spatial resolution, UAV, vegetation index. The “forestry” cluster is composed by the keywords: forestry, 3d-modelling, lidar, monitoring, photogrammetry, radar, remote sensing, satellite imagery, structure from motion, survey. Finally, the “methodological” cluster involves the terms: mapping accuracy, algorithms, assessment, data-set, image processing, vegetation.

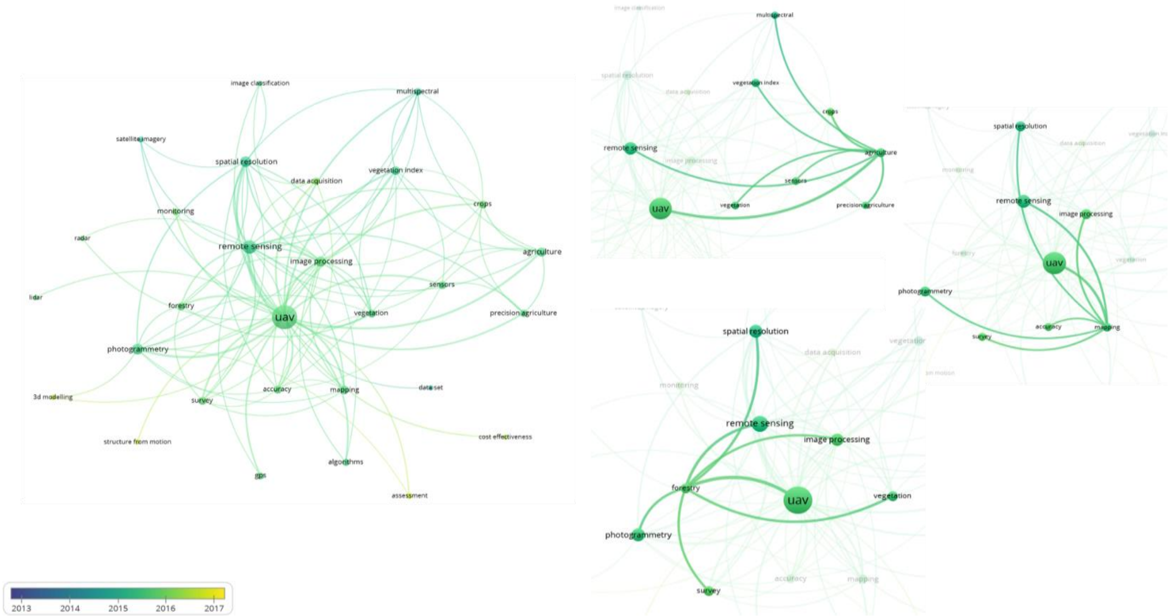

Figure 1: Network map of the main keywords in UAV-based agriculture and forestry scientific studies (right) and focus on the core term connections of the three clusters identified (left).

Conclusions

Science mapping is an emerging research field that enables to frame the topic of interest at national and international level, as well as in a multidisciplinary view point. Furthermore, it allows to highlight research gaps and overlaps within the same research topic. Our study showed that agriculture and forestry exploit different aspects of UAV technologies: the former mainly focused on multispectral data for vegetation status detection, fine-scale information and cost effectiveness, while the latter on laser and radar data for canopy structural analysis, trees inventory and monitoring. Finally, a key research topic, transversal to the previous ones, is the accuracy assessment in UAV-based mapping efforts.

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Yield Mapping In Chickpea Adopting A 3d Machine Vision Approach

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Introduction

Precision agriculture is a farming management concept based on the application of advanced technologies able to improve agricultural crop productivity and reduce environmental impacts through quantitative and qualitative information on field site-specific variability. In this view, remotely sensed data on phenotype, crop yield, canopy geometries and growth parameters enables fast, non-destructive and relatively cheap crop characterization, and provides useful information on crops (Mulla, 2013). Currently, the amount of above-ground biomass is estimated by time consuming procedures of weighting samples, whereas the plants' 3D shape is achieved by various methods (such as laser scanning, time of flight cameras or structured light approaches) which requires huge investment costs. In recent years, with the boost in computational power, photogrammetric approaches, through the crop '3D point cloud reconstruction', are emerging as a cost effective way to collect data, with many advantages over the traditional form reported above, even if it requires heavy post-processing procedures. The present study applied the structure-from-motion with photogrammetric approach from Unmanned Aerial Vehicles (UAVs) images for 3D reconstructed chickpea plants' volume in order to quantify the biomass yield under open field conditions.

Materials and Methods

An open field experiment was carried out on chickpea cultivated in Leonforte (37.59 N, 14.37 E, 460 m asl, Enna, Central Sicily). Plants density was approximatively 30 plants m^{-2} with an inter-row distance of 1.45 m.
The UAV platform used in this study was a Phantom 4 Pro (DJI, China) equipped with a stabilized RGB camera 1"CMOS 20Mb and an onboard Global Navigation Satellite System (GNSS). The images were taken at crop harvest (16/06/2018) at noon of a full sunny day to reduce any shadowing effect. The photogrammetric software Pix4DMapper (Pix4D, Switzerland) was used to derive the Digital Surface Model. The PC used for processing was a MS Windows7 64-bit system with 8 GB of memory and 4 cores of 2.5 GHz.
To investigate the accuracy and the precision of 3D point cloud reconstruction, UAV images of 26 black cylinders targets (∅ 22 cm, height 48 cm, volume 18.24 Litres) were acquired with different flight settings: 15, 20, 30, 50 m above ground flight height; grid and double grid mission. Root-mean-square-error (RMSE), Relative RMSE (RRMSE) and bias indicators were calculated (Miller et al., 2015):

$$RMSE = \sqrt{mean(r-t)^2}\ ; \qquad RRMSE = RMSE/t; \qquad bias = \frac{\sum_{i=1}^{n}(r_i - t_i)}{n}$$

where *r* (reconstructed) is the 3D point cloud reconstructed volume, and *t* (true) is the true target volume.
The chickpea biomass fresh weight was measured in 44 rows sections of different length (from 0.5 to 3.5 m). Immediately before harvest, the rows were photographed from the UAV, and the corresponding 3D reconstructed canopy volume and mean height were calculated. The biomass of 22 georeferenced rows was linearly regressed *vs* 3D reconstructed row section volumes (calibration process), and the obtained regression coefficients were then applied to the remaining 22 reconstructed volumes to obtain estimated biomass fresh weight (validation process). The accuracy of biomass estimates were assessed by means of RMSE and linear regression approach.

Results

The double grid mission coupled with an UAV flight altitude of 15 m, resulted in the highest accuracy of cylinder targets volume estimation, with RMSE of 1.78 Litres (9.8%), whereas, a negative bias (-1.46 L) revealed that 3D reconstruction had a tendency to underestimate the volumes. The flight settings of 30 and 50 m did not allow 3D point cloud reconstruction.

Table 1 – Main images processing details and accuracy assessment of cylinder targets volume estimation

Flight settings	***15 m***		***20 m***	
	Grid	***double grid***	***grid***	***double grid***
Area Covered (ha)	0.39	0.80	0.41	0.61
Dataset (n. of images)	71	239	36	97
Time for image 3D processing (h)	3:09:44	14:23:18	1:32:31	6:00:35
RMSE (Litres)	3.52 (19.3%)	1.78 (9.8%)	8.31 (45.6%)	3.65 (20.0%)
Bias (Litres)	-0.51	-1.46	-6.56	-3.50

RMSE is reported in absolute (Litres) and relative (*vs* Target true volumes) values

The 3D reconstructed chickpea crop volumes correlated strongly with fresh weight biomass values (adjusted R^2= 0.96, Fig. 1A). The obtained regression model was applied to calculate the above ground biomass fresh weight, and then the estimated values were compared to the measured ones (Fig. 1B), obtaining a highly significant degree of correlation (r=0.975***). Similar results have been obtained comparing 3D reconstructed and measured canopy height (Fig. 1C).

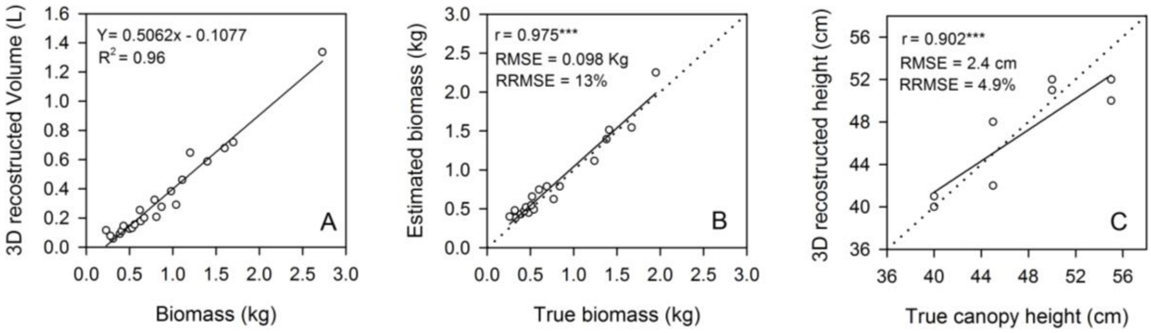

Fig. 1 – Relationship between biomass weight and 3D reconstructed volume (A), true and estimated value for fresh biomass (B), and true and 3D reconstructed canopy height (C)

Our results demonstrated the reliability of the photogrammetric approach for the rapid estimation of crop biomass in chickpea, and obtained good agreement between measured and calculated.

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Use Of Radiometric Techniques To Monitor Phenological Response Of Fourteen Ancient Wheat Varieties To Different Agronomic Management: Preliminary Results

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Introduction

Recent studies demonstrated that ancient wheat varieties, such as Verna, Gentil Rosso, Frassineto, and Andriolo, seem to have health benefits with respect to modern cultivars of common and durum wheat. In particular, the high nutraceutical value in grains, due to the presence of polyphenolic compounds and their antioxidant action, is increasingly requested by consumers. Hence, the re-introduction of ancient varieties may be a valuable opportunity for meeting the needs of both farmers and consumers, offering local products respecting the cultural traditions of the region. As stated by Heimler et al. (2010), wheat productivity, jointly with the phytochemical profile of the grain and the cultivar itself, are strongly influenced by both the pedo-climatic conditions of the cultivation area and by the agronomic technique. In recent years, in addition to in-field measurements, the use of unmanned aerial vehicles (UAVs) has become an essential tool in crop phenotyping (Liebisch et al. 2015). High resolution images allow a fast characterization of all plots in an experimental field, while minimizing the potential rapid change in environmental conditions. This research aims at assessing the effects of climate and of the agronomic techniques, in terms of sowing density and N fertilization, on biomass accumulation and the phenological dynamics of fourteen ancient varieties of winter wheat.

Materials and Methods

The field experiments started in November 2017 in Cesa (Arezzo), Tuscany, Italy (43.31° N, 11.82° E, 45 m asl). The soil is a clay loam, and the 0–30-cm layer contains 11.3 g kg^{-1} total organic carbon, 1170 mg kg^{-1} total nitrogen (N), 20.7 mg kg-1 available phosphoric anhydride (P_2O_5), and 209 mg kg^{-1} exchangeable potassium oxide (K_2O). Air temperature and humidity data are registered by a weather station located in the experimental fields. Fourteen ancient genotypes of common wheat (*Triticum aestivum* L.) are compared to the modern cultivar Bologna. The experiment includes 90 treatments, which are the combinations of fifteen wheat cultivars, three N fertilization levels, i.e. 28, 78 and 128 kg N ha^{-1} (N1, N2 and N3), and two seeding rates, i.e. 200 and 350 seed m^{-2} (D1 and D2). The experimental design is a strip-strip-plot design. Each strip (main plot) is divided longitudinally in the two different seeding density and, transversally, in the three N fertilization levels (subplots). Seeds were sown on the 22nd November 2017. Field surveys were performed to collect phenological data for each subplot at emergence, tillering, stem elongation, booting, anthesis, and harvested product following the BBCH scale (Meier, 2001). In particular, the BBCH scale was used for defining the Julian Day of anthesis (BBCH=61) for each cultivar, and elaborated on the basis of the growing degree days with a cutoff of 0 °C (GDD_0). The monitoring of the cultivars includes: NDVI data measured for each sub-subplot by the Green Seeker handheld crop sensor (Trimble Inc., Sunnyvale, CA); the chlorophyll content in leaves, assessed for each sub-subplot by the use of the SPAD 502 Plus Chlorophyll Meter (Spectrum Technologies Inc., Aurora, IL). For the remote sensing data, the UAV prototype described by Di Gennaro et al. (2017) was used. The UAV was equipped with a modified Sony DSC-QX100 20Mpx RGB camera (Sony Corp., Tokyo, Japan). Digital images of the experimental field were collected during a flight campaign on May the 16th 2018 between 11:30 and 12:30

a.m. under cloudy sky conditions. Digital images have been processed following the workflow suggested by Matese et al. (2016) in order to reconstruct the orthomosaic (using the software Agisoft Photoscan, http://www.agisoft.ru) of the experimental field. Statistical comparisons were performed with ANOVA. Then, pairwise comparisons were assessed using the post hoc Tukey's HSD (honest significant difference) test.

Results

The varieties Acciaio, Autonomia A, Autonomia B and Mentana were the earliest in reaching flowering stage (BBCH 61), while Gentil Rosso and Inallettabile resulted to be the latest. The modern cultivar Bologna showed a shorter growing season of about 4 days, while Inallettabile required 9 additional days. The effect of sowing density, N levels and cultivars on the radiometric response gave the following results: the modern cultivar showed NDVI values significantly lower than those of all the ancient varieties until booting. However, in the flowering phase, differences were no longer statistically significant. No significant differences in NDVI values were found among the ancient varieties between the booting and the flowering phase. Significant differences in NDVI values were observed, at flowering, for N1 with respect to N2 and N3. Nitrogen doses above or equal to 78 kg N ha^{-1} did not show significant differences, regardless of the seeding density and varieties. As regards the sowing density, significant NDVI differences were found for Acciaio, Bianco nostrale, Frassineto, Gentil Rosso Aristato and Mentana, while no significant differences were observed between the two densities for the other varieties. The images taken by the UAV show a strong percentage of lodged wheat. In particular, D2 was always more lodged than D1 and N1 was always less lodged than N2 and N3, that showed similar percentages. Preliminary results show that: varieties showing less than 25% of wheat lodged in D1 and N1 are Autonomia, Verna, Autonomia A, Inallettabile and Acciaio; varieties showing more than 70% of lodging, regardless of the amount of N supplied and sowing density, are: Gentil Rosso Mutico, Andriolo, Gentil Rosso Aristato and Gentil Bianco. The modern cultivar Bologna did not show any lodging.

Conclusions

Preliminary results show that once the NDVI saturation is reached, differences are no longer significant. This might be explained by the different radiometric response since many factors may affect the values, such as the color of the ears, the presence of the awns, the presence of plant diseases, the different concentration of pigments in the leaves. Ancient cultivars seem to be more vulnerable to lodging probably due to their greater height (125 cm) compared to the modern Bologna (85 cm).

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A Simplified Approach Of Phenotyping Platform For Crop Monitoring

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Introduction

The study of crop phenotypic responses represents one of the most important agricultural challenge for understanding the main dynamics of plant growth and improving crop yield under different environmental stress levels (Araus and Cairns, 2014; Furbank and Tester, 2011). However, the traditional methods for monitoring the main phenotypic traits are often destructive, laborious and time consuming. Accordingly, current researches aim to develop new, non-destructive and time saving approaches such as ultrasonic sensors (Finkelshtain et al., 2017), laser scanner systems (Thapa et al., 2018) and digital photography techniques (Moriondo et al., 2016). The use of high resolution images, for example, represents an interesting approach for capturing a wide range of information that allow to reproduce the main morphological traits at high resolution level. Currently, phenotyping platforms are considered one of the most innovative systems for a complete and accurate analysis of plant parameters under different environmental stress (Hartmann et al. 2011; https://www6.montpellier.inra.fr/phenoarch). However, the complex structure, the high cost and the power consumption of the platform restrict the use of the system under many conditions. Building on these premises, this work shows the implementation of a simplified and low-cost phenotyping platform for crop monitoring.

Materials and Methods

The simplified approach of a phenotyping platform proposed in this study consists of a slider rail for camera moving which is able to capture several images of plants positioned on ten automatic turntables (Fig. 1). This structure is constituted of 1m round bars on which a specific moving and rotating (360°) support for the camera. An automatic system moves and positions the camera in front of each turntables for capturing the images. Inside of each turntable and at the beginning of the platform, the stepper motors allow the rotation and the moving of the system.

Beside the mechanical parts, platform moving is driven by the electronic components (i.e. Arduino modules) that determine the rotation steps and speed of the turntables allowing to obtain a satisfactory identification of the plant profile for future 3D reconstruction. Moreover, the platform is equipped with a manual or timer activation for managing different time beginnings of the experiment. Finally, the support system and the turntables are realized through the Prusa i3 3D printer and the program for phenotyping platform has been written in C++ language using Arduino software.

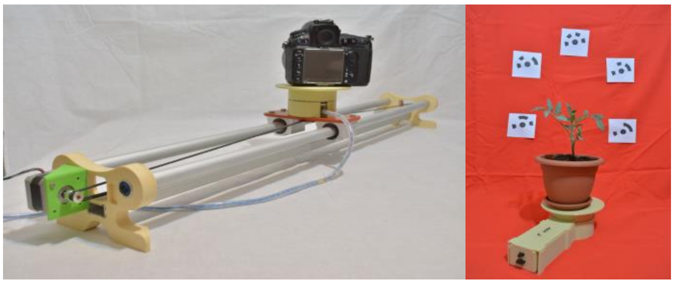

Figure 1 Slider rail with camera (a) and turntable (b) for 3D reconstruction.

Results

The phenotyping platform is currently equipped with the slider rail for moving camera, ten turntables, the timer for platform activation and the recharge battery boxes for soil water sensors. The next steps are:

Phenotyping platform implementations

Future platform implementations arefocused on the introduction and calibration of soil moisture sensors for evaluating water dynamics. These soil moisture sensors will be positioned on each turntable and they will be equipped with the individual battery recharge system. Moreover, the implementation of a wifi system is expected for an automatic and simultaneous collection of the data available for future elaborations.

Phenotyping platform application

The phenotyping platform will be used for crop monitoring and for evaluating the main morphological parameters (e.g. leaf area, inclination, azimuth) under stress conditions (e.g. water stress, nitrogen stress). Accordingly, the experiment will be performed in a controlled environment in which the main weather variables will be constantly monitored. Crops with high economic importance (e.g. wheat, soybean, tomato) will be analysed under different treatments of water supply (e.g. water provision: 50 and/or 25% of the evapotranspiration) and/or nitrogen supply (e.g. optimal and suboptimal amount). The images captured by the platform will be elaborated through software for 3D images reconstruction (Agisoft PhotoScan, CloudCompare, etc.).

Conclusions

The implementation of a simplified and low-cost phenotyping platform represents an opportunity for monitoring and analyzing the main phenotypic traits of the crops. Thus, this study shows a first step of platform implementation with the development of the electronic and mechanical system for the automatic monitoring of ten different potted plants (one per turntable). Future steps will be focused on the wifi system test and on the calibration of the soil moisture sensors. After the platform implementation step, the system will be used for monitoring different valuable crop species.

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Use Of Crop Model And Seasonal Weather Forecasts For Optimizing Wheat N Fertilization: Preliminary Results Of The Ager Project

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Introduction

Nitrogen (N) fertilization on wheat crops has been commonly applied based on the maximization of yield production of high quality. However, spatial variability of the field fertility, which can be measured by remote sensors, has been rarely taken into account. When the amount and availability of soil nitrogen (N) varies, a precision N management approach should be applied (Pierce and Nowak, 1999) aimed at optimizing fertilizer inputs while reducing within-field yield variability. The development of a system for the in-season prediction of the quantitative-qualitative characteristics of the production based on the coupling of crop models with seasonal weather forecasts and remote sensing represents a great opportunity to achieve this goal by adjusting N fertilization, reducing over-fertilization costs and increasing farmers' profits. Developing such a system is the main aim of the project AGER Trasferimento Tecnologico.

Here we report some preliminary results concerning the calibration of the crop simulation model and its ability of reproducing the spatial variability observed during the current growing season. Based on model simulations and seasonal weather forecast, prescription maps of the nitrogen quantity to be provided were calculated and distributed.

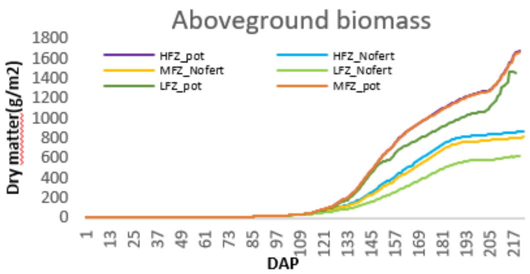
Materials and Methods

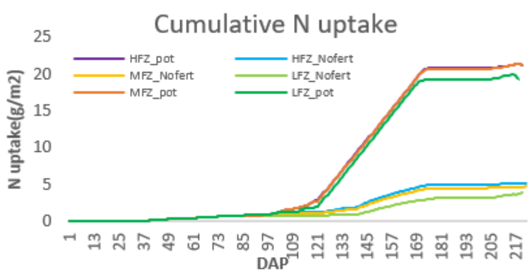
The study was conducted in Mira (Venice, 45°22'N; 12°08'E) in a field of 13.6 ha with a soil texture varying from sand to silt-loam. Based on soil properties, three different Fertility Zones (FZs) were identified: High- (HFZ), Medium- (MFZ) and Low-Fertility Zone (LFZ). The durum wheat variety Biensur was sown on November 30th 2017 (440 plant m^{-2}). Three N application were performed: a homogeneous fertilization on April 6th (50 kg N ha^{-1}) and two variable rate applications on April 26th and May 14th. In these latter, the rate of N to be applied was calculated as the difference between actual and within-season simulated crop N uptake. To simulate crop N uptake, SSM-wheat model was used. The model was first calibrated using observed data from field experiments carried out in Mira during the growing seasons 2010-11 and 2011-12, then a data assimilation process based on measurement carried out in 18 points at stem elongation (April 18th) was performed. To run the model, mixed observed-forecasted weather data were used. Specifically, they were composed by observed weather data (from the sowing date to the day before the variable N distribution), and 100 forecast weather simulations (from the variable N distribution to the simulated harvesting). The observed weather data came from ARPAV (Bureau of Meteorology of Veneto Region), whilst the 100 years of weather forecast series were generated by using the weather generator (LARS-WG) forced with anomalies forecast by the empirical model described in Ferrise et al. (2015). SSM-Wheat was run both in non-limiting N conditions and without any specific N fertilization (i.e. only N from organic matter in the soil) to benchmark the lowest and highest levels of the daily N wheat requirements and uptakes.

Results

Comparisons between observed and simulated data carried out before the first VRA, indicated that SSM- wheat well reproduced phenology and biomass accumulation, but failed to correctly estimate N uptake. After data assimilation, SSM was able to mimic the dynamic of above ground biomass accumulation and the crop cumulative N uptake and variability among the fertility zones with great accuracy. Comparing simulated and observed data at tillering (March 27th), stem elongation (April 18th) and heading (May 8th), the Pearson's coefficient was 0.95 in the HFZ and MFZ and 0.83 in the LFZ.

After the data-assimilation process, cumulative N uptake, simulated using seasonal forecasts, indicated that the final rate of nitrogen to distribute ranged from 20.2 to 21.6 g N m^{-2} for the HFZ; from 20.1 to 21. 5 g N m^{-2} for the MFZ and from 18.5 to 20.2 g N m^{-2} for the LFZ (Figure 2). Moreover, SSM reproduced the variability between the different N treatments. The small difference in N uptake between HFZ and MFZ may be ascribed to low variability observed in the organic matter and the soil texture in the HFZ and in the MFZ (Figure 1).





Conclusions

Data assimilation allowed to improve the calibration of the model, so as to better reproduce crop growth in response to field variability. Coupling crop models and seasonal forecasts may represent a useful tool for optimizing N fertilization particularly in a context of precision agriculture.

Acknowledgements

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Variable Rate Nitrogen In Durum Wheat According To Medium-Term Climate Forecasts

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Introduction

The Ager Project is focused on the development of an innovative monitoring methodology for Precision Fertilization. The monitoring in proximal sensing of the soil apparent electrical conductivity and the acquisition in remote sensing of multispectral images allow managing the spatio-temporal variability in the soil-crop-environment system. Through the identification of homogeneous zones and their representative points as well as the elaboration of prescription maps and with the help of fertilizer spreader, with separate control of the distribution sections (Casa et al., 2011), the right doses of N fertilizer can be applied (Castrignanò et al., 2009).

Materials and Methods

An experimental field of 8 ha (North 42.706950; East 13.891421), located in Mosciano Sant'Angelo (TE-Italy) (Fig.1), was divided into two sub-plots (A and B) related to soil fertility differences (low and high). The N fertilization approach consisted in one application of 50 kg ha^{-1} as Ammonium Sulfate (13/03/2018), homogeneously distributed on the whole field, and two fertilizations at variable rates compared with a conventional approach (CONV). Two strips fertilized with 250 kg ha^{-1} and with 0 kg ha^{-1} were also included.

On 12/12/ 2017, 300 kg ha^{-1} of phosphorus were homogeneously distributed; subsequently, durum wheat (*Triticum durum* Desf.) cv. Aureo at density of 450 seeds m^{-2} was sown with a conventional seed drill Amazone d8-30-special. On 22/12/2017 the Electrical Conductivity (ECa) was estimated with a CMD sensor Mini Explorer (Gfinstruments), multidepth electromagnetic conductivitymeter sensor, connected to Trimble GNSS.

Soil samples from representative points, identified with the ECa map, were collected on 12/02/2018, using the GNSS of Trimble (Juno model) and analysed for texture and residual fertility. Number of plants m^{-2}, dry matter and N accumulation, LAI, NDVI were monitored during the crop cycle. In Remote Sensing, multispectral images from Sentinel 2 satellite platform were acquired, allowing to process the index map of NDVI. A model to estimate the impact of the climate on growth and therefore nitrogen supply of wheat, was applied.

The prescription maps were developed on the relationship between NVDI and N-uptake for the determination of the amount of N supply. The application of N variable rates were carried out with X25 (Topcon) connected to AXIS fertilizer spreader machine (Kuhn) at stem elongation and booting phases.

Results

The ECa map evidenced a large homogeneous central area. The southern band was characterized by material with low magnetic activity with respect to central ground or to the north. Such approach allowed identifying the sampling points, representative of the variability of the plot, to be characterized in terms of soil fertility (Fig.2).

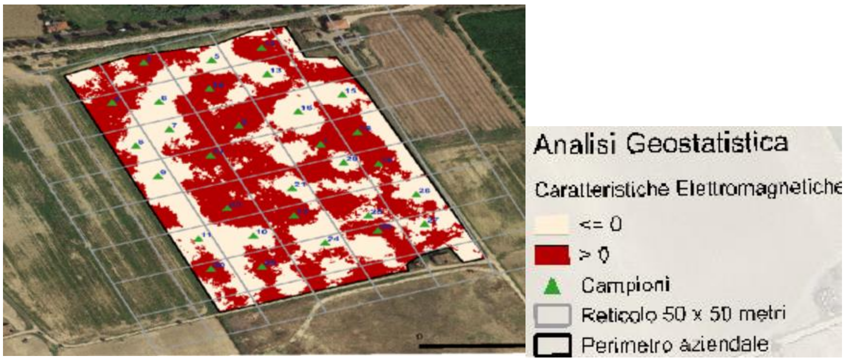

Figure 2. ECa map and identification of soil sampling points

The acquisition of multispectral images showed a good correlation between different soil fertility classes and vegetative development. The processing of remote sensing data provided a classification of the NDVI index under different ranges or classes (Fig.3). With the first VRA (Fig.4A), 30 (red pixels) to 40 (green pixels) units of nitrogen per hectare were distributed, while with the second ones (Fig.4B) from 0 (red pixels) to 100 units (green pixel) of N per hectare.

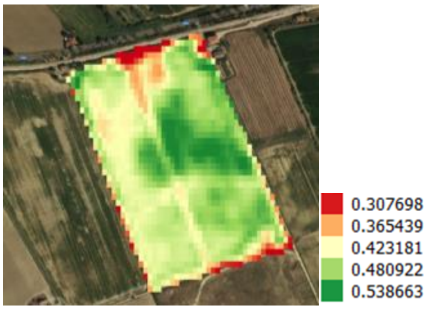

Figure 3. Map of NDVI vegetation index

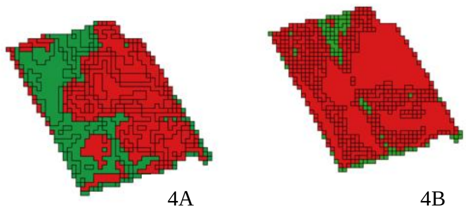

Figure 4. 1° and 2° VRA prescription maps.

Conclusions

The potential of this prototype allows testing the effectiveness of the Nitrogen VRA application with the aim to maximize yield and technological quality of kernels for processing (pasta production) while lowering environmental threats (leaching, air and groundwater pollution) as well as management costs.

Acknowledgements

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Precision Farming Technologies In Veneto Region Farms

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Introduction
Different are the definitions given for Precision Agriculture, but the most popular defines it as the management of an agricultural productive process which allows to "do the right thing, at the right time, in the right place" (Gebbers and Adamchuk, 2010). Indeed, the purposes of Precision Farming are to consider time and space variability as factors which contribute to the agricultural productive process, in order to optimize the efficiency of used inputs to have economic and environmental improvements. Actually, the USA are the country with the highest introduction level of precision farming technologies (Erikson and Widmar, 2015) instead in Europe the introduction levels seems to be contained and primarily concerns Germany, Great Britain, France and Scandinavian countries (Casa and Pisante, 2016). About the precision farming technology in Italy no official statistical data do exist. In view of this the project "Precision Agriculture: Soft and Digital Skill" financed by POR FSE Veneto 2014-2020 aimed to analyze the agricultural professional outlines and their technical-professional knowledges in Veneto region, mapping the emerging digital skills in the farms involved in the project.

Materials and Methods
A questionnaire of 34 queries was made. Eight questions were about the farming profile in particular the farm size, their productive activity and their target market; 9 questions were about the farm organization model focusing on the hired workers and if there was someone specialized in new technologies management; 16 questions were about the trend to introduce new technologies, if they had just bought something and when, what kind of technologies and their aim and future projects. The test was given to 21 farms located in Verona, Padova, Rovigo and Venice provinces in the Veneto region (Italy). Data were collected and translated into results by grouping all the answers of each question and calculating the percentage of identical answers given for each question.

Results
Results showed that 54% of involved farms belong to the arable crops sector and 23% to the wine sector; vegetables and fruits production industries were less represented as reported in Figure 1.

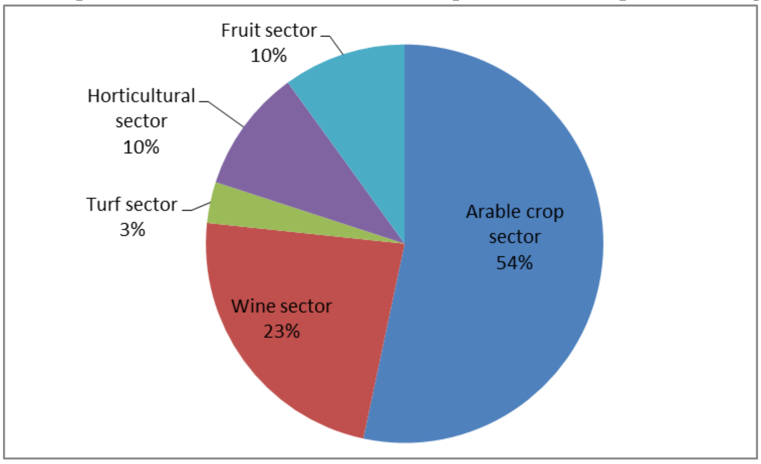

Figure 1. Productive sectors highlighted by the 21 farms interviewed within the project.

About the farm sizes: only one farm has a size lower than 10 ha, most farms have a size between 25 and 45 ha, few farms showed a size between 50 and 450 ha and only one was bigger than 500 ha. Among these farms, 81% had the farm land divided in two or more patches and the 57% declared to have made changes concerning the product, the production methods and/or the farm organization in the last 10 years.

Particularly, many farms have started using minimum tillage techniques and 19% have passed to a more digitalized farm management thanks to the use of software; 42.9% of producers declared the intention to make future changes concerning the production and/or the farm organization. Concerning digital instruments, 66.7% of farms have bought some devices in the last 10 years and, among these, 50% commonly use the driver assistance system, whereas 28.6% have introduced only the GPS system. The variable rate techniques is used by 14.3% both for sowing and fertilization, and 21.4% have installed weather boxes or sensor probes to measure the soil humidity. The purpose to introduce new technologies in the next future was expressed by the 76.2% of the interviewed farms. In particular, 19% have planned to change the irrigation system, improving automation and introducing soil probes; 9.5% are interested in farm management software, 14.3% want to introduce variable rate system on sprayers, spreading equipment or weeding machines, whereas only one farm is interested in buying a unmanned aerial vehicle (drone).
These results showed a good diffusion and knowledge of precision farming techniques although at simple and basic level. This can be explained by the small patches of the farms, furthermore the instruments costs are high compared to the low marginal income of the products. Lastly, technicians and workers are generally not inclined to invest in actions which require time consuming investments. It is also possible to note a good willingness to the improvement of these techniques due to the interesting results both in the environmental and economic domains. It is possible to note that the drive assistance systems are slowly catching on in farms probably because of the services offered by the consultant companies, which are being specialized in precision agriculture techniques and systems and are spreading the knowledge of these systems. It is also notable a certain interest in the use of weather boxes or humidity soil probes. This result shows that forecasts are more and more important to organize the farm work and it also demonstrates an interest towards the environmental protection.
Almost 10% of the farms use their own machine to provide services to other farms, while 14.3% ask for services to use precision farming technologies in their farms. The fact that some farmers use their own machines to provide or ask for some services using precision farming techniques, it depends on the depreciation cost of the machines and on the convenience or not to buy these instruments. All interviewed farms use their in-house expertise to manage digital technologies since, as said before, the technologies in the farms are simple and basic. Only one farm declares to hire a worker specifically to the use of digital technologies.

Conclusions

An increment in the use of precision techniques is expected in the next future in the northern Italy, but to start the change towards precision farming, farmers need to be more conscious about this technique and more open to changes. At the same time they also need financial security and an aid can be obtained by public incentives.

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Comunicazioni orali

“Premi Tesi di Dottorato”

Characterization Of Old And Modern Durum Wheat Genotypes In Relation To Gluten Protein And Dietary Fibre Composition

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Introduction

Durum wheat breeding programmes, started in Italy by the activity of Nazareno Strampelli, resulted in the selection of lines characterized by a better agronomic performance in terms of grain yield and its components, essentially due to the wider adaptability and better resource use efficiency. In the last decades the attention was more focused on technological quality. Several studies demonstrated that modern varieties were selected for favourable alleles in terms of gluten protein (GP) composition, associated with good technological performances (De Vita et al., 2007). Dietary fibre (DF) represents an important quality trait, commonly not selected in breeding programs. In durum wheat, DF mainly consists on arabinoxylan (AX) and mixed-linkage β-glucan (MLG), which have a range of health benefits; for example, the capacity to lower the glycaemic response of diets, reducing the risk of developing type II diabetes (Lafiandra *et al*., 2014) is of particular importance. The recent interest to recover cultivated old genotypes has brought the scientific attention to the evaluation of a possible healthier chemical composition of these wheats with respect to the modern ones. However limited data are available supporting this hypothesis, in particular for durum wheat. The aim of this PhD thesis has been to deep insight into the knowledge on the influence of Italian 20th century breeding on the main grain quality characters, by phenotyping an old and a modern durum wheat group of genotypes in relation to GP and DF.

Materials and Methods

Two groups of Italian durum wheat (Triticum turgidum L. spp. durum) genotypes were chosen on the basis of their release dates: old (1900-1949) and modern (1985-2005). The old group consists of four old Italian landraces (Dauno III, old Saragolla, Russello, Timilia R.B. reste bianche), genotype Cappelli and two cultivars (Garigliano and Grifoni 235) obtained by selection from Cappelli. Relative to the modern genotypes, they were all bred after the introduction of the dwarfing (Rht) genes, from 1985 to 2005 (Adamello, Claudio, Iride, Preco, PR22D89, Saragolla, Simeto, Svevo). Field trials were carried out at Foggia (Italy, 41°28′ N, 15°32′ E and 75 m a.s.l.), in two consecutive growing seasons (2012–2013 and 2013–2014, indicated below as 2013 and 2014, respectively). Differences were observed only in the amount of rainfall during grain filling (53.8 mm in 2013 vs 152.8 mm in 2014). Chemical analysis was carried out on gluten protein (GP) as described in De Santis *et al.* (2017) and on dietary fibre (DF) as in De Santis *et al*. (2018).

Results

Durum wheat genotypes with different release dates were phenotyped in relation to GP and DF composition. The main results are briefly reported in Table 2. The better gluten index observed in the modern group was related to higher contents of glutenin and B-type LMW-GS which were, on average, two times higher in the modern group of durum wheat genotypes. Instead, a drastic reduction of the content of ω- 5 gliadins was observed in the modern genotypes. Assessment of the contents and structures of AX and MLG in groups of old and modern durum wheat genotypes has provided no evidence that intensive breeding has had negative effects on the contents of dietary fibre components in durum wheat. In fact, the modern genotypes had higher contents of WE-AX in wholemeal and higher mean values for % AX solubility in both semolina and wholemeal than old ones, also mean contents of MLG were also about 30% higher in semolina and wholemeal of the group of modern genotypes.

Table 1 Mean of yield, its components and main quality parameters relative to GP and DF composition of old and modern groups of durum wheat genotypes grown in two crop seasons (2013, 2014).

Parameters		old 2013	old 2014	modern 2013	modern 2014
Grain Yield	kg m^{-2}	0.33 c	0.30 c	0.43 b	0.52 a
1000 kernel weight	g	49.4 a	50.3 a	50.7 a	37.9 b
Kernel m^{-2}	n.	6853 c	6137 c	8697 b	13613 a
Test weight	kg hl^{-1}	79.6 ab	77.6 b	82.0 a	74.2 c
Grain Protein Content	%	16.0 a	14.1 b	13.7 b	13.6 b
Semolina Protein Content	%	14.4 a	12.9 b	12.2 b	12.6 b
Gluten Index	%	9.6 b	7.5 b	55.3 a	46.0 a
gliadin / glutenin	ratio	2.6 a	2.9 a	1.6 b	1.8 b
HMW-GS	%	8.9 b	7.3 c	10.1 a	9.8 a
B-type LMW-GS	%	12.6 b	13.2 b	21.4 a	19.3 a
C-type LMW-GS	%	7.1 a	6.5 a	7.1 a	7.2 a
ω- gliadin	%	11.7 a	10.2 a	4.4 b	3.4 b
α, γ- gliadin	%	58.1 ab	61.6 a	55.4 b	58.7 ab
Total AX (semolina)	g/100g	1.65 ab	1.63 ab	1.55 b	1.71 a
Water extractable AX (semolina)	g/100g	0.44 b	0.55 a	0.37 b	0.57 a
AX solubility (semolina)	%	26.9 b	33.9 a	23.7 b	33.3 a
Arabinosylation (semolina)	%	63.9 ab	67.5 a	63.5 ab	61.6 b
Relative viscosity	ratio	1.54 b	1.72 b	1.57 b	1.90 a
MLG (semolina)	nC	13609 b	13777 b	18557 a	16917 a
G3:G4 ratio (semolina)	ratio	2.19 b	2.73 a	2.15 b	2.95 a
Total AX (wholemeal)	g/100g	4.00 a	4.04 a	4.03 a	4.16 a
Water extractable AX (wholemeal)	g/100g	0.45 b	0.51 b	0.65 a	0.67 a
AX solubility (wholemeal)	%	11.4 b	12.7 b	16.3 a	16.2 a
Arabinosylation (wholemeal)	%	50.4 a	39.1 b	48.0 a	37.6 b
MLG (wholemeal)	nC	38778 b	20933 d	49719 a	28723 c
G3:G4 (wholemeal)	ratio	2.40 c	3.23 b	2.51 c	3.75 a

Different letters are significantly different at $P \leq 0.05$ according to Tukey's test.

Conclusions

Breeding activity occurred during 20th century seems to have improved both technological and health quality of Italian durum wheat genotypes. Higher contents of glutenin and B- type LMW-GS were responsible for better gluten quality while a lower content of ω- 5 gliadin (Tri a 19) may indicate a lower allergic potential of gluten from modern genotypes. An increase in the proportion of water soluble AX in wholemeal flour and a higher β-glucan content in semolina seems have also occurred as a consequence of breeding in modern Italian durum wheat varieties. The identification of modern cultivars with high viscosity associated with a high content of MLG suggests that they may be good sources of DF for human health.

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Multiple Ecosystem Services Provision From Perennial Bioenergy Crops

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Introduction
The 21st century will challenge agriculture to feed and fuel a growing world while conserving the environment. An alternative bioenergy land use scenario to the conversion of marginal land has been tested in this work: the bioenergy buffers (Fig.1). Bioenergy buffers are linear landscape elements cultivated with perennial herbaceous or woody biomass crops placed along arable field margins and watercourse (Ferrarini *et. al*, 2017b). The main objective was to determine to what extent do the perennial bioenergy crops affect the delivery of multiple ES when cultivated as bioenergy buffers.

Materials and Methods
A systematic revision of literature on ES provided by perennial bioenergy crops has been combined with a field experiment on bioenergy buffers. An Impact Assessment (IA) methodology was adopted to capture from literature material the direction and the level of confidence of impact on multiple ES including regulating (climate, water and biodiversity), supporting (soil health) and provisioning services (biomass and energy yield). In a sandy loam soil with shallow groundwater, bioenergy buffers of miscanthus and willow (5 and 10 m wide) were planted along a ditch of an agricultural field located in the Po valley (Italy). Soil and groundwater mineral N forms and dissolved organic C (DOC) were monitored over an 18-month period in groundwater before and after the bioenergy buffers.

Results
The IA revealed that the implementation of bioenergy buffers on previous croplands rather than on grasslands sustains long-term provision of multiple ES such as climate, water quality and biodiversity regulation and soil health (Ferrarini *et. al*, 2017a) (Fig.2). Nevertheless, we found two main shortcomings related to bioenergy buffers establishment and management. First, several site-specific factors along field margins must be taken into account, because they can affect crop establishment and buffers long-term productivity. Second, regarding to biomass supply chain, a limited working space for the farm machinery operations has been recognized as the main disadvantages of bioenergy buffers compared to large-scale bioenergy plantations. This spatial logistics constraint may inevitably increase harvest and collection operation times and fossil fuel consumption.
The field experiment with bioenergy buffers in a nitrate-enriched shallow groundwater, showed that miscanthus and willow buffers are able to efficiently intercept and remove from groundwater the incoming NO_3-N as much as buffer strips with spontaneous species (Ferrarini *et. al*, 2017a). Yet, due to their deep rooting systems, bioenergy buffers promote significant plant-microbial linkages along the soil profile (Ferrarini *et. al*, 2017c). At deeper soil layers, a higher fine root biomass led perennial bioenergy crops to outperform patches of adventitious vegetation in terms of biological N removal from soil and belowground GHG mitigation potential. The results on biomass production and N removal via harvesting further confirmed that the cultivation of perennial bioenergy crops along watercourses is an effective win-win strategy: biomass production and protection of the environment.

Conclusions
The revealed potential of perennial bioenergy crops on multiple ES provision implies that their cultivation as perennial landscape elements in strategic locations within landscape is a promising option to promote the ecological sustainable intensification of agroecosystems. Establishing a network of bioenergy buffers increases landscape connectivity and the overall area of ES provision in the agricultural landscape. Payments for ES

obtained from bioenergy buffers can ultimately improve the economics of sustainable bioenergy and help achieving environmental goals of EU policies on water, soil and biodiversity protection.

Fig. 1. Bioenergy buffer trials with perennial energy crops in Piacenza (NW Italy) (courtesy of Andrea Ferrarini)

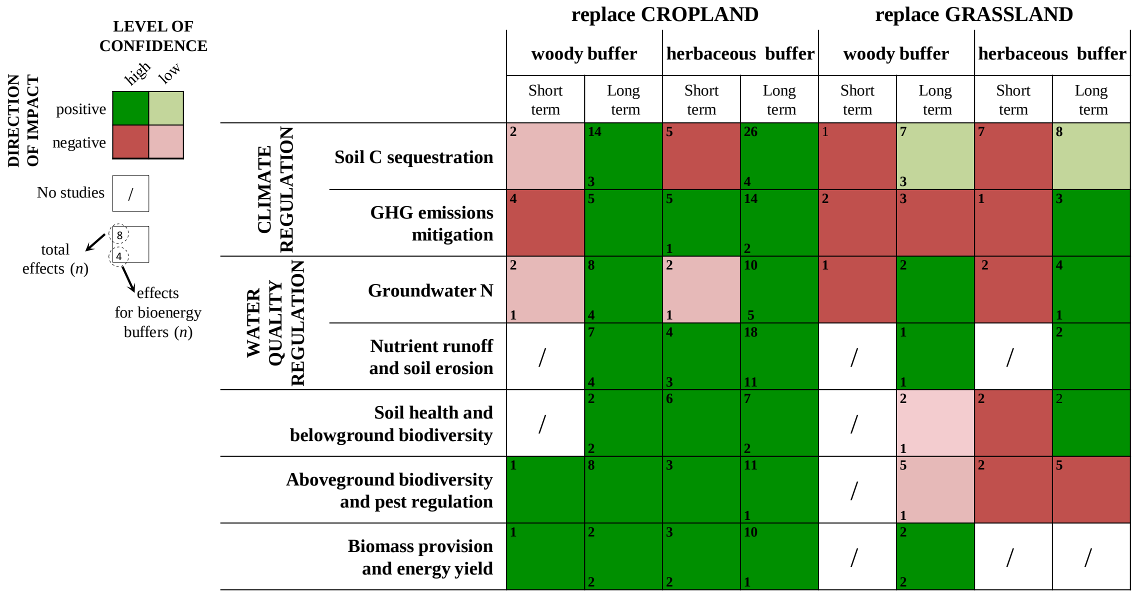

Fig. 2. Impact matrix reporting the impacts on the provision of ecosystem services (ES) of bioenergy buffers replacing cropland and grassland (Ferrarini *et al.*, 2017b). Impacts were scored according to their direction and classified according to their level of confidence. In each cell, the total number of effects on ES recorded in literature (top left) and those specifics for bioenergy buffers (bottom left) are reported.

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Long-Term Effect Of Tillage And Crop Sequence On Soil Microbial Community And Nitrogen Emissions In A Mediterranean Environment

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Introduction

Conservative agronomical techniques, such as minimum mechanical soil disturbance and crop rotations, are being promoted to manage agro-ecosystems in order to improve and sustain productivity, increase profits and food security, while preserving the resource and the environment. For example, no-tillage can provide several environmental, ecological, and economical benefits, such as the mitigation of soil erosion, reduction of energy use and labour time, reduction of C emissions and increase C sequestration, improvement of soil biota, affecting positively crop growth and yield (Ruisi et al., 2014). Crop rotations can play an important role in the agroecosystems, by reducing erosion and increasing water holding capacity, improving the quantity and quality of soil organic matter, with higher release of nutrient, contributing to decrease weeds, pest and diseases infestations. Moreover, among crop rotations, including legume species can provide additional benefits (Ruisi et al., 2017). They can fix atmospheric nitrogen thanks to the symbiosis with Rhizobium bacteria, leading to reduce N fertilizers in the following crop, to mobilize P making it available, permitting to achieve higher production levels with higher stability over the time on the next crop, and improving soil quality and C sequestration. Since the effect of soil and crop management are also dependent on time, short-term study often can lead to inconsistent results. Therefore, measuring the effect of different treatments under long-term experiments can provide a better understanding of soil properties changes, interrelations and functioning. The aim of this study was to investigate the effect of no-till and wheat/faba bean crop rotation, in comparison with conventional tillage and continuous wheat, on soil properties, microbial community and nitrogen gaseous emissions (ammonia and nitrous oxide) in order to assess the long term effects of this two conservative practices on soil ecosystem and their repercussions on cultivation sustainability and the environment, under Mediterranean climate conditions.

Materials and Methods

The field crop trial was carried out under rainfed conditions at the experimental Pietranera farm of the University of Palermo. The farm is located about 30 km North of Agrigento (Sicily, Italy, 37°30′ N, 13°31′ E; 178 m a.s.l.). This study has been carried out in a framework of a more complex experiment which began in 1991 and is still on-going. Briefly, the experiment was set up as a strip-plot design with two replications. The experimental factors tested were tillage system (conventional tillage, CT, and no tillage, NT) and crop sequence (continuous wheat, WW, and wheat/faba bean rotation, FW and WF). More details are reported in Amato et al. (2013). In order to assess the treatment effects on soil chemical, biochemical properties and soil microbial community structure during the 2013/14 cropping season, four samples per treatments were collected from 0-15 cm and 15-30 cm soil layers in December, April and July. Soil samples were analysed for total carbon (TOC), total nitrogen (TN), extractable carbon (EC) and nitrogen (EN), microbial biomass carbon (MBC) and nitrogen (MBN), basal respiration (BR) and denitrifying enzyme activity (DEA). Effects on soil microbial community were assess analysing soil phospholipid-derived fatty acids (PLFA) for total microbial community, gram positive and gram negative bacteria, fungi. In the same years soil samples were collected from the 0-15 cm soil layer in order to analyse amoA (nitrification chain) and nosZ gene (denitrification chain) abundance. Soil nitrogen gaseous emissions, ammonia and nitrous oxide, were measured during two cropping seasons (2013/14 and 2014/15) with 6 replicates per treatment. Ammonia emissions were measured after the fertilization at sowing and tillering by Conway's microdiffusion-incubation method adapted for soil according with Qi et al. (2012), while nitrous oxide emissions were measured over two cropping season by the closed chamber technique (Baker et al. 2003).

Results

Long-term conservative practices application determined a significant effect on soil properties, with repercussions on soil microbial community and nitrogen gaseous emissions. In particular, long-term NT use determined a significant ($P<0.05$) increase of all soil chemical and biochemical parameters, such as TOC (+32%), TN (+41%), EC (+24%), EN (+20%), MBC (+62%), MBN (+42%), BR (+91%) and DEA (+501%), in the superficial soil layer, while the effect on the deeper layer was limited. Crop rotation effects on soil properties were scarce and they were mainly linked to their fertilization regime (WW 120N, FW 80N, WF 0N) highlighting higher levels in wheat plots than under faba beans. NT use increased the abundance of all microbial group investigated, but with a greater effect in favour of gram negative bacteria. Moreover, wheat cultivation under NT system selectively stimulated this kind of bacteria (gram negative) (Tillage × Crop, $P<0.05$). Definitely, NT determined an increase of the global microbial community with a slight shift toward gram negative bacteria. Analysis of amoA and nosZ genes abundance confirmed the positive effect of NT system on soil microbial community, showing higher values by +173% for amoA and +73% for nosZ gene. However, with regard to nosZ gene, a significant interaction between experimental factor was observed (Tillage × Crop, $P<0.05$): under NT, both plots involved in crop rotation (FW and WF) show a lower nosZ gene abundance than WW (-16%). Soil NH_3 emissions measured after fertilization at sowing and at tillering along two cropping cycles were significantly influenced exclusively by crop system ($P<0.05$). In particular, fertilization regime determined a trend WW>FW (+60%, total emission). Under faba bean (WF), which had not received any nitrogen fertilization, ammonia emissions were negligible. Total soil N_2O emission was affect by the interaction between the experimental factors tested (Tillage × Crop, $P<0.05$). On average, NT showed greater emissions than CT (+43%). Moreover, NT use exacerbated N_2O emission in the plots involved in crop rotation (FW and WF) than in continuous wheat (WW) (+13%).

Conclusions

The combination of field surveys and laboratory tests allowed to depict a clear picture of the treatments effects on soil microbiota dynamics and nitrogen emissions during the cropping cycle. The information obtained from this research showed that the adoption of the no tillage can greatly impact the soil microbiota, improving its activity and determining a change on the community structure and functioning. However, despite several economic and agronomic benefits may arise from the application of no tillage system, both surveys in the field as well as laboratory analysis showed that the application of this technique can lead to an augmented risk of emissions of nitrous oxide. With regards to the crop, this study showed how the crop type can directly affect some soil microbial group whereas the fertilization strategy can affect the ammonia emissions. In particular, previous faba bean cultivation, limiting the use of N fertilizers, leads reduce NH_3 emission. Moreover, the interaction between tillage system and crop sequences indicated that a two-year crop sequence can lead to higher nitrous oxide emissions than wheat monoculture in no tilled soil characterized by higher soil microbial activity.

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Comunicazioni orali

“Agricoltura conservativa”

Outcomes After 6-yr of Conservation Agriculture Adoption in Veneto Region Silty Soils. Effects on Soil Physical Properties Combining Classical Methods and Geophysics

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Introduction

Nowadays, the idea that agriculture should not only be high yielding, but also sustainable has spread among the scientific community, and conservation agriculture (CA) has been suggested as a widely adapted set of management principles that can assure more sustainable agricultural production (Verhulst et al., 2010). CA is based on three pivotal points: 1) minimum soil disturbance, 2) permanent soil covering and 3) crop diversification. As in other European countries, CA adoption in Veneto Region is also increasing and was subsidised during the two last rural development programmes (Regione Veneto, 2013, 2016). Despite the first estimates, CA practices are recently not recognized as a win-win solution for agroecosystem improvement since the absence of tillage operations may impact the crop root growth through an increase in soil strength, reduced soil porosity and gas exchanges. Furthermore, the overall benefits of CA have been strictly related to soil type and climate (Soane et al., 2012). For these reasons, the aim of this study was to evaluate the effects of CA practices on Veneto Region silty soils combining classical disruptive methods with geophysical survey within a 3-yr monitoring period corresponding to one cropping rotation cycle.

Materials and Methods

The field experiment was established in 2010 on four farms located in Veneto Region comparing conservation agriculture (CA) *vs* conventional (CV) management. Three out of four farms were characterised by silty loam texture while the last one had a loamy soil. Cultivation protocols of CA consisted in no-tillage, crop residues retention on soil surface and cover crop usage while CV involved traditional tillage practices based on mouldboard ploughing (35 cm) and secondary tillage operations (e.g. chisel ploughing and disk harrowing). The 3-yr crop rotation was the same in both treatments (wheat-maize-soybean). Every year (2014-2016), inside 24 areas, 648 soil samples were collected for bulk density (BD) and volumetric water content (VWC) calculation while 216 soil penetration resistance (PR) profiles (0-80 cm) and 32 3D electrical resistivity tomography (ERT), were performed directly on the field in the inter-row. In addition, in 2015, 144 undisturbed 100 cm^3 soil cores were collected for air permeability (k_a, steady-state method) and relative gas diffusivity (D_p/D_o, non-steady state method) measurements. Statistics were based on mixed effect models.

Results

Results showed soil physical properties clusterization depending on texture.

In silty loam soils, CA was associated with higher VWC and degree of compaction (higher BD and PR) in the top soil layers as a result of crop residues on soil surface and absence of tillage operation and high traffic load respectively. Gas transport measurements highlighted low transmission properties of silty soils independently from agronomic management and observed poor aerated conditions (k_a<20 μm^2 and D_p/D_o<0.005). Geophysical survey reflected classical measurements with low resistivity in CA shallow layers as results of both higher VWC and BD (Fig.1).

On the contrary, in the coarser soil with lower soil organic carbon content, a dense soil layer below the ploughing depth (35 cm) was observed in CV and linked to a plough pan. Such dense layer was seen with ERT survey as a high resistivity layer (Fig.1) and with classical methods with an increase of BD and PR. As a matter of fact, CA treatment did not show this dense layer but suffer instead a higher soil compaction in the 10-30 cm soil layer. CA-related topsoil compaction was also confirmed by gas transport measurement in terms of air permeability (0.81 *vs* 10.51 μm^2) and relative gas diffusivity (0.0022 *vs* 0.0196).

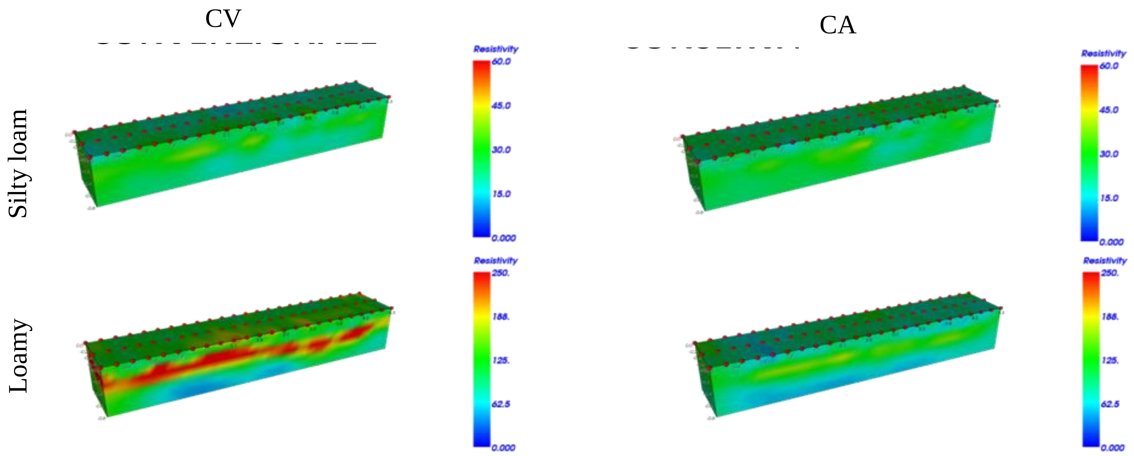

Figure 5 Electrical resistivity tomography (ERT) survey in conventional tillage (CV) vs conservation agriculture (CA) in both studied soils, silty loam and loamy soils. Resistivity values are expressed in Ohm-m.

Conclusions

The strong interactions existing between management systems and soil local conditions explained the results clusterization according to soil texture. In the silty soil no specific benefits of CA practices were highlighted on soil physical properties after 4- to 6-yr of conservation management adoption.
On the contrary in the coarser soil, CA treatments affected both the topsoil compaction and transmission properties. The CA-induced reduction was related to the tillage effect on soil bulk density and suggested that CA not only affected the air-filled porosity but also continuity and tortuosity characteristics of pore network.

Acknowledgement

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Sustainable Intensification Of Crop Production Requires Agricultural Equipment Innovation: The Case Of Strip-Till For Fine Seedbed Preparation In Silty Soil

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Introduction

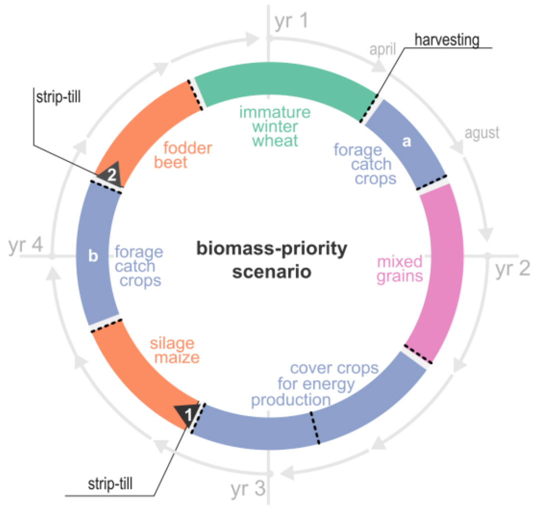
Sustainable intensification of crop production calls for agricultural innovations. In the past, the solution was to bring new land into cultivation, whereas current and prospected trends in world population growth orient instead to foster more efficient use and management of the resources (Pisante et al. 2012). Various solutions are being developed in function of the local agropedoclimatic conditions. In this context, agronomists are questioning the soil tillage practices, eventually to reduce the tillage intensity. On the one hand, the goal is to reduce fuel use, time and labour. On the other hand, a lower tillage intensity might improve soil organic matter building and, in the end, soil health (DeJong-Hughes 2017). Rethinking soil tillage inevitably underpins and follows farming system design (Leclercq and Corfdir 2017; Yatskul and Ugarte 2018). Indeed, the evolution of agriculture is inherently systemic, thus requiring to address the production intensification across the various components of the agricultural system and beyond (Darnhofer et al. 2012). Altogether, this results in taking into greater account multiple stakeholders and embracing the complexity of the farmers' decision-making (Douthwaite and Hoffecker 2017). The sustainable intensification process has though two main barriers: the learning curve to master new techniques and the cost of equipment suited for the new practices. This communication aims to discuss a project of strip-till design following an innovation system approach. First, we present the agronomic challenge and our approach for a custom supply development. Then, we discuss the relevance of our some early outcomes for the wider goal of sustainable intensification of crop production.

The agronomic challenge: designing a strip-till for fine seedbed preparation

Sustainable intensification can be pursued (and evaluated) in different way according to the local farming system and agropedoclimatic condition. In this context, the European Regional Development Fund, the French State and the Hauts-de-France Regional Council invested about 2.7 million EUR in a project called "Demonstrating site network" ("Réseau de sites démonstrateur IAR" in French) for the period 2015-2020. This project aims to study and show the feasibility of the diversification of current cropping systems in the region by the introduction of food and non-food crops for feed, bio-based products and bioenergy (Lamerre et al. 2017). The project particularly addresses the production of knowledge to support farmers at embracing the innovation. Accordingly, it includes 4 demonstration sites and 3 areas to explore the organization of new supply chains. Three 4-year crop sequences, each replicated with or without soil tillage, are tested on each site. The crop sequences are designed on three scenarios: baseline, food-priority and biomass-priority. The baseline is the regional mixed farming system that includes canola, winter wheat and silage maize. We focus here on the biomass scenario, which fosters the intensification of fodder and energy crop production by introducing fodder beet and harvested catch crops (Fig. 1). Introducing these crops requires therefore to simplify the soil tillage.

The region shows a predominance of silt and silt loam soils (USDA). These soil types are characterized by a weak structural stability presenting a high risk of crusting and erosion. They thus benefit from simplified soil tillage, when operated shortly before the seeding, because reducing soil degradation. Amid the different approaches, strip-tillage appeared as the most promising because combining the reduction of labour time, and the preparation of fine seedbed, as required for maize and beet (Duval 2014; Laufer and Koch 2017). Though, available commercial strip-tillage tools, mostly passive, can achieve fine seedbed if operated months ahead, or at a speed of 10-12 km/h. So, they can be combined only with recent planters or operated separately by using RTK-GPS. Altogether, these machines and technologies may require high investments by farmers, eventually hampering the whole farming system innovation.

A group of 6 students specializing in agricultural equipment at UniLaSalle (centre for higher education in Northern France) were challenged to prototype a strip-till fitting commonly available beet planters operating at low speed (3 km/h). This was achieved by an ad-hoc combination of tools, part of which power-operated (Fig. 2). The field tests realized at the end of the current academic year with the single-element prototype succeeded at preparing a fine seedbed 10 cm wide and 20-25 cm deep.



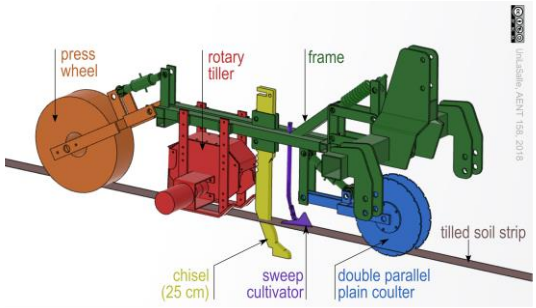


Fig 1 (left). Crop sequence of the biomass priority scenario. ***Forage catch crops***: (a) forage canola and Italian ryegrass; (b) triticale 50%, forage pea 30% and fava beans (*Vicia faba* L. var. *minor*) 20%. ***Mixed grains***: bere 50%, forage pea 25% and common vetch 25%. ***Strip-tillage*** (1 and 2) is planned before the seeding of silage maize and fodder beet.

Fig 2 (above). Schematic representation of the prototype strip-till (adapted from F. Pastol, CC BY-NC-SA 4.0 UniLaSalle, AENT 158, 2018).

Conclusions and perspectives

Reducing the width and frequency of soil tillage appeared as a lever to deploy the sustainable intensification of crop production in a mixed farming system on silt soil. Though, cost and customization of tillage equipment emerged as a major barrier for desired innovation. By adopting a systemic approach, we involved a group of agronomy students to design a fully adapted strip-tillage tool, thus based on farmers' and agronomic constraints. In conclusion, we widen the farming system innovation to include a farmer-centred perspective, with the final goal to operationalize the design and adoption of sustainable production practices.

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Stability Analysis Of Winter Wheat Productivity In Conservation Agriculture Compared To Other Management Systems In Southern Italy

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Introduction

Two long-term experiments based on continuous cropping system of winter durum wheat and conservation agriculture (CA), compared to two different management systems based on conventional tillage (CT) and two-layer ploughing (TLP), were established in 2012 and 2002, respectively, in Foggia (Apulia region, Southern Italy) with the objective to investigate their long-term effects on soil fertility and productive responses of main parameters in a continuous cropping system of winter durum wheat. In this paper we assess the productive response of winter wheat to three management systems and analyse the annual temporal stability of yield, protein and hectolitric weight. This study was carried out in the framework of the Project "STRATEGA" (Sperimentazione e TRAsferimento di TEcniche innovative di aGricoltura conservativA) funded by Puglia Region.

Materials and Methods

The field experiments were established in 2012 at the experimental farm "Menichella" (MEN) of CREA-CI and in 2002 at the experimental farm "Podere 124" (P124) of CREA-AA. The two experimental layouts, about 1 km apart, are located in Foggia and consist of a simple comparison two main plots and a randomized block for P124 with three replications, respectively. In both layouts two treatments are compared: conservation agriculture (CA) vs. conventional tillage (CT) in MEN and CA vs. two-layer ploughing (TLP) in P124.
After durum winter wheat (*Triticum durum*, Desf.) harvesting straw and stubble of winter wheat are chopped to 10–15 cm lengths and spread back on the plots. Nitrogen and Phosphorus (36 and 92 kg ha^{-1} of N and P_2O_5, respectively) are then applied as diammonium phosphate. Under CT, primary ploughing of 40 cm is carried out followed by secondary tillage consisting of tooth-harrow or disc-harrow for seedbed preparation. CA is a no-tillage based on direct sowing that allows for minimum disturbance of soil and maintenance of soil cover with residues and chemical treatment with Glyphosate (5 L ha^{-1}). TLP has been carried out by combined farm device with subsoiler and rotary cultivator. In all treatments, 68 kg ha^{-1} of N are applied as top dressing (NH_4NO_3). Durum wheat is sown with the same sowing machine (Laseminasodo IGEA 2500 of La valle Verde S.r.l.) at rows 15 cm apart and 3–4 cm deep. During the research periods, different cultivars were sown: in MEN, Latinur (2010), Grecale (2011-12) and Claudio (2013-2016); in P124, Simeto (2002-12) and Claudio (2013-16). After harvesting, yield, grain protein content (PC) and hectolitric weight (HW, weight per unit volume) were determined.
Statistical analysis of variance (ANOVA), based on resolution of General Linear Model (GLM), was applied by MEN and P124, considering a strip-plot layout including the "year" (Y) as strip factor, treatment (T) and interaction "YxT". T included the comparison between CA and CT and CA and TLP for MEN and P124, respectively. The response variables of GLM were yield, PC and HW.
A comparative regression stability analysis was also carried out applying the metodology proposed by Borrelli et al. (2012) and Ventrella et al. (2016a). However because this study is based on the comparison between two thesys, mean response variable obtained with CA were regressed against those of CT and TLP.

Results

Temporal yield variability, that ranged beteween 2.5 to 5.5 t ha^{-1}, was mainly affected by meteorological factors (air temperature, rainfall and their interaction). This confirms the results obtained in similar agronomic studies (Ventrella et al., 2016b). Less variability was found for PC and HW, ranged from 12 to 17% (with an average of about 14%) and from 74 to 85 kg hl^{-1}, respectively. ANOVA results were very similar for MEN and P124. Y was highly significant for all variables, while T was not significant for all six combinations. YxT was significant for yield in MEN (P≤0.0001), as well as for HW and yield in P124 (P≤0.006 and P≤0.05, respectively). This findings was confirmed by the results of stability analysis regression reported in Fig. 1, where the 1:1 dashed line and the six linear equations with the regression coefficient (R^2) were also reported. Moreover, significativities of intercept, slope and R^2 (different from 0, 1 and 0, respectively) are also reported. In MEN, except for the yield, the regression analysis were always significant or highly significant, while the six intercepts were not significant. In two cases out of 6, the slopes were statistically lower than one (i.e., yield in MEN and PC in P124).

With the slope statistically less than one for yield, a trend occurred in the comparison with the CT in MEN where CA performed better than CT in the most unfavourable years, contrary to favorable ones (yield higher than 3.6 t ha^{-1}). No difference among favourable and unfavourable years were detected between yields of CA and TLP. In P124, with a discriminant value of 13.5% of PC, CA performed better in unfavourable years and worse in favourable ones.

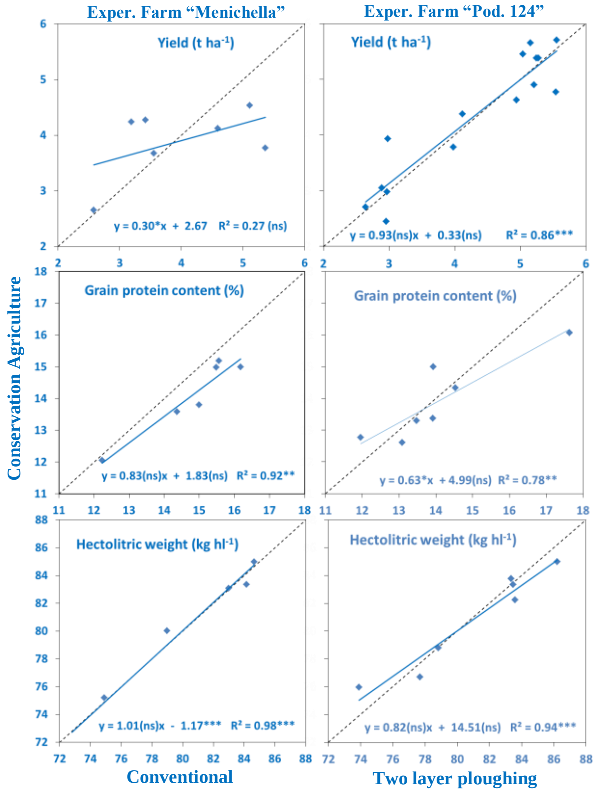

Figure 1. Regression analysis between productive parameters obtained in three tillage systems. Details are reported in the text.

Conclusions

Field researches performed in Foggia during the 2002-2017 period on the applicability of Conservation Agriculture, here defined in terms of no-tillage to reduce soil disturbance, suggest that it is a valuable cropping system in cereal-based systems of Mediterranean environments with low rainfall and high temperature during the crop cycle. Reduced Tillage, as two-layer ploughing, determined no significant differences in productive indicators, whereas the comparison with Conventional Tillage highlighted best performances of Conservation Agriculture in less favourable years for the wheat productivity.

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Early Sowing Allows To Reduce Weed Pressure In No-Till Organic Durum Wheat Production

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Introduction

In organic farming, the adoption of the conventional tillage (CT) technique is considered by many farmers to be necessary to control weeds. Such tillage system, in fact, permits to bury weed seeds deep in the soil by means of soil inversion with moldboard plowing and to eliminate the weed plants that gradually emerge by means of the secondary tillage operations. However, it is also true that intensive tillage progressively reduces the soil organic matter content and the stability of soil aggregates, thus increasing the risk of soil erosion (Six et al. 2000). This is in contrast with one of the basic principles of organic agriculture, which is the conservation of soil fertility. Alternatively to CT, the no tillage (NT) technique can maintain or even enhance soil fertility by increasing C storage, soil biological activity, and soil aggregate stability, but, as a matter of fact, its application relies on herbicide use as the primary weed control mechanism (Gattinger et al. 2011). In the light of these considerations, efforts must be made to revisit the NT technique to make it applicable in organic farming. Without prejudice to the fact that this challenge should be addressed through a systemic approach (Peigné et al. 2007), one possible option could be to take advantage of the possibility given by the NT technique to sow the crop in an earlier period than what usually the farmer does when adopts the CT technique. Anticipating the sowing time would allow operating when most of the weed plants are still poorly developed, so that the sowing operation itself can kill many of them. Moreover, sowing early, when temperatures are still relatively mild, could accelerate the initial growth, thus reducing the period during which the crop is particularly vulnerable to weed competition. Usually, early sowing in the CT systems is not possible since a proper seedbed preparation needs time so that clods formed as a result of plowing could be broken down by natural weathering processes and by one or more secondary tillage operations. Therefore, an experiment was performed under organic management to study the effects of NT compared to CT on durum wheat (*Triticum durum* Desf.) grain yield, and to verify whether early sowing under NT conditions, compared to sowing at the ordinary time for the study area, can provide an advantage to the crop by increasing its competitiveness against weeds. Furthermore, the above effects were investigated on two durum wheat genotypes highly different for pheno-morphological and agronomic characteristics, assuming for them different competitiveness against weeds.

Materials and Methods

The experiment was performed in 2016‒2017 growing season in Sicily, Italy (37°32′N, 13°31′E; 178 m a.s.l.) on a Vertic Haploxerept soil with the following characteristics: 525 g kg^{-1} clay, 227 g kg^{-1} silt, and 248 g kg^{-1} sand; pH 8.2; 16.8 g kg^{-1} total C and 1.78 g kg^{-1} total N. The trial was set up in a split-plot design with four replicates. Three tillage system/sowing date combinations (NT-early sowing, NT-ordinary sowing, and CT-ordinary sowing) acted as main plots and two durum wheat genotypes (cv. Orizzonte and landrace Scorsonera) as sub-plots. Sub-plot size was 70 m^2 (3.5 by 20.0 m). No tillage consisted of sowing by direct drilling whereas CT consisted in one moldboard plowing to a depth of 0.30 m in the summer (August), followed by one harrowing before planting. Ordinary sowing date corresponded to the time at which durum wheat is usually sown in the study area (mid-December) whereas early sowing plots were sown one month before the ordinary date. Orizzonte is a modern cultivar with short plant height, early heading and maturity, and high yield potential whereas Scorsonera is an old Sicilian landrace with tall plant attitude, medium-late heading and maturity, and moderate yield potential. Organic N fertilizer (hydrolyzed leather meal Dermazoto N11; 11% N, 40% organic C) was applied before planting to all plots at the rate of 400 kg ha^{-1}. Before planting, very shallow weed harrowing with a spring tine harrow was carried out in all NT plots to eliminate early-emerged weeds; one weed harrowing treatment was done in the NT-early sowing plots and two in the NT-ordinary sowing plots (one month apart). Wheat was planted in rows spaced 0.18 m apart at 400 viable seeds m^{-2}, using a no-till seed drill with hoe openers (Sider.Man) in all tillage treatments, making the appropriate adjustments to ensure a homogeneous planting depth; seeds were inoculated with a mixture of *Glomus* spp., *Trichoderma harzianum and PGPR (Ekoseed Cereals) at a dose of 200 g per 100 kg of seed*. At maturity, two sample areas (5.4 m^2) were identified within each sub-plot to assess grain yield of durum wheat and weed biomass. The data recorded were submitted to the analysis of the variance according to the experimental design. Treatment means were compared using Tukey's test ($P < 0.05$).

Results

The presented results are from a one-year experiment that is currently being replicated; hence, they are to be considered as preliminary results that will have to be validated once the database is complete. The two durum wheat genotypes used in the study produced different grain yields (on average 4.69 t ha^{-1} for the cv. Orizzonte and 2.49 t ha^{-1} for the landrace Scorsonera; Fig. 1A), but they responded in the same way to the type of tillage system applied.

Grain yield was significantly higher under CT than NT when the ordinary sowing date was used (3.96 vs 3.10 t ha^{-1} in CT and NT respectively; averaged values over the two genotypes). Considering the NT systems, early sowing increased grain yield by 20% on average compared to the ordinary sowing date. Moreover, early sowing in NT resulted in grain yields similar to those obtained in CT. The grain yield advantage of the early sowing over the ordinary sowing in the NT systems can be attributable, at least in part, to the effects determined by the sowing time on weed growth. Great reductions were in fact observed for weed biomass in the NT-early sown plots compared to the NT-ordinary sown plots (−42% on average; Fig. 1B), showing in this way how the anticipation of the sowing time has increased the competitive ability of the crop against weeds. The lowest weed biomass values were observed, however, in the CT plots, where the possibility of eliminating through the secondary tillage operations the weed plants that progressively emerged in autumn (before crop planting) resulted in a considerably lower weed biomass at crop harvesting time (0.78 t ha^{-1} in CT vs 3.55 t ha^{-1} in NT-ordinary sowing and 2.06 t ha^{-1} in NT-early sowing; averaged values over the two genotypes). Overall, a key role in determining the grain yield differences among treatments can certainly be attributed to the different level of weed infestation, although other factors (e.g. differences in duration of the crop cycle, amount and time of nutrient availability, etc.) may have also contributed to discriminate treatments.

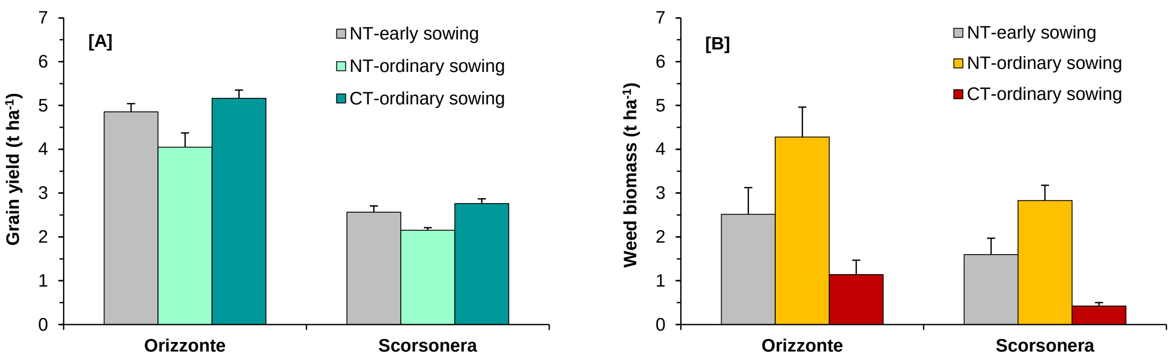

Fig. 1. Grain yield [A] and weed biomass [B] recorded in the two durum wheat genotypes Orizzonte and Scorsonera (G, "Genotype" treatment) grown under the three tillage system/sowing date combinations (T, "Tillage" treatment). NT, no-tillage; CT, conventional tillage. Each value is a mean of 8 data (2 samples × 4 replicates). Vertical bars indicate standard errors of each mean value. In [A], mean effects of both T and G treatments were significant at $P < 0.001$ ($LSD_{0.05} = 0.36$ for T; and $LSD_{0.05} = 0.29$ for G); in [B] mean effect of T was significant at $P < 0.001$ ($LSD_{0.05} = 0.83$) and mean effect of G was significant at $P = 0.004$ ($LSD_{0.05} = 0.68$). For both grain yield and weed biomass, the T × G interaction was never significant.

Conclusions

The results of the present study, although preliminary, highlight that the NT technique can be applied effectively within organic cereal-based systems of Mediterranean environments as long as it is associated to changes in other agronomic practices, such as the time of sowing. In fact, when NT was applied merely as a substitute of the CT, a 22% reduction in grain yield was observed, and, at the same time, a considerable increase in weed biomass (with a consequent increase in weed seed spreading) was recorded. On the other hand, when NT was

associated to an early sowing, the negative effects were significantly attenuated, so much that grain yield was similar to that obtained in CT.
These results let us hope that a more effective and sustainable application of the NT technique within the organic farming systems could be achieved by acting on other factors of crop management (e.g. use of specially designed seed drills, choice of genotypes more responsive to early sowing, etc.).

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Poster

“Agricoltura conservativa”

Swiss Chard Response To Different Organic Amendments

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Introduction

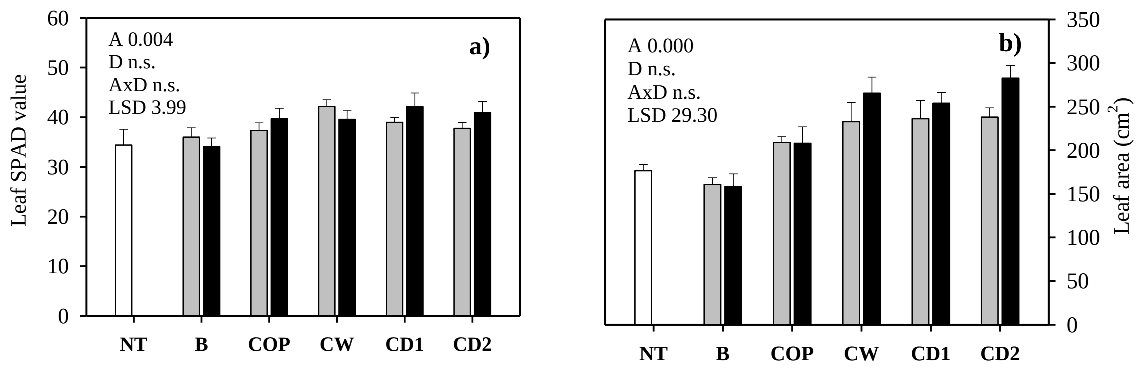
There is an increasing interest to explore benefits and potentials as well as limitations of organic amendments on soil quality and crop productivity. Currently, studies are focusing on biochar and compost. Biochar is a carbon-rich compound obtained by pyrolysis of agricultural biomasses; compost is the product of stabilization and sanitation of organic waste through aerobic decomposition. The effects of their addition to agricultural soils depend on feedstock and process conditions, application rate, type of soil, environmental conditions and crop species. Then, the physiological and productive response of crops to compost or biochar applications are often contrasting and either positive or negative effects on yield and quality have been reported (Martinez-Blanco et al. 2015; Subedi et al. 2017). In this respect, the effect of soil treatment with five organic amendments (biochar and four composts obtained from different feedstocks) on the behaviour of Swiss chard (*Beta vulgaris* L. var. *cycla*), a species largely consumed in Italy and known as "Bieta erbetta da taglio", was evaluated.

Materials and Methods

A greenhouse experiment was carried out in 2017, at the University of Basilicata (PZ), in pots (12×12 ×24 cm) filled with 2 kg of sandy-clay-loam soil. A non-treated soil (NT) was compared with the application of biochar produced by pyrolysis of vine pruning residues (B), compost derived from olive pomace (COP), worm composting or vermicompost (CW) and two composts obtained from different cattle anaerobic digestates with straw addition (CD1 and CD2, respectively). Each amendment was applied to the soil at two rates (single and double dose) in order to provide 140 and 280 kg N/ha, respectively. In B, COP, CW, CD1 and CD2, total nitrogen content was respectively equal to 1.5, 2.5, 1.7, 2.3 and 2.2 %; organic carbon content was 68, 34, 20, 35 and 36%. Two months after amendments application to the soil, two seedlings of *Beta vulgaris* L. var. *cycla* (cv. Eolo) were transplanted in each pot (8 Sept. 2017). During the experiment, leaf SPAD values were detected on the youngest fully expanded leaf of each experimental treatment by using a chlorophyll meter SPAD-502 (Konica-Minolta corporation, Ltd., Osaka, Japan). At the harvest of the Swiss chard leaves (12 Oct. and 7 Nov. 2017), the leaf area (LA) (LA meter LiCoor 3100) and the leaf fresh weight (FW) were recorded.

Results

Leaf SPAD values (Figure 1a) and LA (Figure 1b) of Swiss chard were significantly higher in plants treated with composts derived from animal wastes (on average 40 and 250 cm^2, respectively), followed by olive pomace compost (38.5 and 208 cm^2) and then biochar (35 and 160 cm^2) that not differed from the untreated control. No significant differences were observed between the two application doses in any of the considered amendments. Instead, significant differences of leaf FW (Figure 1c) were found among the different types of amendment, the two application doses ($p \leq 0.01$) and their interaction ($p \leq 0.05$). Indeed, by adding composts from animal wastes and olive pomace, increases of 41.6 and 12.5% of leaf FW were respectively observed in comparison to the untreated control, while a decrease of 16% was found in plants treated with biochar. Furthermore, again in plants treated with composts derived from animal wastes (CW, CD1, CD2), when the double dose of amendments was applied, the leaf FW increased by 25% on average, while no differences were found in plants treated with COP and B. These results suggest that growth-enhancing effects of composts from animal wastes on Swiss chard plants could be associated with a greater release of nutrients, in particular nitrogen, from these organic amendments as also suggested by the highest leaf SPAD values. Referring to olive pomace compost, Garcia-Ruiz (2009) reported effects of N immobilisation during its decomposition in the short-term period (3-12 months) and Morra et al. (2015) indicated that the higher the quantity of olive pomace compost applied the greater the slow release of NO_3-N for crop needs. The application of biochar did not showed any positive effect on physiological and productive response of Swiss chard plants likely due to the more limited supply of nitrogen to the plants and the biochar benefits that could better evidenced over the time, in comparison with the composts.



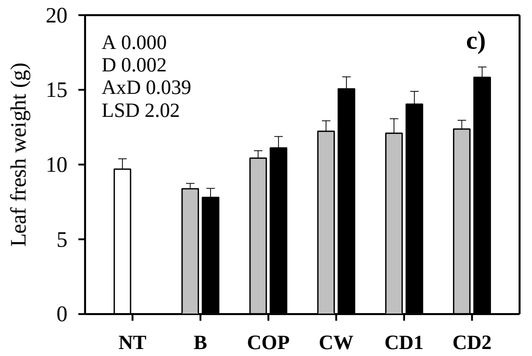


Figure 1. Leaf SPAD values (**a**), leaf area (**b**) and fresh weight (**c**) of Swiss chard grown on soil treated with different organic amendments: biochar from vine pruning residues (B), compost from olive pomace (COP), vermicompost (CW) and two composts from two digestates with straw (CD1 and CD2), supplied at two doses (single and double, grey and black bars, respectively) plus an untreated control (NT, white bar). Data presented in each graph were analysed by two-way ANOVA followed by LSD test at $p \leq 0.05$. Values are means (n=4) ± s.e.; A, amendment; D, dose; n.s., not significant.

Conclusions

The Swiss chard responded positively to the application of composts with significant increases of leaf area and fresh weight, indicating the high fertilizing value of the organic materials tested. Instead, the biochar application did not lead to positive or negative effects, showing values similar to those of untreated plants. The moderate increase in plants growth achieved by applying the double dose of the amendments suggest that further experiments are needed to optimize the application rates in order to improve crop productivity, especially for short-season crop, and agricultural sustainability.

Acknowledgements

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Minimum Tillage And Conventional Tillage Effects On Durum Wheat Yield In Central Italy

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Introduction

Durum wheat represent one of the main field crop in Italy, whose conventional tillage system utilizes moldboard ploughing followed by repeated secondary shallow tillage (CT). To reduce the environmental impact of soil tillage, the European Community agricultural policy encouraged farmers to adopt conservative tillage practices (European Union, 2000). However, despite its lower production costs and the effectiveness in increasing water infiltration (Busari et al., 2015), minimum tillage (MT) late to spread as an agricultural practice in Italy. Our objective was to determine the effects of MT and CT practices on durum wheat yield and grain quality over a 11 years period (from August 1st, 2000 to July 31st, 2011).

Materials and Methods

The effect of conventional tillage (CT: moldboard ploughing at 0.4 m depth and disk-harrowing at 0.15 m depth) and minimum tillage (MT: 3-point rigid cultivator at 0.15 m depth) on fallow-durum wheat (*Triticum durum* Desf., var. Claudio) rotation were studied over eleven-years from August 1st 2000 to July 31st 2011. The study was conducted under rainfed condition on a clay loam soil at the experimental farm of Florence University in San Casciano Val di Pesa, Italy. During the study period, the annual average rainfall amount was about 744.3 mm, ranging between 587.6 and 980 mm, while the annual average temperature was about 15 °C, ranging between 13.8 and 16 °C. Every year, duplicate sets of plots (8 × 54 m) were established to evaluate the two phases of the crop-fallow system. The CT treatments were always maintained undisturbed during the fall following wheat harvest and were moldboard ploughed at 0.4 m depth the successive spring. On the contrary, the MT treatments were generally maintained undisturbed during the "fallow" period. Nitrogen (120 kg N ha^{-1}) was split broadcasted: 30% N was broadcasted before sowing as diammonium phosphate, 30% N top-dressed applied at the end wheat tillering (BBCH scale 29) as ammonium nitrate and 40% top-dressed applied just before the end of stem elongation (BBCH scale 37) as ammonium nitrate. Weeds were controlled with Glyphosate at a rate of 1.44 kg of active ingredient for hectare (kg a.i. ha^{-1}) before planting and by means of Pendimetalin (0.9 kg a.i. ha^{-1}) and Diflufenican (1 kg a.i. ha^{-1}) within the growing season. Plots were mechanically harvested in July when grain moisture content of no more than 13% was reached. The hectolitre weight (kg hl^{-1}) was measured in triplicate for each plot by mean a Shopper chondrometer. Grain N content was determined by means of a Perikn Elmer CHNSO elemental analyser. Grain protein concentration was calculated by multiplying N by 5.7 and then expressing the result on a dry weight basis. At harvesting, soil was sampled in triplicate for each plot for laboratory analysis. The effects of tillage were determined by ANOVA by choosing a significance level of 0.05.

Results

At the harvest, the determined bulk density in the top 0.15 m of soil was significantly lower in MT (1098 ± 27 kg m^{-3}) than that in CT (1287 ± 116 kg m^{-3}), as reported by Busari et al., (2015). On the contrary, MT resulted in a higher ($p > 0.05$) bulk density (1353 ± 54 kg m^{-3}) than CT (1273 ± 62 kg m^{-3}) at a soil depth of 0.3 m, as reported by Steyn et al. (1995). The average grain yields over the study period were not significantly different for CT (3.6 ± 0.9 t ha^{-1}) and MT (3.5 ± 1.2 t ha^{-1}) treatments. Grain yields with CT exceeded MT in 5 out of 11 years (Figure 1), while yields with MT equalled and significantly exceeded those with CT in five and one years, respectively. The highest annual yield (4.7 ± 0.7 t ha^{-1}) was reached on MT the second year of tests, but at the cost of the lowest protein value (10.6% ± 0.7%). The hectolitre weight resulted slightly greater under MT than CT each year. The hectolitre weight values were higher than the values expected for the Claudio variety in Central Italy (80 kg hL^{-1}). High values of hectolitre weight indicated that grain was turgid with high starch accumulation, thus resulting in lower protein concentration values (Troccoli et al., 2000). In fact, the average protein content in MT tillage systems (12.2% ± 1%) and CT (12.9% ± 1%), was lower than the expected value for the same variety in Central Italy (13.4%). On average, results indicated that the tillage system affected the protein accumulation. In fact, the grain protein content with CT significantly exceeded MT in 6 of 11 years. Consequently, grain protein content values reach the standards for "pasta industry" (12.5%) in 8 out of 11 year in CT and only 3 times in MT. Amato et al. (2013), suggested that MT determine changes in the nitrogen cycle, thus leading to a reduction in plant-available soil nitrogen. Therefore, it could be appropriate to increase the rate of N fertilizer in MT.

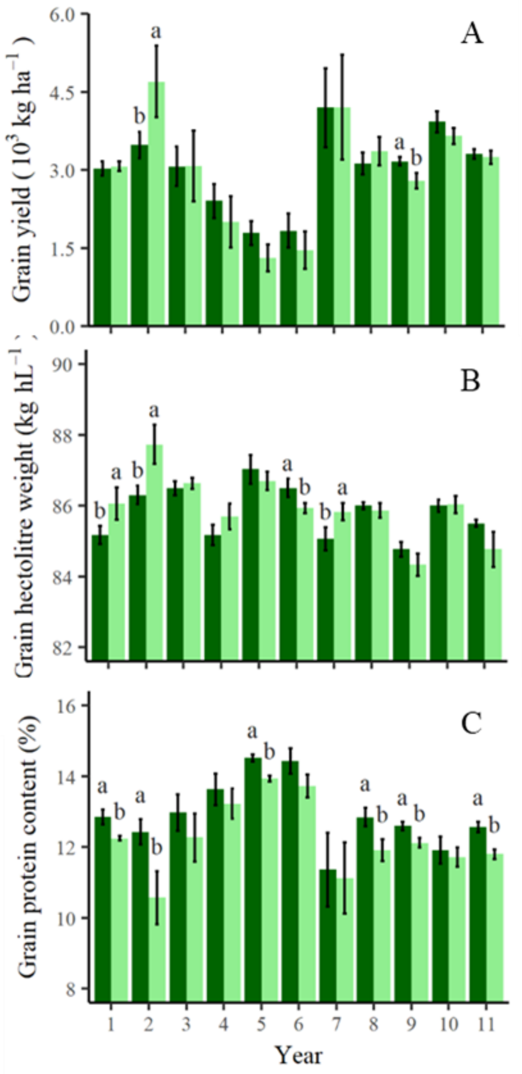

Figure 2: Comparative effect of conventional tillage (darkgreen) and minimun tillage (lightgreen) on grain yield (A), hectoliter weight (B) and protein content (C). Different letters indicated statistically significant difference according to ANOVA ($P < 0.05$)

Conclusions

The bulk density determined at the harvest in the top 0.15 m of soil was significantly lower in MT than that in CT. On the contrary, MT resulted in a bulk density than CT at a soil depth of 0.3 m. The results, performed during 11 yrs on a clay loam in central Italy, under rainfed Mediterranean conditions, show that wheat grown in MT systems produced grain yields comparable to those grown in CT. However, results for grain protein content indicated that under MT grain protein content did not met the standard values for "pasta industry", thus suggesting that under MT conditions it could be necessary to increase the rate of N fertilizer. In general, these results indicate that farmers can successfully produce durum wheat in a crop-fallow system using MT, but increasing the distributed nitrogen to reach a grain protein content comparable to that of CT.

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Evaluation Of Different Pre-germination Treatments, Temperature And Light Conditions, To Improve Seed Germination Of *Passiflora incarnata* L.

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Introduction

Among the conservation agriculture practices, the introduction of perennials in crop rotations has been proposed as a viable opportunity to improve the long-term sustainability and productivity of systems thanks to the reduction in tillage, the protection of the soil surface, and the decrease in erosion and runoff. As a consequence, a considerable improvement in soil organic matter and nutrient cycling as well as the overall physical and biological health of the soil can be achieved. In this context, perennial medicinal and aromatic plants (MAPs) may represent an interesting environmentally friendly non-food-crops for Mediterranean countries. In the last years, the attraction of MAPs as worthy farm crops has grown due to the demand created by consumer interest for these plants for culinary, medicinal, and other anthropogenic applications. Among MAPs, *Passiflora incarnata* could represent an interesting crop for Mediterranean systems, due to its perennial cycle and its potential agronomic benefits. *P. incarnata* (maypop) is mainly cultivated for its pharmaceutical and homoeopathic properties (Dhawan, 2004). In Italy, *P. incarnata* is grown mostly in the central regions (for a total area of approximately150-180 hectares, of which 50 ha under organic farming), where it behaves as perennial spring-summer crop with a stand duration of 5-7 years. The main problem in maypop large-scale cultivation is the poor seed quality with erratic and low seed germination, due to its apparent pronounced seed dormancy. This makes difficult in growing a maypop crop from seeds, so the nursery reproduction is generally carried out by cuttings, with a substantial increase in the cultivation costs. Little is known about the seed germination behavior of Passiflora species, and no information is reported on the “International Rules for Seed Testing” (ISTA, 2018), regarding minimum germination requirements or optimal conditions for germination. Although seeds of some Passiflora species show a combination of physical and physiological dormancy, studies regarding *P. incarnata* are very limited and not conclusive. Therefore, the aim of this work was to investigate different chemical and physical treatments for overpassing seed dormancy and for enhancing seed germination rates of *P. incarnata*.

Materials and Methods

The experiments were carried out at the Seed Research and Testing Laboratory of the Department of Agriculture, Food and Environment of the University of Pisa. The responses of the seed lots of three *P. incarnata* accessions grown in 2016 in Central Italy (F2016, FF2016, and A2016) to different treatments (pre-chilling, GA3, leaching, scarification, non-treated control), different light (L) or darkness (D) exposure and temperature conditions (25, 30, 35°C constant temperatures and 20-30°C alternating temperatures) have been examined. The seeds were kindly supplied by F.I.P.P.O. (Federazione Italiana Produttori Piante Officinali) and by Aboca srl company (Sansepolcro, Arezzo). Three replications for each treatment have been adopted. The seeds were placed in 12 cm Petri dishes and incubated in climatic cabinets. Preliminary Tetrazolium tests (according to ISTA, 2015) were conducted to estimate the seed viabilities of a three *P. incarnata* accessions. Germinated seeds (defined as cotyledon appearance) were counted. Germination counts were stopped when final germination percentages were reached (up to 30 days as a function of temperature). Mean germination time was calculated as follows: $MGT = \Sigma (n \times g) / N$, where n = number of germinated seeds per day; g = number of days needed for germination and N = total number of germinated seeds. Germination percentage were converted into angular values. Data were subjected to analysis of variance (ANOVA).

Results

The obtained results confirmed as *P. incarnata* seeds are photoblastically negative and have pronounced heat requirements for germination. Optimal germination percentages were achieved with 35°C under dark, while very low values were observed at 25°C. Data showed significant interaction between complete light/dark exposition and temperatures, underlying that the light exposition had an inhibitory effect on the germination of *P. incarnata* seeds. The time required for germination decreased progressively with increasing temperatures, but only under dark conditions. In complete light conditions, no variation was observed, and MGT values remained almost constant while increasing temperatures. In addition, alternating temperature did not improve germination energy, except when combined with pre- chilling. Among accessions, the highest and faster germination rates (germination percentage up to 90%) were observed for the untreated/control seeds of F2016 accession, followed by FF2016. Among the pre- treatments here tested, pre-chilling, GA3 and leaching enhanced normal seedlings germination, while under scarification, the dead seeds percentage considerably increased in all accessions, due to embryo damaging.

Table 1. Effect of the different pre-treatments and temperature/light conditions and their interaction on germination percentage (%) and mean germination time (days) on *P. incarnata* F2016, FF2016 and A2016 seed lots.

		25°C		30°C		35°C		20/30°C	
		D	L	D	L	D	L	16/8h	8/16h
F2016	Pre-chilling	8.00 $^{H-N}$ (n.d.)*	2.67 $^{L-O}$ (n.d.)	49.33 ^{CD} (5.73 ^{AB})	34.67 $^{D-F}$ (7.70 $^{A-G}$)	80.00^{AB} (6.47 $^{A-C}$)	70.67 ^{BC} (13.13 M)	78.67 ^{AB} (7.87 $^{A-G}$)	46.67 ^{D} (9.53 $^{E-L}$)
	GA3	16.00 $^{F-I}$ (n.d.)	0.00 ^{O} (n.d.)	73.33 ^{AB} (5.80 ^{AB})	20.00 $^{E-I}$ (6.43 $^{A-C}$)	80.00 ^{AB} (7.07 $^{A-E}$)	69.3 ^{BC} (9.30 $^{D-I}$)	25.33 $^{E-G}$ (10.10 $^{G-L}$)	29.33 $^{D-F}$ (9.90 $^{G-L}$)
	Leaching	9.33 $^{G-M}$ (n.d.)	0.00 ^{O} (n.d.)	76.00 ^{AB} (7.83 $^{A-G}$)	24.00 $^{E-H}$ (7.00 $^{A-E}$)	84.00 ^{AB} (6.47 $^{A-C}$)	81.33 ^{AB} (8.00 $^{A-G}$)	17.33 $^{F-I}$ (12.83 ^{M})	46.67 ^{D} (9.67 $^{F-L}$)
	Scarification	2.67 $^{L-O}$ (n.d.)	1.33 $^{N-O}$ (n.d.)	25.33 $^{E-G}$ (5.73 ^{AB})	17.33 F-I (5.47 ^{A})	69.33 ^{BC} (6.07 $^{A-C}$)	46.67 ^{D} (6.77 $^{A-D}$)	12.00 $^{G-L}$ (11.90 ^{LM})	33.33 $^{D-F}$ (10.80^{H-M})
	Control	0.00 ^{O} (n.d.)	0.00 ^{O} (n.d.)	40.00 ^{DE} (7.03 $^{A-E}$)	12.00 $^{G-L}$ (7.27 $^{A-F}$)	90.00 ^{A} (8.20 $^{B-G}$)	40.00 ^{DE} (9.40 $^{E-L}$)	21.33 $^{E-H}$ (11.07 $^{I-M}$)	8.00 $^{H-N}$ (8.50 $^{C-H}$)
FF2016	Pre-chilling	22.67 $^{N-Q}$ (n.d.)	2.67 ST (n.d.)	57.33 $^{A-F}$ (5.77 ^{A})	20.00 $^{O-Q}$ (10.50^{H-L})	50.67 $^{C-H}$ (6.97 $^{A-F}$)	69.33 $^{A-C}$ (8.53 $^{B-I}$)	74.67 ^{A} (7.90 $^{A-H}$)	38.67 $^{F-N}$ (8.73 $^{C-I}$)
	GA3	28.00 $^{L-Q}$ (n.d.)	6.67 ^{RS} (n.d.)	70.67 ^{AB} (6.10 $^{A-C}$)	34.67 $^{G-O}$ (7.73 $^{A-G}$)	69.33 $^{A-C}$ (7.23 $^{A-F}$)	42.67 $^{E-M}$ (8.93 $^{D-I}$)	30.67 $^{I-P}$ (10.43 $^{H-L}$)	42.67 $^{E-M}$ (8.63 $^{B-I}$)
	Leaching	13.33 $^{Q-R}$ (n.d.)	1.33 ST (n.d.)	53.33 $^{B-G}$ (7.55 $^{A-F}$)	24.00 $^{M-Q}$ (9.20 $^{E-I}$)	74.67 ^{A} (8.30 $^{A-H}$)	46.67 $^{D-L}$ (9.50 $^{F-I}$)	17.33 ^{PQ} (10.25 $^{G-L}$)	33.33 $^{H-P}$ (9.50 $^{F-I}$)
	Scarification	26.67 $^{M-Q}$ (n.d.)	4.00 ST (n.d.)	64.00 $^{A-D}$ (6.00 ^{AB})	21.33 $^{N-Q}$ (7.63 $^{A-G}$)	58.67 $^{A-F}$ (6.53 $^{A-E}$)	49.33 $^{D-I}$ (7.67 $^{A-G}$)	18.67 $^{O-Q}$ (12.60 ^{LM})	33.33 $^{H-P}$ (9.57 $^{F-I}$)
	Control	0.00 ^{T} (n.d.)	0.00 ^{T} (n.d.)	60.00 $^{A-E}$ (6.50 $^{A-D}$)	20.00 $^{O-Q}$ (7.00 $^{A-F}$)	60.00 $^{A-E}$ (7.90 $^{A-H}$)	48.00 $^{D-I}$ (10.20 $^{G-L}$)	20.00 $^{O-Q}$ (13.93 ^{M})	20.00 $^{O-Q}$ (11.00 ^{IL})
A2016	Pre-chilling	0.00 ^{S} (n.d.)	0.00 ^{S} (n.d.)	65.33 ^{A} (6.43)	13.33 $^{I-P}$ (9.10)	53.33 $^{A-C}$ (11.10)	36.00 $^{C-H}$ (11.77)	64.00 ^{AB} (10.20)	16.00 $^{I-N}$ (10.40)
	GA3	6.67 $^{O-R}$ (n.d.)	4.00 $^{P-S}$ (n.d.)	50.67 $^{A-C}$ (7.50)	22.67 $^{F-L}$ (11.87)	60.00 ^{AB} (8.57)	55.33 $^{A-C}$ (12.87)	16.00 $^{I-N}$ (11.33)	45.33 $^{B-E}$ (13.63)
	Leaching	6.67 $^{O-R}$ (n.d.)	1.33 ^{RS} (n.d.)	37.33 $^{C-G}$ (8.23)	20.00 $^{H-M}$ (7.53)	65.33 ^{A} (8.30)	48.00 $^{A-D}$ (12.67)	18.67 $^{H-N}$ (16.83)	29.33 $^{D-I}$ (10.77)
	Scarification	4.00 $^{P-S}$ (n.d.)	4.00 $^{P-S}$ (n.d.)	28.00 $^{E-L}$ (8.63)	18.67 $^{I-N}$ (7.83)	65.33 ^{A} (6.40)	49.33 $^{A-C}$ (10.23)	13.33 $^{I-P}$ (18.23)	24.00 $^{F-L}$ (12.57)

	25°C		30°C		35°C		20/30°C	
	D	L	D	L	D	L	16/8h	8/16h
Control	0.00 [S] (n.d.)	0.00 [S] (n.d.)	48.00 [A-D] (10.70)	8.00 [M-Q] (10.00)	60.00 [AB] (7.00)	40.00 [C-F] (9.80)	21.33 [G-M] (17.20)	8.00 [M-Q] (14.00)

* *Mean Germination Time*.

Conclusions

In conclusion, this study underlined that dark and suitable thermal conditions are necessary for high and rapid germination of P. incarnata seeds. These findings are useful for the choice of the most suitable seed pre-treatments to improve P. incarnata seed germination, in order to reach stable, high and agronomically acceptable germination rates.

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Soil Properties As Affected By Irrigation With Treated Municipal Wastewater

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Introduction

The use of unconventional water in agriculture is a common practice, especially in arid and semi-arid regions, where water deficit is a limiting factor in crop production. The reuse of treated municipal wastewater for irrigation is a potential solution to reduce fresh water demand and protect the environment. This alternative water source can be also an opportunity to recycle plant nutrients. In fact, the effluent is rich in macro and micro nutrients essential for plant growth (Bedbabis et al., 2015). Moreover, the reclaimed water can affect physical, chemical and biological soil properties and consequently crop production. These effects depend not only on the quality of irrigation water but also on soil type, amount of wastewater used, duration of irrigation and local climate (Tarchouna et al., 2010).

In this study, the effects of short-term irrigation with treated municipal wastewater on main soil properties were evaluated, in an olive grove under Mediterranean conditions.

Materials and Methods

The experimental trial was carried out in an irrigated olive grove in an Apulia coastal area, characterized by a loam soil. The climate is typical Mediterranean with long periods of dryness and high evaporation rates. The olive grove was irrigated over three years with treated municipal wastewater (TWW) obtained from water treatment plant near the experimental field.

Treatments compared were: FW, irrigation with fresh water and full fertilizer supply; R1, irrigation with TWW and full fertilizer supply; R2, irrigation with TWW and fertilizer supply reduced by the amount provided by TWW. Treatments were arranged in a randomized complete block design with four replicates. Single plot size was of 108 m^2 consisting of three olive trees.

Table 1. Effects of different water quality on chemical soil properties

Treatments	TOC	WEOC	WEN	$EC_{1:5}$
	g $100g^{-1}$	mg kg^{-1}		dS m^{-1}
FW	1.6973	34.33 b	9.991	0.178
R1	1.9532	68.21 a	15.771	0.249
R2	1.8982	68.40 a	15.904	0.248
P=	$0.0673^{n.s.}$	0.0354^{*}	$0.2552^{n.s.}$	$0.0593^{n.s.}$

Soil characterization was performed collecting from each plot six soil samples at 0-0.20 m depth. On air-dried and sieved soil, total organic carbon content (TOC), pH (1:5 soil:water, W/V) and electrical conductivity ($EC_{1:5}$) were quantified. On fresh and field-moist soil samples, water extractable organic carbon (WEOC) and nitrogen (WEN) were measured; in addition, on three out of the six samples per plot, soil respiration was quantified using the incubation method (Ferrara et al., 2017) after 1, 3, 7, 10, 14, 21 and 28 days. Data were subjected to a nested analysis of variance and means were compared using SNK post hoc test at P = 0.05 level. Moreover, correlation analysis was performed to investigate relationships between chemical and biological parameters under study. Data analysis was carried out using the SAS software.

Results

The TWW used to irrigate the olive trees for three consecutive years slightly increased soil TOC, pH and EC, compared with fresh water. In particular, although not significant, TOC and EC were higher in R1 and R2 (on average +13 and 7%, respectively) than in FW. Therefore, the irrigation with TWW can be a source of organic matter but also of salts that, in the long term, could accumulate in the root zone and increase soil salinity. In any case, in this study the EC values were below the salinity threshold. Greater and significant effect was found in WEOC after irrigation with TWW as compared to freshwater. In fact, in R1 and R2 treatments, WEOC was on average almost double compared with FW. So, wastewater application enhanced the most labile form of soil organic matter fraction, that represents an immediate energy source for microorganisms, involved in several soil biological processes (organic matter decomposition, nutrients cycling, etc) (Zhang et al., 2011). Soil respiration, estimated as the CO_2 produced and released during an incubation period of 28 days, did not show significant differences among treatments (Fig. 1). In any case, in R2 treatment, characterized by the highest values of WEOC and WEN, higher respiration rates were observed, in particular during the first seven days of incubation. The WEOC was significantly and positively correlated (r = 0.3695*) with respiration rate in the first day of soil incubation; WEN was strongly and positively correlated in the first and third day of soil incubation (r = 0.4385** and 0.3346*, respectively). Moreover, the correlation analysis showed a strong and positive correlation between TOC and soil respiration rates during the whole period of soil incubation. EC and pH were not significantly correlated with soil respiration, whereas the pH was positively and significantly correlated with WEOC and WEN (r = 0.5192** and 0.3613*, respectively).

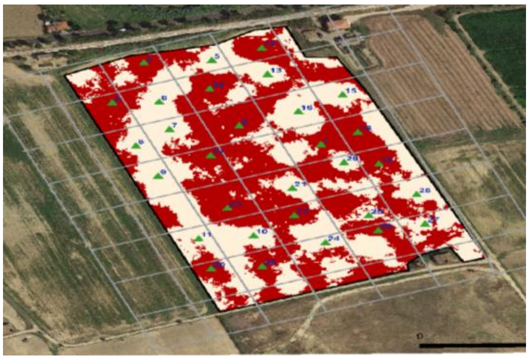

Figure 1. Soil respiration during 28 days of incubation

Conclusions

TWW reuse in semi-arid areas, such as Southern Italy, can be an important strategy to save limited freshwater resources and provide essential nutrients. With regard to the soil chemical properties, the TWW, in the short term, seems to increase TOC and its most labile and biodegradable fraction (WEOC and WEN) and in turn soil microbial activity and community composition, being a source of readily available energy for soil microbes. Further studies should be therefore carried out to evaluate the effects of wastewater on other sensitive indicators, such as enzymatic activities. In any case, potential detrimental effects, due to salt accumulation, should be monitored in order to avoid soil fertility losses in the long term.

Acknowledgments

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Use Of Biodegradable Films For Solarization: Effects On Temperature, Moisture And N-NO_3 And N-NH_4 Content Of Soil

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Introduction

The solarization is a no-chemical method that is largely used in many temperate regions for soil disinfestation such as pathogens (fungi, bacteria, nematodes) and weeds control. Soil solarization is usually made covering soil with transparent plastic film for 4-6 weeks with the aim to increase soil temperature. But the solarization has also other secondary effects such as the increase of ammonium- and nitrate-nitrogen concentrations (Stapleton, 2000). Currently soil solarization is usually made with plastic films like polyethylene, but they have a great limit as their disposal since they require about 100 years for completing their decomposition. The disposal can be made by burying of these materials in the agricultural land, burning, composting and recycling (Kyrikou et al. 2007), but the recycle is often difficult and expansive because the mulching films are contaminated by soil. Therefore the use of biodegradable films could allow to overcome these problems because they, after solarization, degrade progressively in the soil. However, it is need to verify if the biodegradable film can obtain the same performance of plastic film in terms of soil disinfestation (data not showed) and so in terms of temperature increase, but this research aims also to evaluate the possible effects of these films on moisture and some chemical proprieties of soil (ammonium- and nitrate-nitrogen concentrations).

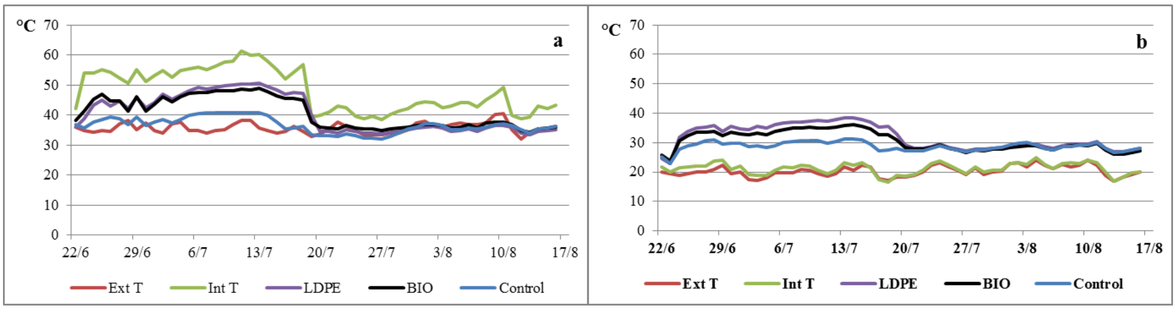
Materials and Methods

The experiment was carried out in the summer 2017 at experimental field of Dept. of Agriculture, in Portici (Naples-Italy; lat. 40° 49' N; long.14° 20' E) in a polyethylene greenhouse. A completely randomized block design with 3 replicates was used to compare bare soil (control) with 2 different mulching films for solarization: the traditional transparent low density polyethylene (LDPE with 60 µ thickness) and the transparent biodegradable film-PC17T6/35 (BIO with 35 µ thickness). The films were manually placed on 22 June 2017; at the same time the temperature probes, three per treatment, were installed for measuring continuously the soil temperature at depth: 0-20 cm. The films were removed after one month, but the trial lasted two months for monitoring the trend of chemical soil proprieties also in the first month successive to films removal. Before the test started, a soil sampling was made at 0-20 cm for physical and chemical characterization; the soil was a sandy loam soil (USDA classification) with pH of 6.94, EC of 0.6 dS m^{-1} and high content of organic matter (2.2%), phosphorus (87 ppm) and potassium (1800 ppm) and discrete content of nitrogen (0.12%). Every fifteen days, a soil sample per treatment and replicate were made to determinate water content and nitrogen (nitrate and ammonium) content.

Results

In the first month, the air maximum temperature (Fig. 1a) under the greenhouse was on average 19°C higher than external temperature (54.7 *vs* 45.7°C respectively) with a peak of 61.4°C. The temperature of two covered soils was about 7°C higher than control soil, but there were not differences between them (average value was 46.2 and 45.7°C for LDPE and BIO, respectively). Instead about the minimum temperature (Fig. 1b), the LDPE showed the best performance with almost 2°C and 5.6°C more than BIO and control respectively. The soil heating is evident also by Tab. 1, where the soil temperatures have been grouped in 4 ranges (36-40, 41-45, 46-50, 51-55°C) and per each ranges the number of hours have been calculated. Both cover films showed obviously a greater number of warmth hours than control in the all ranges with the LDPE higher than BIO: the total hours higher than 36°C were 537 and 476 respectively. The control showed only 228 *hrs* with soil temperature higher than 36°C. During the two test months the soil moisture (Fig. 2) had a decreasing trend and the control showed the lower values (8.6% vs 10.8% average value of cover films) at the last sampling.

Fig 1. Trend of maximum (a) and minimum (b) temperature during the test period.



The N-NO$_3$ (Fig. 3a) increased until the removal of films, then it decreased, but the BIO values was always higher; the N-NH$_4$ (Fig. 3b) was about constant in the soil control, it had a peak in the two films at day 15, higher in LDPE, then it was stable for BIO and decreased for LDPE, that reached final BIO value.

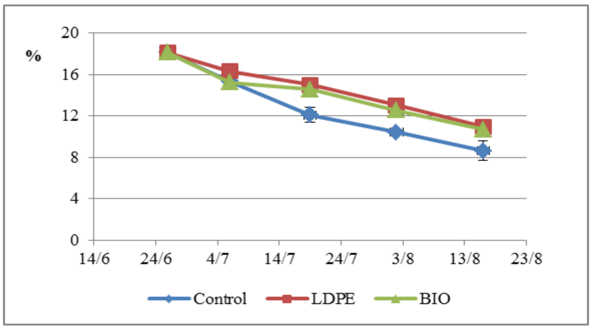


Fig. 2 Trend of soil moisture during the test period.

Table 1. Number of hours per each treatment respect to 4 ranges of temperatures during the solarization.

T ranges °C	**Control**	**LDPE**	**BIO**
		n° hours	
36-40	192	214	209
41-45	36	188	139
46-50	0	114	120
51-55	0	21	8

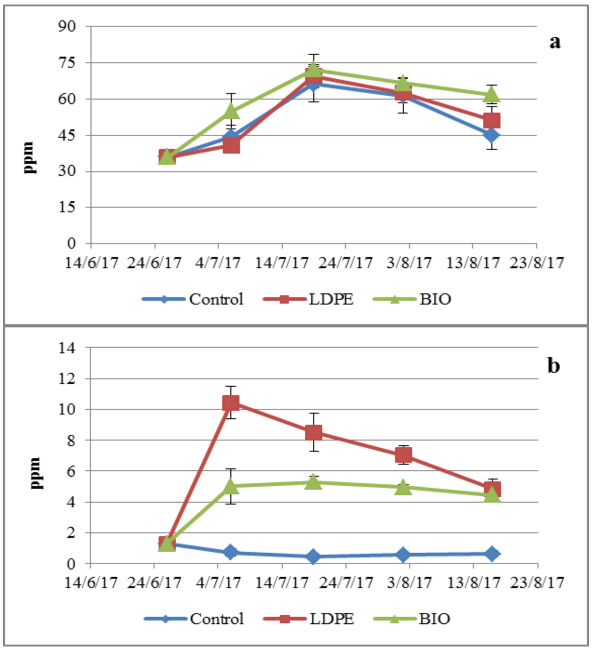


Fig. 3 Trend of nitrate (a) and ammonia nitrogen (b) during the test period.

Conclusions

The biodegradable film would seem suitable for solarization, because it has a behavior similar to LDPE but, being more porous than that, it allows a greater activity of aerobic bacteria with a greater NO$_3$ production.

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Weed Seed Decay In No-Till Soil

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Introduction

The three important pillars of conservation agriculture (CA) are minimal tillage, permanent residue cover, and crop rotation. Weed control in CA is a greater challenge than in conventional agriculture because there is no weed seed burial by tillage operations. The behaviour of weeds and their interaction with crops under CA tends to be complex and not fully understood. The objective of this work was to compare the level of seed degradation by soil microorganisms of five weed species between a field managed using CA and an adjacent buffer zone.

Materials and Methods

The experiment took place at the experimental farm of Padova University in Legnaro, in two adjacent sites: a no-till field and a buffer zone. During the experiment, the field was covered by soybean. The buffer zone was delimited by two rows of trees and bushes. The inter-row soil where seeds were buried was covered with tree leaf litter. The studied species were: *Abutilon theophrasti, Alopecurus myosuroides, Amaranthus retroflexus, Digitaria sanguinalis,* and *Portulaca oleracea*. For each species, 4 small steel mesh nets were filled with 50 seeds. The net bags were buried on 12/07/2017 at 12 cm depth, both in the no-till field and in the buffer zone. Net begs were exhumed on 05/10/2017. After the exhumation, the seeds were cleaned and firstly classified using the 'unimbibed crush test' (Borza et al., 2007); those that failed the test were marked as degraded, those that passed the test were subjected to a germination test. So, seeds were placed in Petri dishes, using 4 repetitions per species, and the germination process was monitored every 3-4 days. After roughly 3 weeks of incubation, a tetrazolium test was performed on not germinated seeds to control their vitality. Ultimately the seeds were classified as degraded, germinated, dormant (vital under tetrazolium test), and dead. The microbial activity in both sites was tested using fertimeters (PCT/IB2012/001157 - Squartini, Concheri, Tiozzo). The analysis consisted of burying the fertimeters in the soil in both sites for 7 days, and afterwards measuring the degradation of fertimeter threads using dynamometer. In order to have more information about the microbial activity in the soil, fertimeters were used, made of cotton and silk, with three treatments: nitrogen, phosphorus and control not treated. After 7 days the fertimeters were exhumed, dried and their degradation level tested. The method is described in more detail by Stevanato et al. (2014). The fertimeters were buried two times in July and in September. The percentage data of germinated, degraded, dormant, and dead seeds were presented as average values with standard deviations. Factorial analysis of variance (ANOVA) was performed to analyse the effect of site and species and their interaction on seed degradation. ANOVA was performed also to analyse fertimeters degradation. Homogeneity of variance was tested using Levene's test. Significant differences among means were identified by using the Newman-Keuls ($p<0.05$) test.

Results

The results of the seed classification after the exhumation are reported in tables 1 and 2 for the field and buffer zone respectively. The species with most degraded seeds was *A. theophrasti,* while the least degraded were the seeds of *A. myosuroides,* less than 5%. Similar values of degradation were observed for *A. retroflexus* and *D. sanguinalis* (38% and 34% respectively), while the seeds of *P. oleracea* had 18% of degraded seeds (figure 1). Higher percentage of degraded seeds was also noted in the no-till field than in the buffer strip (figure 2). There was no significant difference among silk threads of fertimeters, while the cotton threads buried in the field showed higher degradation than those buried in the buffer strip (figure 3). The control fertimeters showed higher level of degradation than the treated ones, indicating that in both zones there were no deficiencies of the nutrients N and P (figure 4).

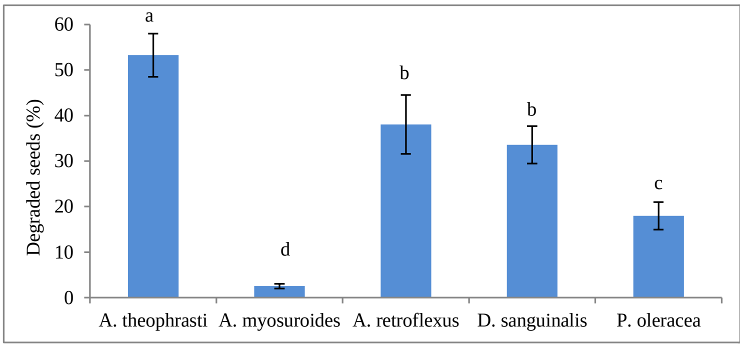
Table 1. Classification of the seeds exhumed from the field.

Specie	Germinati (%)		Degradati (%)		Dormienti (%)		Intatti morti (%)	
	Media	Dev.st	Media	Dev.st	Media	Dev.st	Media	Dev.st
Abutilon theophrasti	2	1.9	60	14.9	33	13.1	6	2.8

Alopecurus myosuroides	97	2.6	2	1.7	1	1.0	1	1.0
Amaranthus retroflexus	31	12.2	50	13.9	3	2.6	15	6.1
Digitaria sanguinalis	32	7.5	39	14.8	7	2.6	21	8.5
Portulaca oleracea	79	8.9	21	8.9	0	0.0	0	0.0

Table 2. Classification of the seeds exhumed from the buffer strip.

Specie	Germinati (%)		Degradati (%)		Dormienti (%)		Intatti morti (%)	
	Media	Dev.st	Media	Dev.st	Media	Dev.st	Media	Dev.st
Abutilon theophrasti	11	5.0	47	9.9	39	5.8	3	3.5
Alopecurus myosuroides	97	1.2	3	1.2	0	0.0	0	0.0
Amaranthus retroflexus	53	15.4	26	13.8	0	0.0	21	2.2
Digitaria sanguinalis	59	8.5	28	3.8	0	0.0	13	5.1
Portulaca oleracea	85	8.5	15	8.5	0	0.0	0	0.0



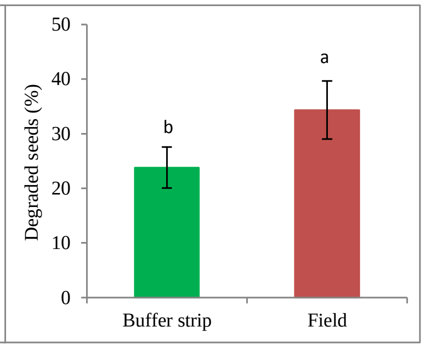
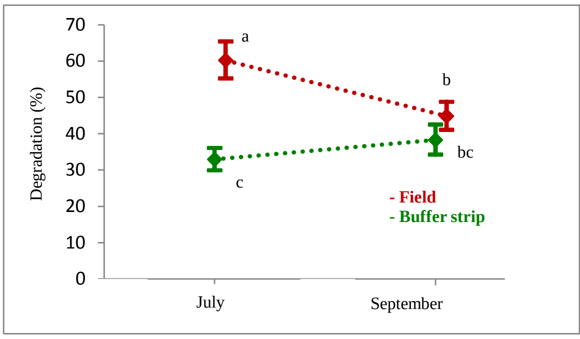
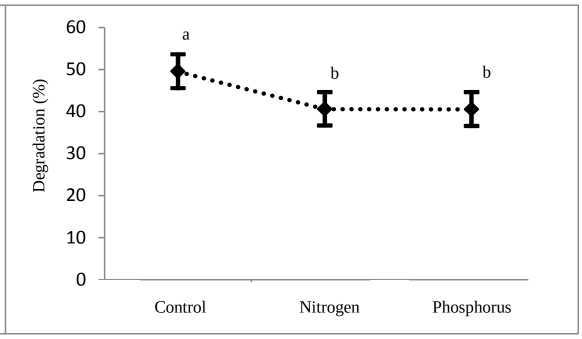


Figure 1. Percentage of degraded seeds per species.

Figure 2. Percentage of degraded seeds in the two sites.





Conclusions

The degradation of weed seeds was different among species and in no-till soil was higher than in the buffer strip. The data about soil microbial activity obtained using fertimeters showed greater degradation of the seeds in the no-till field than the buffer zone, in accordance with the data of seed degradation.

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Tillage Erosion: The Hidden Threat In Semiarid Vineyards

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Introduction

Soil erosion has been considered a several threat for semiarid land, due to the gradual removal of solid materials by water and wind through mechanical and physical actions.

Although water erosion is currently considered the most responsible process of soil degradation, a growing interest is addressed towards the erosive and translocation processes due to soil tillage.

The first studies on tillage erosion assessment were carried out in 1942 by Mech and Free, who deduced that the intensity of erosion was linked to the slope. In the 90s researchers from different parts of the world such as Lindstrom et al. (1990), Lobb et al. (1995) and Govers et al. (1994) showed that soil erosion is the main cause of land redistribution models in cultivated fields, demonstrating that soil translocation is affected by tillage depth, speed and soil condition (van Oost et al., 2006). Different methods have been used to measure tillage erosion through the use of chemical and physical tracer such as Caesium, Chloride, Aluminium cubes, Stones (Zhang et al., 2004; Barneveld et al., 2009). Although numerous studies on tillage erosion have been carried out on arable land using mouldboard plough, chisel, tandem disc, there are no studies on the effect of shallow tillage on soil redistribution in vineyards. The aim of this work was to evaluate the soil tillage erosion rate in a vineyards using ^{13}C natural abundance tracer.

Materials and Methods

The experiment was carried out in a vineyard located in Santa Margherita del Belice, in Sicily. The soil is clayey with a slope of 15%. The soil translocation was measured using the difference of ^{13}C natural abundance between vineyard soil (C_3-C soil) and C_4-C used as tracer. Two adjacent inter rows were selected. In each inter row, a strip of soil (1m lenght * 0.2m wide, 0.15m depth) was removed, carefully weighted and mixed with ground biomass of posidonia (C_4 plant; $\delta^{13}C$=-17‰). Tillage (upslope direction in one inter row and downslope direction in the other inter row) was performed with a cultivator and with a speed of 4km h^{-1}. After tillage, soil was collected with PVC cylinder tube and bulk density was measured. Three soil subsamples of each plot were collected along the slope with an interval of 0.2 m from C_4-C strip. Soil samples were sieved and carbonates were removed, before soil organic carbon and $\delta^{13}C$ analyses. Furthermore, three soil subsamples for each plot were taken in the C_4-SOC strip and in vineyard soil before the experiment ($\delta^{13}C$=-26.5‰).

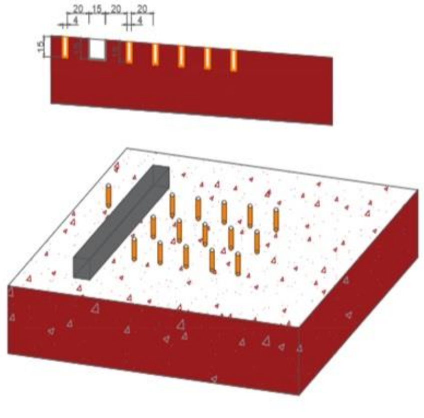

Figure 1 Experimental layout

Natural abundance of $\delta^{13}C$ was used to determine the proportion of C in SOC that was derived from the C_4-SOC strip and the consequent soil translocation (Kg), as follows:

$$Soil\ traslocation\ (kg) = \left(1 - \frac{(\delta^{13}C_{sample} - \delta^{13}C_{strip})}{(\delta^{13}C_{vineyard} - \delta^{13}C_{strip})}\right) * SOC_{sample} * \frac{SM_{strip}}{SOC_{strip}}$$

where $\delta^{13}C_{sample}$ is the isotopic composition of soil sampled after tillage; $\delta^{13}C_{strip}$ is the C isotopic composition of soil in the strip after posidonia adding, $\delta^{13}C_{vineyard}$ is the C isotopic composition of vineyard soil, SOC_{sample} is the SOC content of soil sampled after tillage (g kg^{-1}), SM_{strip} is the mass of soil in the strip (kg), SOC_{strip} is the SOC content of soil in the strip (g kg^{-1}).

Results

In relation to experimental conditions (soil type, moisture, tractor speed etc), $\delta^{13}C$ increased significantly from the labelled strip up to 1.20m in downslope tillage direction and 0.80m in the upslope tillage direction. Analysis of soil translocation showed that soil erosion can be calculated as the sum of translocated soil considering the maximum translocation distance (Figure 2). Results of this work showed that 4.7 kg m^{-1} and 1.4 kg m^{-1} were translocated in downslope and upslope tillage direction, respectively, from 20cm labelled strip.

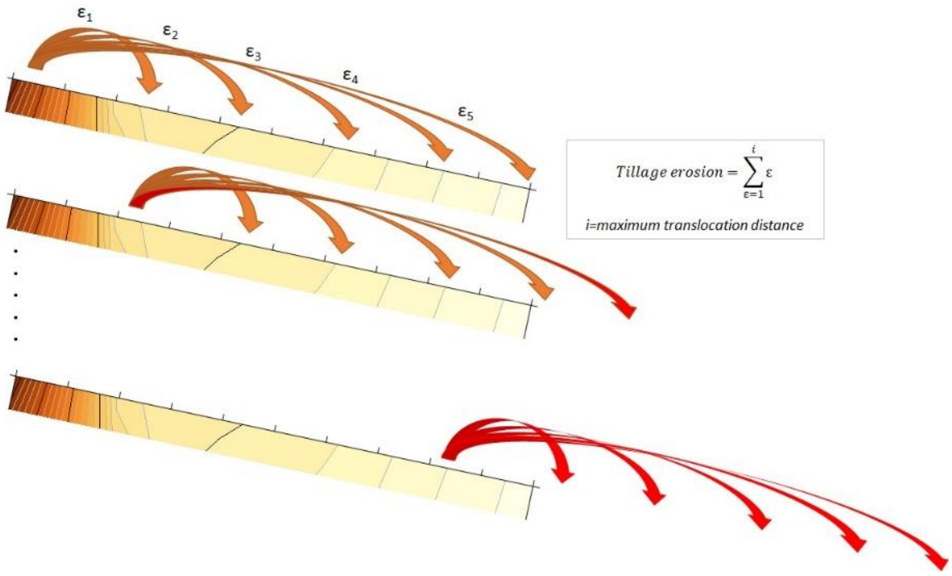

Figure 2. *Scheme of tillage translocation and total soil erosion*

Conclusion

Results of this research showed that tillage erosion rate is relevant also with shallow tillage and therefore further studies on factors affecting the soil translocation should be analysed to reduce the loss of soil in semiarid vineyards.

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Durum Wheat Yield And Quality In A No-Tillage Experiment

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Introduction

Soil fertility, due to soil erosion and organic matter depletion, is the biggest sustainability challenge for conventional tillage in dryland agriculture of Southern Italy and the adoption of no tillage practices can address these issue (Troccoli et al., 2015). No tillage and residues management are widely considered the most important conservation agriculture practices as alternatives to conventional ploughing and tillage disturbance (Gristina et al., 2018).However, although direct seeding and residues surface disposal increase water holding capacity, crop yield resulted often limited in the transition period. Soil physical, chemical and microbiological changes, typically long term effects, occur in the 3-5 years range from the beginning of tillage management (Colecchia et al., 2015).

Aim of this work is to assess the response to two different soil tillage management in a Vertisol of Southern Italy of durum wheat grain yield and quality in a 4-year experiment.

Materials and Methods

The experiment was established in the fall 2013 at the Research Centre for Cereal and Industrial crops (Foggia, Italy; 41° 28'N, 15° 32'E; 75 m a.s.l.) on a clay-loam soil (Typic Chromoxerert). Main soil traits were 30% clay, 25% sand; pH 7.5; 12.5 g kg^{-1} total C. Mean long-term rainfall of the site is 479 mm. Mean air temperatures are 12.2 ºC in fall, 8.2 ºC in winter, and 17.6 ºC in spring.

The experiment was a randomized block design, replicated 5 times and elementary plots of about 1 ha size. Two soil management systems (SMS) were compared: direct seeding on no tillage soil (NT) and minimum tillage (MT).MT included wheat straw removal before the tillage operation, disk cultivator at 15 cm depth and chisel at 10 cm before sowing; NT included crop residues left on soil surface, use of glyphosate at a rate of 720 g of active ingredient $ha^{-1}$for weed control one week before sowing (Gaspardo NO-TILL).Common durum wheat management was followed: sowing at the beginning of December, cv. Sfinge, fertilization at the end of tillering with 400 kg ha^{-1} of ENTEC 25:15:0, chemical weed control at boot stage, harvest at the end of June.

Grain yield was recorded in 30 georeferenced sub-plots of 30 m^2 for each plot; on the grain sample test weight and protein content was measured with grain analyzer Foss Infratec 1241. A FAO-UNEP Aridity Index (AI = ΣRainfall/ΣET0) of the period March-May for each year, was also calculated.

A total of 1200 observations (30 subplots x 5 plots x 2 SMS x 4 Years) were tested for normality and variance homogeneity and submitted to a mixed model, considering "Year" as repeated factor and the subplot geographic coordinates.

Results

The grain yield data distribution resulted not Gaussian in the four years (Fig. 1) and for the two SMS. The means and standard deviations of the SMSxYear interaction are reported in Fig. 2. Since the distributions by years are not generally Gaussian, the (ordinary non-parametric) bootstrap procedure has been applied to estimate reliably the average difference between NT and MT values.

The difference between the averages are always significant and the tillage effect is dominant with except the year 2017, when NT produced more grain yield than MT treatment. The general grain yield level, low for the continuous wheat cropping, showed an inversion of tendency in the 4^{th} year of experiment, and specifically from -4.9% (average of first 3 years) to +8.6% (about 0.21 t ha^{-1}) of NT respect to MT. This change can be due to the soil quality improvements and a steady-state condition of soil, after a period of some years from the start of SMS application.

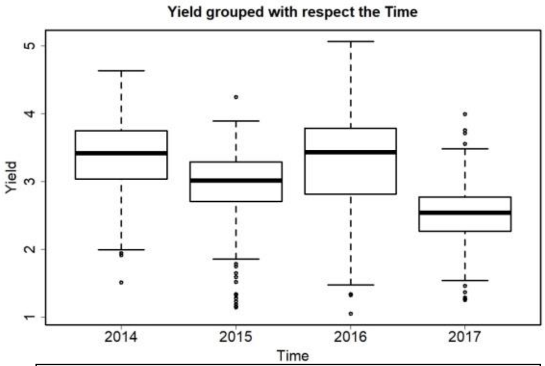

Fig. 1. Box plot of the data distribution in the 4 years of experiment.

In this short transition period, changes in soil compaction has been also observed, with a reduced penetration resistance at the 4th year of SMS application in NT (Rinaldi et al., 2018). Furthermore, a climatic effect can also be considered, because the 2017 experienced as a very dry cropping season, with a large evapotranspirative demand and an AI of 0.37.

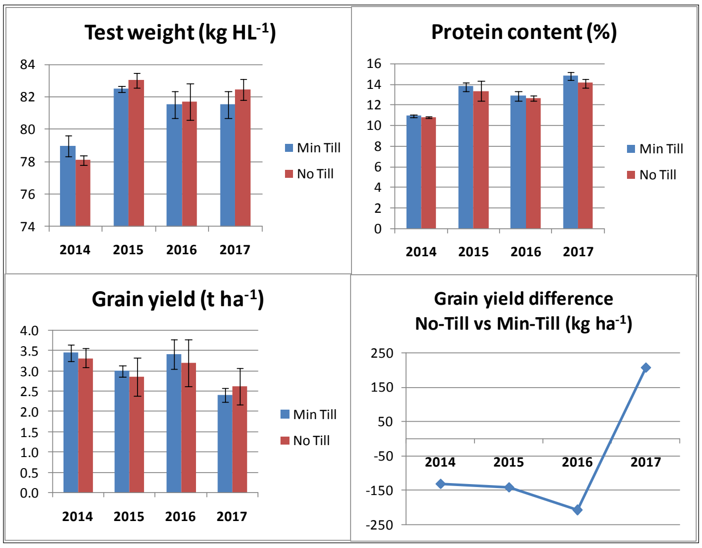

Fig. 2. Means and std of SMSxYear interaction of the 3 examined characters; in the last graph the grain yield difference (NT - MT) has been reported.

The statistical analysis showed significant differences in the SMSxYear interaction for test weight, showing a superiority of NT respect to MT only in the 2ndand in the 4thyear of treatment application: these years both resulted "semi-arid" for the AI values. This can be explained by soil moisture at grain filling stage, wetter in NT than in MT for crop residues mulch effect (Rinaldi et al., 2015).The grain protein content resulted greater in MT (+0.4%) than in NT, following, in general, an inverse correlation with grain yield.

Conclusions

Even if preliminarily, the experiment confirms a minimum length period of 3 years as time-frame for reaching a new steady-state in no-tillage management, characterized by an enhanced soil quality and a stabilized production levels. In semi-arid environment in Southern Italy, no tillage and residues application can improve soil moisture at grain filling stage, soil characteristics and, finally, grain yield, after some years of transition period, especially in dry years. Further in-depth analysis is, however, necessary, especially about soil chemical and microbiological aspects.

Acknowledgments

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Monthly Rain Erosivity And C Factor Interaction For A Correct Uncertain Estimation Of Soil Erosion In Covered Vineyard

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Introduction

Soil erosion in vineyard represents an important environmental issue. In the semi arid environment where the soil is maintained free from weeds for soil water conservation and the rainfall trend is erratic and elevated mainly in the winter period, protective practices are also supported from economic point of view both for soil erosion control and soil organic matter improvement. For these reasons not only the distribution over time of the factors involved in the USLE equation (RI and C factor) must be known, but also their interaction with the goal to identify the most risky period considering uncertainty.

Materials and Methods

Study area

The study area is located in southern Sicily and is one of the 18 vineyard Controlled Denomination of Origin (DOC) areas on the island. The mean annual precipitation is 516 mm. On average, 3% of the mean annual rainfall occurs during summer (June, July, and August) while 42% occurs during November, December, and January. Two vineyards managed with Conventional Tillage (CT) (at least five shallow tillages per year) to control weeds and reduce water competition and with Agro-Environment Measure (AEM) management involving annual cover cropping using legumes like faba bean (*Vicia faba*) were investigated.

C factor determination using MODIS temporal dataset

Two large vineyards were chosen in relation to traditional management and AEM management. For these two vineyards NASA-Modis imagery was used to obtain approximate C-factor values. Particularly, NDVI (Normalized Difference Vegetation Index) time series (from 2003 to 2017), characterized by a 250 m spatial resolution and an 8-day temporal resolution, were selected as proxy variable to estimate C values using the following relationship (Van der Vnjiff et al., 2000):

$$C = \exp\left(-2\frac{NDVI}{1 - NDVI}\right)$$

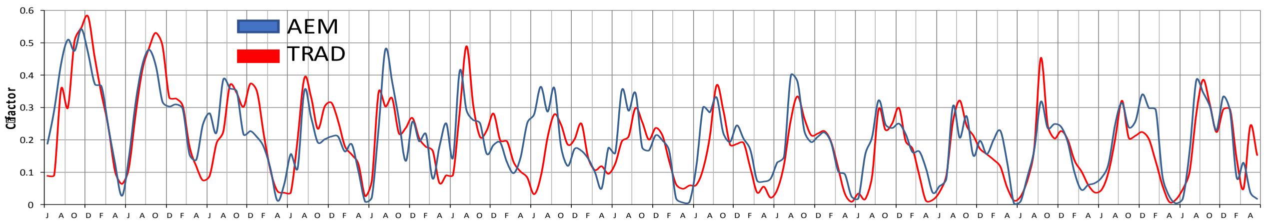

Figure 6 – Over time C factor for two soil management

Monthly Rain erosivity

The R-factor calculation requires the identification of erosive rainfall events The Rainfall Intensity Summarisation Tool (RIST) software (USDA, 2014) was used to calculate the R-factor. The RIST can be used for R- factor calculations using 25 years precipitation data.

Statistical procedure

Uncertainties were estimated using a Monte Carlo approach and estimated PDFs (probability density function); 10,000 estimates of monthly C factor and monthly IR were simulated and then used the outputs of each run to produce an empirical distribution of 10,000 monthly soil erosion. A 95% confidence interval for the change rate of SOC was used as a descriptor of uncertainty. Analyses were performed using SPSS software (IBM, 2010).

$$PDF_E=PDF_C*PDF_{RI}$$

Where: PDF is the probability density function, E is erosion (t ha^{-1} $month^{-1}$), C is C factor (adimensional) and RI is the monthly rainfall intensity.

Results

Figure 2 compares soil erosion due to soil management. The average value clearly indicates the control ability of the AEM management during winter period, also considering the estimate C factor trend during the year.

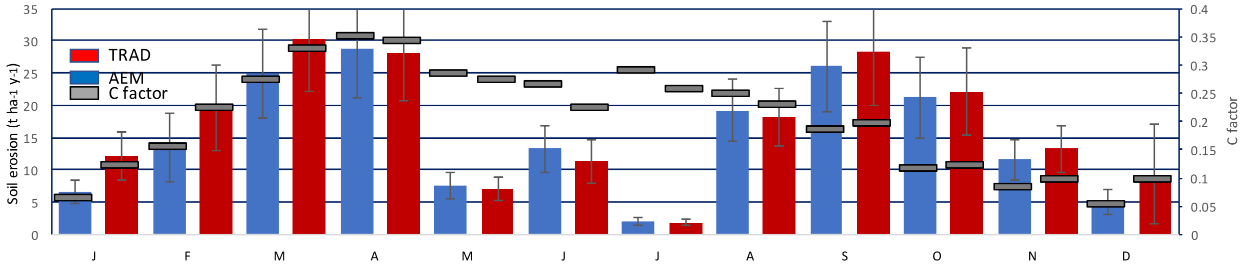

Figure 7 –Average soil monthly erosion and C factor for traditional and agroenvironmental management

But considering the PDF_E , the lower C factor during winter period assumes a strategic role in relation to high rainfall probability (Figure 3).

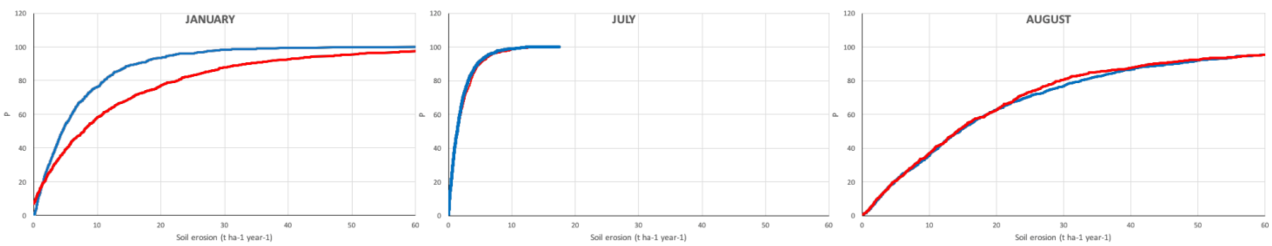

Figure 8 – Soil erosion PDFs function in three different months

Conclusions

Results show the need to consider both rainfall intensity and C factor PDFs at monthly step to have the perception of risk and the linked uncertain of soil erosion. The use of cover crops is very effective in soil erosion control during winter period when the probability of rain event is high.

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Durum Wheat: Qualitative Traits And Yields During Transition To Conservation Agriculture

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Introduction

In the last decades the needing of sustainable agriculture systems, where production is simultaneously environmental friendly, socially fair, and economically beneficial, is growing (Wezel et al., 2014). Several approaches are proposed, ranging from high technology-based practices (i.e. precision farming or use of genetically modified crops) to ecology-based practices (i.e. natural biological control of pests and no- or minimum- tillage), all aimed at higher and sustainable food production (Médiène et al., 2011; Perfecto and Vandermeer, 2010). Conservation agriculture (CA), based on the principles of conservation tillage, crop rotation and soil cover, should be very effective under Mediterranean and dry climates (Stagnari *et al*., 2013), where often farmers rely on short rotation based on durum wheat. In this work we investigated the effect of different combination of tillage treatments and crop sequence (conventional tillage and wheat monocropping, CT-WW; conventional tillage, and wheat following faba bean, CT-WF; zero tillage and wheat monocropping, ZT-WW; zero tillage and wheat following faba bean, ZT-WF (CA management) on yield and some important grain quality traits, poorly investigated, of durum wheat (var. Saragolla). The introduction of leguminous-based crop rotations, in association with no tillage, may represent a valid strategy to recover soil fertility, crop productivity with high quality performances.

Materials and Methods

A long term experiment, consisting of two soil tillage systems (main plots) and two crop sequences (sub-plots) combined in a split-plot design with three replications, has been carrying out in Teramo from 2010. During 2016 and 2017, yields data were collected in each plot, thousand kernel weight (TKW) was calculated as the mean weight of three sets of 100 grains per plot and specific weight, expressed as kg hl^{-1}, was measured with a Shopper chondrometer. Sub-samples of grains were milled with Knifetec TM 1095 (Foss, Hillerød, Denmark) to obtain a fine powder and whole-meal flour was used to evaluate quality-related parameter. Grains protein concentration (GPC, %) was calculated multiplied by 5.7 the grain N content determined by the standard Kjeldahl method (Sosulski and Imafidon, 1990). Gluten proteins were extracted according to the procedure of Singh et al. (1999) and single fraction concentration was detected by Bredford's method.

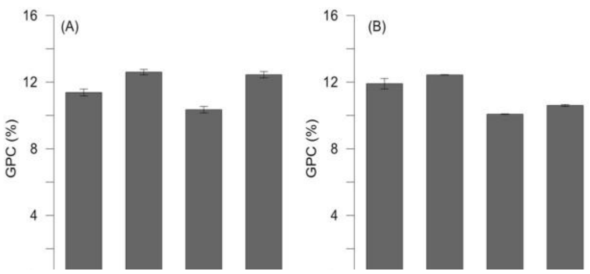

Fig.1: Grain protein concentration (GPC, %) in 2016 (A) and 2017 (B): Data are averages±standard errors of n=3 independent replicates.

Results

The combination ZT+WF favoured the highest yields in both years, although the values were significant only in 2017 (6.2 and 3.7 t ha^{-1} respectively in 2016 and 2017). Soil management and crop sequence affected significantly also grain protein concentration (GPC %) (Fig.1): again, ZT+WF exhibited highest values (see 2017, 12.6 %) and in general ZT approach induced GP accumulation (12.2 and 10.3% for ZT and CT, respectively, averaged over crop sequence). Besides, in both years glutenins fraction accumulation (HMW-GS and LMW_GS) was significantly enhanced by ZT management (Table 1), while gliadins concentrations (GLIA) seems to decrease. The influence of crop sequence was pretty unclear.

Table 1: Gluten fractions (mg g^{-1} flour) as recorded at harvest for durum wheat affected by different combination of tillage treatments and crop sequence, in 2016 and 2017.

Gluten fractions[a]	**2016**			**2017**		
GLIA	ZT	CT	Overall mean	ZT	CT	Overall mean
WW	9.0	9.4	9.2	9.7	10.2	9.9
WF	9.8	9.8	9.8	9.7	11.5	10.6
Overall mean	9.4	9.6	9.5	9.7	10.9	10.3
Soil management		*n.s.*			**(0.19)*	
Crop Sequence		**(0.11)*			*n.s*	
Soil management x Crop Sequence		*n.s.*			*n.s.(0.12)*	
HMW-GS						
WW	1.4	1.2	1.3	1.9	1.6	1.7
WF	2.3	1.1	1.7	1.9	1.1	1.5
Overall mean	1.9	1.2	1.6	1.9	1.1	1.5
Soil management		** (0.01)*			***(0.05)*	
Crop Sequence		*n.s.*			*n.s.*	
Soil management x Crop Sequence		*n.s.*			*n.s.*	
LMW-GS						
WW	2.8	2.0	2.4	3.2	2.1	2.6
WF	3.6	2.2	3.9	2.9	2.2	2.5
Overall mean	3.2	2.1	2.6	3.0	2.2	2.6
Soil management		***(0.03)*			***(0.05)*	
Crop Sequence		***(0.04)*			*n.s.*	
Soil management x Crop Sequence		*n.s.*			*n.s.*	

[a] Glia: Gliadins; HMW-GS: High Molecular Weight Glutenins; LMW-GS: Low Molecular Weight Glutenins; GS_Total: HMW-GS + LMW-GS; Total: Glia + HMW-GS + LMW-GS. *p < 0.05; **p < 0.01; ***p < 0.001; *n.s.* = not-significant. In brackets: standard error of differences between means (s.e.d.). Degrees of freedom: Soil management, 1; Crop Sequence, 1; Soil management x Crop Sequence, 1; Residual, 2.

Conclusions

Our work indicates that under Mediterranean and dry climates, the application of zero-tillage as well as the introduction of leguminous into crop rotations, exert full benefits, in terms of yield and quality traits, already after a six/seven-year period of CA adoption. In particular, grains are characterized by higher GPC and a more favourable ratio Total GS/GLIA thanks to high soil water and nutrient availabilities.

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Effect Of Cover Crop On Soil Water Plant Relationships: Experimental Set-Up In A Semiarid Vineyard

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Introduction

Soil water content (SWC) availability has been considered one of the main constraints for yield in semiarid vineyards and this reason has discouraged farmers to use cover crop (CC), especially permanent cover crop in rainfed vineyard. Several studies recorded that CC interferes with vine for water resources with a consequent increase of vine water stress (Monteiro et al., 2007; Pou et al., 2011). On the contrary, other researches showed no difference in water stress between vines under CC and conventional soil management (Giese et al., 2014).
The objective of the research is studying the SWC dynamic behavior in four different soil management in vineyards, with a detail regarding the effect of interrow and subrow SWC over the crop water status.

Materials and Methods

The research was carried out in a rainfed vineyard in Salemi, Sicily (IT). Different soil management were compared: conventional soil management (CT), *Trifolium subterraneum* cover crop (Tcc), *Hordeum vulgaris* cover crop (Hcc) and spontaneous vegetation (Scc).
Soil under conventional soil management was managed with continuous shallow tillage during the year to control weeds. Cover crop were seeded on Dicember 2016 and cut two times during spring. Soil managed with spontaneous vegetation was not tilled and the biomass was cut twice each spring. The biomass residues were not removed.
Volumetric SWC was measured with a FDR (Frequency Domain Reflectometry) handheld probe (Diviner2000, Sentek Sensor Technologies; Australia) at depths of 10, 20, 30, 40 and 60 cm in all soil management systems. The access tubes were located one in the subrow and one in the interrow for each treatment. In the subrow position, the access tube was located in mid position between two vines. Interrow access tubes were located perpendicular to the subrow access tube positions approximately at 1.25 m into the interrow.
In order to monitor vine water status, midday stem water potential (MSWP) was measured using a Scholander pressure chamber on six replicates per treatment at two dates: 06 and 19 June 2018.

Results

The paper shows the first results of a soil-crop monitoring activity started in March 2018 and still in progress. Figure 1 shows the correlation in 1:1 plot between the SWCs measured during the entire observation period at interrow and subrow locations. In the same graph, the average SWCs data pairs for both locations are also shown. In the Scc treatment a 1:1 distribution between $SWC_{interrow}$ and SWC_{subrow} was found. On the contrary, in the CT the change in SWC_{subrow} are not depending from the variation of $SWC_{interrow.}$ A positive correlation was found for *Trifolium subterraneum* cover crop (Tcc) and *Hordeum vulgaris* cover crop (Hcc), but with a different behaviour. In Tcc the SWCs in interrow locations were lower then SWCs measured in subrow. An inverse behaviour was observed for the Hcc treatment. Figure 2 shows the relationship between the midday stem water potential and the corresponding soil water content measured at interrow location for the two monitored dates.

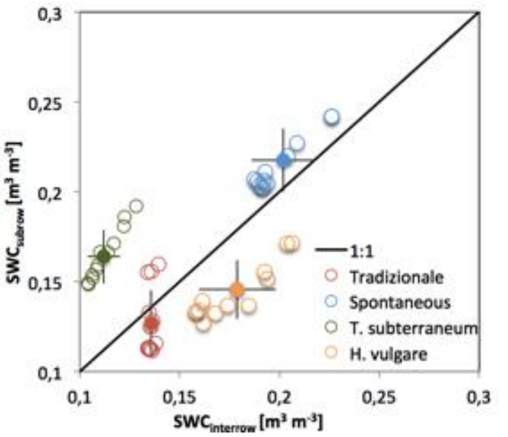

Figure 1 - Relationship in 1:1 plot between the SWCs measured during the entire observation period for interrow and subrow locations. Filled dots represent the average values of the dataset

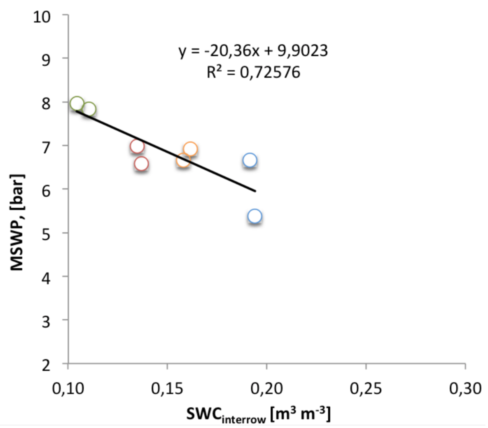

Figure 2 - Relationship between midday stem water potential (MSWP) and soil water content measured at interrow location ($SWC_{interrow}$)

Conclusions

This study highlights the behavior of different cover crops and soil management on water availability in semiarid vineyards. Further activity will regard the effect of the hydrological properties of the soil. Moreover, the analysis of the soil water plant relationship will use more performed indicator like the fraction transpirable soil water (FTSW).

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Conversion To No Tillage Consisted In Reduced Soil Penetration Resistance Below Tillage Depth After 3 Years In A Vertisol

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Introduction

Root growth, nutrient uptake and plant yield can be negatively affected by soil compaction, which depend on the interaction of a number of environmental and management aspects. These includes soil type, texture and stabilized and non-stabilized organic matter (OM) contents and distributions in the profile, soil moisture, tillage and machine load, crop rotation, etc.. The role of tillage, especially conservation strategies, is of paramount importance in shaping soil strength at increasing depth, but it can vary depending on other management issues (Hamza and Anderson, 2005) and time length of application (Radford et al., 2007). In particular, soil tillage effects on soil strength can greatly vary depending on soil type, with special emphasis on texture and total OM, and contrasting results were found in a range of soils either with or without fluctuating soil moisture content (e.g. Lopez-Bellido et al., 2016). Aim of this work was to study and model the penetration resistance (PR) of a Vertisol at increasing depth since the application of no tillage compared to minimum tillage.

Materials and Methods

An experiment was established in the fall 2013 at the Research Centre for Cereal and Industrial crops (Foggia, Italy; 41° 28'N, 15° 32'E; 75 m a.s.l.) on a clay-loam soil (Typic Chromoxerert). Main soil traits were 30% clay, 25% sand; pH 7.5; 12.5 g kg^{-1} total C. Mean long-term rainfall of the site is 479 mm. Mean air temperatures are 12.2 ºC in fall, 8.2 ºC in winter, and 17.6 ºC in spring. The experiment was a randomized block design with 5 reps and two soil management systems (SMS), direct seeding on no tilled soil (NT) and minimum tillage (MT). MT included wheat straw removal before the tillage operation, disk cultivator at 15 cm depth and chisel at 10 cm before sowing; NT included crop residues left on soil surface, use of glyphosate at a rate of 720 g of active ingredient ha^{-1} for weed control one week before sowing. Within each replicate, measurements of penetration resistance (PR) were taken in 3 to 10 sub-replicates. In each sub-replicate, data were taken nine times throughout the experiment. In each sampling date, PR was measured by a penetration dynamic system (Rimik CP20, Agridry Rimik PTY LTD; terminal cone of 10 mm^2 area) at steps of 25 mm until a 600 mm depth. Soil moisture was computed gravimetrically after soil drying at 84°C until constant weight from soil sample at 0-20 cm and 20-40 cm depth. Data were checked for fitting a Gaussian distribution and thus transformed to square root prior the statistical analysis. Data were presented as original values in the tables and figures. A general linear mixed model of variance analysis was performed with both depth and sampling site as repeated measures. Differences among means were compared by t-grouping with Tukey-Kramer correction at the 5% probability level to the LSMEANS p-differences sliced by time. The direct role of soil moisture at varying depth and time and SMS on PR was modelled by the GLMSELECT procedure (SAS/STAT 9.2) including either interactions among effects or only the main effects of predictors. Model predictor selection method was the forward selection, with average square error (ASE) as stop criterion. Model was subjected to a 10-fold validation randomly fractioning the database in a 0.75 training set and a 0.25 validation set.

Results

Mean PR along the soil profile increased with time, with slight increases from the beginning of the experiment (fall 2013) to the 2nd of March 2017 and a sharp increase from the measurement of the 2nd of March 2017 to that of 24th of April 2017, after which it slightly decreased. Along the whole profile, the effect of the soil management system on PR was negligible from the beginning of the experiment until the measurement of the 2nd of March

2017 (Table 1). After this date, NT showed on average along the whole profile studied a PR 21% lower than MT. Mean variation between NT and MT decreased linearly with time at a rate of 0.612 N m^{-2} day^{-1} (R^2=0.63; data not shown). The role of variation of PR in NT compared to MT after the 24th of April 2017 was not constant along the profile. In particular, in the last 2 dates, NT showed a similar PR of MT from the soil surface to a depth of 250 mm. Below such depths, NT showed lower PR than MT (Fig. 1).

Few differences were found in models of PR at varying soil moisture, depth, time, and SMS with or without interactions (R^2=0.675 and 0.640, respectively). Modelling of PR by means of the main effects clearly showed that depth and time were the major contributors to the prediction (Fig. 2) with a mean effect of +0.578 kPa mm^{-1} and +0.484 kPa day^{-1}, respectively. Soil moisture reduced PR by 0.167 kPa per delta %, whereas the role of SMS was negligible in the model with no interactions. When interactions were considered, MT increased PR compared to NT in Depth*Time*SMS by 0.259 kPa.

Table 1. Results the fixed effects of the general linear mixed model of soil penetration resistance at varying soil management system (SMS), Depth (D), and Time (T)

	F	p
SMS	71.55	<.0001
D	422.54	<.0001
SMS×D	5.6	<.0001
T	63.7	<.0001
SMS×T	153.5	<.0001
D×T	20.84	<.0001
SMS×D×T	4.36	<.0001

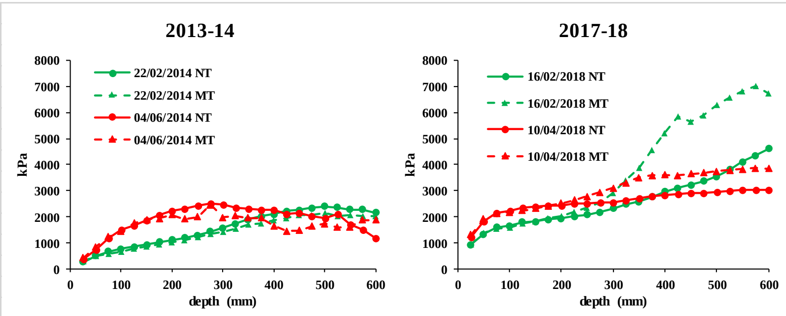

Fig. 1: Penetration resistance (kPa) in the first (2013-14) and last growing seasons (2017-18) at varying depth (mm) and sampling occasions in a Vertisol grown with durum wheat under no tillage (NT, continuous lines and circles) or minimum tillage (MT, dashed lines and triangles).

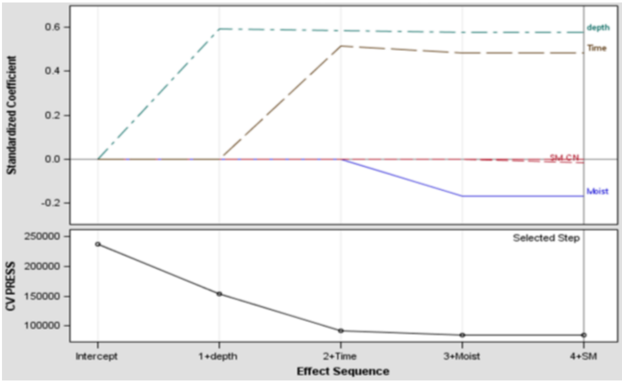

Fig. 2: Coefficients of the PR model at varying soil moisture (moist) depth and time of application of SMS (SM CN for no tillage). Cross validation predicted residual sum of squares (CV PRESS) of the model is shown

Conclusions

NT can reduce soil penetration resistance, however, such an effect occurs after a given time-lapse, estimated in 3 years. Similar results were found by Radford et al. (2007). Differences from our results and those of Lopez-Bellido et al. (2016), which worked on a soil with barely twice the clay content and half the sand and soil organic matter than the present, could have depended on the ability of the soil to form water-stable aggregates. Further studies will be aimed to study PR resistance when manipulating soil moisture content and retention of plant residues.

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Agronomical Benefit Of No Tillage Application In Rainfed Faba Bean Cultivation

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Introduction

Faba bean (*Vicia faba* L.) represents an important source of proteins in several parts of the world adding a socio-economic value to the crop. Its cultivation in Italy has experienced a dramatic decline in the cultivation area over the last 50 years (Ruisi et al., 2017) due to lower profitability compared to other crops and its high sensitivity to several kind of stresses (Sillero et al., 2010). Reintroducing faba bean into Mediterranean rainfed cropping systems is believed to involve several agronomic, environmental and ecological services (Kopke and Nemecek, 2010), which go in line with the need to reduce the negative impact on the environment by reducing the fossil energy consumption. In today's agricultural, soil tillage and fertilization are the greatest consumers of energy and labor. Since fertilization is lowered to the minimum due to N_2 fixation, an appropriate tillage method will lead to an improvement of energy use (Hamzei and Seyyedi, 2016) and increase crop profitability. In Mediterranean areas, no-tillage is becoming increasingly popular due to its potential to generate environmental, agronomic (Alhajj Ali et al., 2015) and economic benefits (Giambalvo et al., 2012) compared to traditional methods. Despite the yield advantage of no tillage system due to water conservation, the role of this technique in faba bean production with reference to energy consumption, is not well investigated especially in southern Italy. Therefore, we tested the performance of no-tillage practice in faba bean cultivation in order to have optimal grain yield of high quality with reduced energy requirements for sustainable production.

Materials and Methods

From 2009 in Policoro (Southern Italy) has started a long-term experiment related a wheat-faba bean rotation, comparing three different cultivation technique: no tillage (NT), conventional (CT) and reduced (RT) tillage. Agronomic parameters include yield and quality traits, while energy input/output (EO) analysis and energy parameters (energy use efficiency (EUE), energy production (EP), net energy (NE), energy intensity (EI), energy profitability (EPF), and human energy profitability (HEPF)) were calculated in order to investigate the intensity and the efficiency of energy consumption in faba bean production.

Results

The analysis of results revealed that NT gave better or comparable yield and quality results compared to CT, whereas RT gave the lowest results for all parameters. Agronomical parameters exhibited year-to-year variation due to weather conditions. In particular, yield advantage of NT over CT and RT was influenced by rainfall amount and distribution throughout the growing season. The fluctuation of yield and quality values across the years indicated the importance of inter-annual variation of rainfall and temperatures during the growing season, especially in the dry regions. On average, faba bean yield was 2928 kg ha^{-1} with 25% of protein content, which varied significantly among tillage systems and across years (Tab. 1). Tillage effects were highly significant ($P \leq 0.001$) for number of plant m^{-2}, for grain yield ($P \leq 0.01$) and less significant ($P \leq 0.05$) for grain protein content and 100-seed weight. Year effects instead were highly significant ($P \leq 0.001$) for all yield components and quality traits. Likewise, the effects of both tillage system and the study year were significant for all energy parameters (Tab. 2). Among the input parameters, diesel fuel (45.6%), seed (28.6%), and phosphorus (18.8%) were the major contributors to the total energy use in faba bean under rainfed conditions. Total energy output was very much linked to the biological yield. On average, total energy output was 10 times higher than energy input indicating the system sustainability. Despite the significant higher energy output under CT, the NT system gave the best results in terms of energy efficiency, energy production, net energy, energy intensity, energy profitability and human energy profitability. In addition, NT used 39% and 36% less non-renewable energy than CT and RT respectively.

Table 1- Analysis of variance (ANOVA) and comparison of 6-year (2010/11 to 2015/16) means of yield, yield components and quality traits of faba bean as influenced by treatments and their interactions.

Treatment	N. plant m^{-2}	Yield (kg ha^{-1})	Straw (kg ha^{-1})	HI (%)	Humidity (%)	Hectoliter weight (kg/hl)	100-Seed weight (g)	Protein (%)
Tillage (T)	***	**	ns	ns	ns	ns	*	*
CT	30 a	3029,7 a	5702,5	0,35	8,4	79,5	55,2 a	25,8 a
RT	31 a	2768,4 b	5424,9	0,34	8,4	79,4	53,8 b	25,4 b
NT	26 b	2986,6 a	5584,7	0,35	8,5	79,6	53,6 b	25,8 a
Year (Y)	***	***	***	***	***	***	***	***
2011	28 c	1332,8 e	2542,1 d	0,34 c	9,7 a	77,3 c	49,4 d	23,8 c
2012	33 a	2476,9 d	5027,8 c	0,33 c	6,7 f	79,4 b	46,5 e	27,5 a
2013	29 bc	3047,4 c	4930,6 c	0,38 b	8,4 d	79,1 b	50,0 d	26,1 b
2014	30 b	3474,6 b	8866,7 a	0,28 d	7,6 e	78,8 b	68,4 a	27,5 a
2015	34 a	4583,9 a	5223,5 c	0,47 a	9,4 b	81,6 a	53,3 c	23,5 c
2016	22 d	2653,8 d	6833,3 b	0,28 d	9,1 c	81,0 a	57,7 b	25,8 b
Mean	**29.2**	**2928,2**	**5570,7**	**0,35**	**8,4**	**79,5**	**54,2**	**25,7**
Y x T	***	***	***	***	***	ns	**	**

Table 2- Analysis of variance (ANOVA) and comparison of 6-year (2010/11 to 2015/16) means of energy indexes in faba bean production as influenced by treatments and their interactions.

Treatment	EUE (MJ ha^{-1})	EP (Kg MJ^{-1})	EI (MJ kg^{-1})	NE (MJ ha^{-1})	EPF (MJ ha^{-1})	HEPF (MJ h^{-1})	Tot. EO (MJ h^{-1})
Tillage (T)	***	***	***	*	***	***	*
CT	10,6b	0,199b	6,5a	146013 a	9,6b	23852,4b	161242,2a
RT	10,3b	0,189b	6,4a	136457,8 b	9,3b	22927,8b	151117,5b
NT	14,7a	0,278a	4,1b	147556,6 a	13,7a	66906,8a	158301,6ab
Year (Y)	***	***	***	***	***	***	***
2011	5,5e	0,103e	11,2a	57980,6 d	4,5e	17819,2e	71525,3d
2012	10,5d	0,188d	5,5b	124734,1 c	9,5d	33823,5d	138278,7c
2013	11,4c	0,234c	4,6bc	134427,8 c	10,4c	38114,7c	147972,5c
2014	16,9a	0,260b	3,9cd	212443,7 a	15,9a	52153,5a	225988,4a
2015	13,9b	0,346a	2,9d	170328,9 b	12,9b	43831,1b	183873,6b
2016	13,1b	0,200d	5,7b	160139,6 b	12,1b	41632,2b	173684,3b
Mean	**11,9**	**0,222**	**5,6**	**143342,5**	**10,9**	**37895.7**	**156887**
Y x T	***	***	***	***	***	***	***

*P≤0.05, **P≤0.01 and ***P≤0.001; Data followed by the same letter are not significantly different at P≤0.05 significant level as determined by Least Significant Difference test (LSD)

Conclusions

Considering the site-specific conditions, the agronomic results indicate that NT performed better and/or is comparable to CT, while its application was 28% and 30% more energy efficient compared to CT and RT respectively. Our findings revealed that the key benefits of NT over RT and CT are its ability to produce sufficient yield of high quality with significant reduction in energy inputs entailed the fewest field operations and therefore the lowest energy requirements. Therefore, NT can be identified as a mean of reducing reliance on fossil fuel while maximizing grain yield in Mediterranean environment, in compliance with sustainability criteria.

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Conservative Tillage And Nitrogen Inputs On *Conyza Canadensis* Seed Bank

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Introduction

Conservation Agriculture (CA) promotes, mainly, minimal soil disturbance and low application of inputs, reducing Greenhouse Gas (GHG) Emissions.
Weed flora in arable fields is strictly dependent from all agronomic practices such as tillage and fertilization management. Differently from conventional tillage, CA practices include a range of tillage regimes, such as no-tillage (direct drilling) and minimum tillage (shallow tillage), that avoid soil inversion. Consequently, it is reasonable to suppose that weed community can be affected by these management systems (Nichols et al., 2015). Weed community and soil seed bank can be also modified by nitrogen availability as a consequence of different amounts and types of fertilizers (Jiang et al., 2014). In any case, the response of each species can be very different. *Coniza canadensis* (L.) Cronq. (*Asteraceae* family) is among weed species potentially affected by soil disturbance and different input levels; it is a winter or summer annual species found typically in orchards, vineyards, roadsides and arable fields, especially where tillage has been reduced or eliminated. Seeds (up to over 200,000 per plant) are produced in late summer (Buhler *et al.*, 1997; Weaver, 2001). In many countries, populations of *C. canadensis* have also evolved resistance to several herbicides and, in Italy, populations resistant to glyphosate have been detected (weedscience.com).
The aim of the present paper is to evaluate the combined effects of different soil management and nitrogen fertilization levels, on a long-term <Durum Wheat – Faba Bean> rotation, on the *C. canadensis* seed bank.

Materials and Methods

Data were collected in a field located in Policoro (Basilicata – Italy) in the experimental farm "E. Pantanelli" (University of Bari). Since 2008, the field (9 ha) hosted a long term <Durum Wheat – Faba Bean> rotation. The field had been divided into 3 replicates (each of 3 ha) including plots with three different tillage systems: (NT) No Tillage and sod seeding, (CP) Chisel Ploughing, (MP) Mouldboard Ploughing. Each tillage system had been split into two subplots where nitrogen inputs of 30 or 90 kg ha^{-1}, supplied as urea, were applied to durum wheat. Both in faba bean and durum wheat, weeds were chemically controlled. Soil sampling was done in November 2015 (i.e. seven years after the beginning of the crop rotation) before the preparation of the seedbed for the sowing of faba bean.
Twenty soil cores were randomly collected at 40 cm depth in each experimental unit using a 2.3-cm diameter cylindrical steel probe. Each core was divided into two sub-cores of 20 cm and then merged to form a single sample per layer (0-20 and 20-40 cm) for each experimental unit. Seed bank was assessed by direct observation of the plantlets emerging from each soil sample. Actual data were square root transformed to increase homogeneity of error variances (Barberi and Locascio, 2000) before statistical analysis.
In order to investigate the effects of the different soil managements and N supplies on C. *canadensis* seedbank, Stepwise Discriminant Analysis (SDA) was first used. To this aim, data analysis was carried out considering both the different managements separately (TI and N) and their interaction (TIxN). Afterwards, ANOVA was performed according to a three way completely randomized design.

Results

21 species in total were found in the soil seed bank. Stepwise discriminant analysis (SDA) identified *C. canadensis* among the weed species most able in discriminating both the different soil managements (TI) and the whole

treatments studied (TIxN interaction). *C. canadensis* was indeed selected respectively as second and third species, with partial R-Square values of 0.4781 (F=14.65, P<0.0001) and 0.7085 (F=13.61, P<0.0001). Analysis of variance (Table 1) showed that the highest number of seeds was on average found in the NT-plots, followed by CP and MP, and with the low nitrogen supply (30 kg N ha^{-1}). No significant difference was found between the two soil depths investigated. Significant interactions (Table 1) were found among depths and tillage systems as well as N supply. Particularly, the highest number of seeds was observed in the upper layer of NT plots. In the 20-40 cm layer the number of seeds was higher only in the plots fertilized with 90 kg ha^{-1}, whereas no difference was detected in the 0-20 cm layer between the N fertilization levels.

Table 1. Effects of Tillage, Nitrogen and soil depth on the number of seeds m^{-2} (1)

MAIN FACTORS							INTERACTIONS			
Tillage			Nitrogen (Kg ha^{-1})		Depth (cm)		T X N	T x D	N X D	T X N X D
NT	CP	MP	30 Kg ha^{-1}	90 Kg ha^{-1}	0-20	20-40	ns	*	*	*
48.76 a	34.2 b	25.3 c	40.8 a	31.4 b	36.2	36.0				

(1) Data are reported as square root of the actual ones. Only the means of the main factors are shown: data followed by different letters are significantly different at 0.05 P (Duncan's Test)

Conclusions

Results of this study show that *C. canadensis* seems to be favoured by low cultural inputs in terms of soil disturbance and nitrogen supply. Glyphosate was effective in controlling *C. canadensis* and thus no resistant populations were observed in the field. Similar results are reported by other studies particularly regarding the spreading of this weed caused by "no-reverse" tillage systems such as no-tillage (Buhler and Owen, 1997; Weaver, 2001) or chisel ploughing (Barberi and Lo Cascio, 2000). Moreover, the seed bank tends to be higher in the surface layer (0-20 cm) only in the no-tillage plots; with the other tillage systems, there are no clear differences among the number of seeds along the 0-40 cm soil profile. In our study, a greater *C. canadensis* seed bank was observed with lower nitrogen inputs, although mainly in the superficial layer. As far as we know from literature, no data are available about the effects of nitrogen fertilization. Weed functional traits are important to determine the spreading of a specific flora as consequence of crop management (Storkey et al., 2010). Therefore, further studies about this species could start from the hypothesis that higher nitrogen levels could favour those species able to capture soil nutrient resources faster than *C. canadensis* whose presence could be thus lowered in the flora community.

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Comunicazioni

“Agricoltura biologica e Agroecologia”

Agroecology And Organic Agriculture: Opportunities For Innovative Agronomic Research

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Introduction

It has long been recognized that mainstream intensive agricultural and food systems are not sustainable, as clearly highlighted by the current global economic crisis and the increasing divide between farmers' incomes and food prices. An exception to this trend is organic agriculture (OA), which is experiencing increased attractiveness from farmers, the agri-food industry and consumers, resulting in double digit growth rates in the national food market. Agroecology is a relatively new paradigm that is quickly gaining pace in the international discussion on sustainable agriculture and food systems, also thanks to the support from important players like the FAO. Whereas OA principles and practices are relatively well known, agroecological ones are still to be consolidated. The purpose of our paper is to shed light on agroecology, its relationship with OA, and the contribution that both could give to revitalise agronomic research and the role of agronomists in science and society.

What is agroecology?

Despite the ongoing dispute on the history of agroecology, which is geographically biased (Europe *vs* Latin America), the fact that agroecology is at the same time (i) a science, (ii) a practice, and (iii) a movement (Wezel et al., 2009) is generally accepted. These three souls share the vision of undertaking the transition towards truly sustainable agricultural and food systems on a planetary scale. A key concept in agroecology is that this transition can only be possible by taking an agri-food system approach, i.e. by sustaining not only innovation of agricultural practices but also a profound change in resources (land, water, biodiversity) accessibility, labour requalification, landscape rehabilitation, food distribution, and food consumption patterns (Bocchi, 2017). By reconnecting farmers with consumers through the support of local healthy food production and short food supply chains (e.g. Community Supported Agriculture schemes), agroecology aims to create new job opportunities, increase farmers' income, prevent agricultural land abandonment, revitalise countryside, and facilitate knowledge sharing. This will result in better environmental protection, economic prosperity and social cohesion, and will meet most of the 17 UN Sustainable Development Goals. In an overall perspective, the similarities between agroecology and OA are rather obvious.

Convergences and divergences between agroecology and organic agriculture

Agroecology and OA share the same vision for sustainable production, based on wise use and protection of local natural resources and on reduction of external input use in farming systems, whose management should be tackled from a system perspective. Actually, the four IFOAM principles at the base of OA (care, ecology, fairness and health) have a somewhat wider vision than those set forth in national and international regulations. For example, the EC Regulation 834/2007 on OA, despite enunciating some general principles, mainly focuses on prescriptions on which methods and tools should and should not be used in organic systems (Migliorini & Wezel, 2017). IFOAM and agroecological principles are aligned, to the extent that agroecology can be considered the theoretical approach upon which OA systems should be designed and implemented. This is clear in our Country, where the history of agroecology very much coincides with that of OA (Bàrberi et al., 2017). However, the recent commercial success of OA is posing a risk of 'conventionalisation' of organic systems (Darnhofer et al., 2010), i.e. over-reliance on input substitution and downplay of the system approach. As such, the rise of agroecology could be instrumental to bring back (part of) OA to its original spirit and to create synergies. Currently, the main divergences between agroecology and OA are (i) the lack of prescriptive regulations, and (ii) the higher emphasis on transformation (*vs* conformation) of food systems (and its wider socio-economic implications) in agroecology. Nevertheless, convergences are far more evident than divergences, which is of utmost importance for the role that both approaches could play on the pathway leading to truly sustainable agricultural and food systems.

Innovation in research: participatory approaches

Nowadays agri-food systems require deep and diffuse innovation, which is an excellent opportunity for agronomic research. First of all 'innovation' should be considered in its wider meaning, i.e. including novel processes and methodologies (Ingegnoli et al., 2018) as well as novel products and tools. Agronomy should embrace methods typical of 'soft sciences', e.g. participatory research approaches. These have first been applied to breeding (Ceccarelli & Grando, 2007), but are gaining pace in other agronomic research domains linked to agroecology and OA, e.g. the introduction of cover crops and intercrops/living mulches. At present, the most important research funding schemes (e.g. the EC Horizon 2020 Framework Programme) often request participatory research (the so-called 'multi-actor approach') as a compulsory requirement. In addition, many themes related to agroecology and OA are subjects of present and future H2020 calls. These are clear signs that these approaches are being privileged in sustainable agriculture research. Furthermore, stakeholders participation is the pillar of European Innovation Partnerships (EIPs), a novel funding instrument in regional rural development programmes which seems particularly suited to foster agroecological innovations.

Innovation in research: inter- and transdisciplinarity

The time has come for agronomy to decidedly embrace inter- and transdisciplinary research. This is not only to accompany an emerging trend in sustainable agriculture innovation, but also because agronomists – more than other experts – have the appropriate background, vision and sensitivity to commit themselves in such direction. Two examples are: (i) the EU project CAPSELLA (www.capsella.eu), where novel ICT solutions on agroecological issues upon participatory engagement with farmers, ICT experts and stakeholders have been implemented; (ii) the newborn Osservatorio per l'Agroecologia (OPERA, www.osservatorioagroecologia.it). Inter- and transdisciplinary approaches can also unravel the answers to open questions related to OA research, e.g. long-term interactions among agroecosystem components and their relationship to the provision of agroecosystem services. These research methods can help agronomists pave the road towards agroecology following the Efficiency-Substitution-Redesign (ESR) pathway (Hill & McRae, 1995). We contend that innovative agronomic research – not only in the realms of agroecology and OA – could only take place should agronomists be willing to get out of their comfort zone and fully embrace system-based participatory and transdisciplinary research. There is much more than the Impact Factor out there!

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Agroecology And Organic Agriculture For The Transition To Sustainable Food Systems: Research And Education In Italy

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Abstract
For the forecasted 9.1 billion population in 2050, agricultural production should provide sufficient food while being ecologically sound, economically viable, socially just, culturally appropriate.
There is thus an active debate on new farming systems and practices that could produce this food in a sustainable way. In this frame, different approaches in agroecology and organic agriculture are presently discussed, including to what degree they can contribute to sustainability of agrifood systems. In this paper, first the approaches to agroecology and organic agriculture are presented. Then the actual development of agroecology and organic agriculture in Italy is discussed with particular focus in Academic's education and research. Following this, future challenges for research is illustrated and discussed including the potential use of agroecological practices for future agriculture.

Introduction
There is ongoing debate among stakeholders about the future development of agricultural and food systems to meet the global challenges of food supply, biological and cultural diversity, climate change, social and economic justice. Among other options, agroecology (AE) and organic agriculture (OA) are discussed. The UN Special Rapporteur on the Right to Food (De Schutter 2011) asserts that agroecology can play an important role in finding solutions for the above challenges. Also, another international authority (IAASTD 2009) states that agroecological methods are already available and used, and that smallholder farmers in the world, which make up 80% of the total farm numbers that produce over 50% of the world's food on 20% of agricultural land, could double food production within 10 years in food-insecure areas of the planet using agroecology. Currently, agroecological farming is not market-driven: no certification systems nor labels exist so far for the produce, it is not yet uniquely defined, and clear entry thresholds are absent, e.g. origin and amount of inputs (organic or chemical). In contrast, organic farming has clear and rigorous regulations and restrictions (e.g. no synthetic pesticides and fertilisers, processing aids and additives, no genetically modified organisms or products), and farms lose certification and access to markets when they violate the regulations. Today, the demand for organic products is constantly increasing and is no longer a niche segment, although it still represents a low percentage share of the global market. Organic farming is a response to the global need for more sustainable farming practices. The organic agriculture label implies a system of control and certification that it is recognised worldwide. The global market for organic food in 2016 has reached more than 80 billion euros. Worldwide there are 2.7 million organic producers using a total of 48 Million hectares. Italy is the 6th country with largest area with 1,8 Mh (14,5% shares) and 64.210 organic producers (Willer and Lernoud 2018). When speaking about ecologically based agriculture, agroecology is increasingly mentioned and recognized. As seen nowadays, agroecology represents the ecology of food systems (Francis et al. 2003) and includes (i) scientific and educational approaches, (ii) social and political movements, and (iii) a set of practices (Wezel et al. 2009).
Both, AE and OA, have similar principles and use a systems approach; many proposed cropping practices are similar but the origin and quantity of products potentially used for soil fertilisation and pest, disease, and weed management are different (Migliorini and Wezel, 2017).
AE and OA offer promising contributions for the future development of sustainable agricultural production and food systems, especially if identified challenges have been addressed (Wezel et al., 2018a). Among others, education, training, and knowledge sharing and research approach and funding are in the responsibility of academia. The need to strengthen the connection between academia and society has received increased attention over the past years. The importance of bringing university students closer to stakeholders in society as part of their learning process is high regarding sustainable agriculture, because of its applied approach. University programs

based on experiential and action-oriented learning have been developed over the past decades in Europe, but not so much in Italy (Migliorini and Lieblein, 2018).

In this paper, the status of research and educational dimension have been used to confront and discuss the status of AE and OA in Italy.

Materials and Methods

A questioner has been sent to members of Italian Society of Agronomy asking information on actual research projects and academic course offered in AE and OA sector.

Results

17 universities and research centres responded.

Regarding educational initiatives 11 universities declare to be lively in AE and OA with 20 courses: 12 at Ba, 7 at Master and 1 at PhD level, activated from 2000 till 2018, all of them in Italian, except for 1 university courses and the PhD one. However, only 4 courses have named in the course title AE or OA and the others are mainly in agronomy.

The respondents reported around 40 projects: 20 international, 10 national and 10 regional, with very diverse topics, started from 2010 and 2018 but only 12 of them are still active (11 end in 2018).

Results show that the enhancement of education and knowledge exchange in agroecology and organic agriculture as well as the investment in agroecological research is started. In fact, a review of the published literature on the ScopusTM showed that Spain and Italy emerged as the Mediterranean countries (excluding France) with the highest number of papers published on agroecology (Migliorini et al. 2018) with 43 papers.

Still, it seems that the scientific approach identified in agroecology and organic agriculture that "gives priority to action research, holistic and participatory approaches, and transdisciplinary including different knowledge systems" (Agroecology Europe, 2017) is not easy to be implemented.

Conclusions

In Italy various academic research and education initiatives have been taken which show interest in agroecology and organic farming. Nevertheless, given the importance that this sector has in our country for history, extension of surfaces and market demand, more efforts and investments would be desirable, especially if compared to other European countries (Wezel et al. 2018b).

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Chickpea (*Cicer arietinum* L.) Genotypes In Organic And Conventional Regimes

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Introduction

Breeding of chickpea has slowed down in recent decades as a result of eating habits modifications more oriented toward animal protein sources (Saccardo et al., 2001). In the last years, we are observing a re-evaluation of this crop by both farmers (alternative to cereals in crop rotation and ecological services) and consumers (vegetal protein source, cheap food) (Annicchiarico, 2017). Both, however, require varieties with high productivity and adequate quality standards, especially in organic cropping regime. In dry Mediterranean environments, chickpea is commonly grown in winter sowing and in rotation with durum wheat to improve soil fertility and to break the cycles of cereal pests. Main yield limiting factors to chickpea cropping, and in particular in organic regime, are the pest and weed control and the genotype choice (Rinaldi et al., 2006).

The aim of the research is to assess, from an agronomic point of view, chickpea genotypes cultivated in Southern Italy according to organic and conventional agriculture regimes.

Materials and methods

In the 2013/14 and 2014/15 years, two experimental trials were carried out in Foggia, under conventional and organic regimes, comparing 16 chickpea genotypes, different in seed colour and size.

The soil is alluvial clay and the climate is "thermo-accentuated Mediterranean" with temperatures below 0 °C in winter and above 40 °C in summer and with average annual rainfall of 550 mm. A randomized block design, with 3 replications and elementary plots of 10 m^2, was repeated in two fields, about 500 meters apart, one in organic regime since 8 years and the other one in conventional farming. The sowing (December) was performed in rows 50 cm apart and with a density of 40 seeds m^{-2}. In the conventional regime a pre-emergence herbicide treatment with Pendimethalin (800 g of a.i./ha) and a fungicide treatment for anthracnose with Azoxystrobin (200 g of a.i./ha) were applied.

On January 2014, when the chickpea plants were about 20 cm tall, a floristic survey was carried out to determine the botanical genus and the density of the main weeds present. After flowering a sampling was performed to determine the number of plants with anthracnose symptoms. At harves tin July, grain yield and its components were determined; nitrogen seed content was measured with Dumas combustion method (Leco FP528). Standard statistical analysis of variance was carried out and means were separated by the LSD test at $P < 0.05$.

Results

The first year resulted warmer and rainier than the second one (367 mm vs 224 mm from Dec to Jun) and this favoured plant biomass growth and the anthracnose attacks, especially in organic regime; the organic regime also suffered for weed competition especially for *Cirsium* and *Fumaria* spp. (Table 1). The seed yield resulted higher in the second than in the first year and double in conventional compared to organic regime (Table 2). On the contrary, chickpea cropped in organic regime showed bigger seeds and higher protein content than conventional regime even if a significant interaction with year was observed. The critical aspects of organic regime - weed and anthracnose control - were highlighted in both years, with seed yield halved respect to the conventional one, mainly due to a low seed number per plant. The highest yielding genotypes resulted the two black seeds (Nero Lucano and Nero Senise) followed by Sultano and Califfo (yellow seed) genotypes, in both cropping regimes.

Makarena variety experienced anthracnose in both years and was completely destroyed. Several genotypes resulted quite anthracnose resistant (R1, Principe, Visir, Cairo, Califfo, Sultano, Nero Lucano, and Nero Senise), useful for future breeding programs.

Pascià and Reale presented seed size higher than other genotypes, while Principe showed high protein content especially in organic cultivation and these are important characteristics for food quality.

Conclusions

Indications about the difficult to obtain high seed yield in organic chickpea, mainly for weed competition and anthracnose attacks, emerged from this study. Some genotypes showed high yield in both cropping regimes.

Table 1. Weed plants (n per m^2) in two cropping regimes on chickpea sampled on 24/01/14. Different letters between cropping regimes indicate significant differences at $P < 0.05$ (LSD test).

Cropping regimes / ***Weeds***	**Organic**	**Conventional**
Cirsium spp.	8.73 **a**	0 **b**
Fumaria spp.	3.47 **a**	1.20 **b**
Galium spp.	0.49	0
Muscaria spp.	0.15 **b**	1.38 **a**
Veronica spp.	0.98 **b**	1.93 **a**
Graminacee	0.29	0
Total	**13.98a**	**4.51b**

Table 2. Main agronomic results of 16 chickpea genotypes cropped for 2 years in conventional and organic management in Foggia. At the bottom of the table, significances of analysis of variance are reported.

Genotypes	**Grain yield ($t\ ha^{-1}$)**	**100 seeds weight (g)**	**Number of seeds per plant**	**Protein content (%)**
Baraka (Y-R) §	1.12	30.19	27.07	21.33
Calia (Y-R)	1.04	31.96	22.15	22.02
Califfo (Y-S)	1.34	30.97	22.90	22.72
Kairo (Y-R)	1.29	31.68	22.43	22.34
L103 (Y-R)	1.18	34.10	22.88	22.11
L131 (Y-R)	1.04	34.89	21.47	20.71
Nero Senise (B-R)	1.49	23.90	27.63	22.52
Nero Lucano (B-R)	1.41	23.70	36.38	21.81
Pascià (Y-R)	1.05	40.40	17.52	20.89
Principe (Y-R)	1.24	37.64	20.38	23.58
R1 (Y-S)	1.24	30.23	24.67	22.21
Reale (Y-S)	0.88	42.45	22.68	21.58
Sultano (Y-S)	1.37	30.94	27.20	21.96
Visir (Y-S)	1.23	33.72	18.60	22.06
Vulcano (Y-S)	0.78	29.98	25.31	21.82
Makarena(Y-R)§§	n.a.	n.a.	n.a.	n.a.
Cropping regimes				
Organic	0.76	33.31	19.39	22.15
Conventional	1.54	31.71	28.79	21.88
Years				
2013/14	0.83	31.10	24.86	23.76
2014/15	1.49	33.63	23.27	20.50
Year (Y)	***	*	n.s.	*
Cropping regime	***	*	***	*
Y x CR	n.s.	*	**	***
Genotype (G)	***	***	***	***
Y x G	n.s.	n.s.	n.s.	n.s.
CR x G	n.s.	n.s.	n.s.	n.s.

§ Seed characteristics: Y=yellow; B=black; S=smooth; R=rough.

§§ Completely destroyed by anthracnose attack.

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Characterization Of A Soft Wheat Germplasm Collection Suitable For Organic Farming

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Introduction

The organic agricultural systems deeply differ from conventional farming systems in terms of biodiversity at soil, crop, field, whole rotation or polyculture, and landscape level and the greater focus on integration of crop and livestock production systems on the farm (Van Bueren et al. 2010). To date, there are only few varieties that were specifically bred for organic and low-input systems in developed countries: more than 95% of organic agriculture is based on crop varieties that were bred for the conventional high-input sector. Recent studies have shown that such varieties lack important traits required under organic and low-input production conditions (Van Bueren et al. 2010). As regards wheat varieties, some of the traits (e.g., semi-dwarf genes) that were introduced to address problems like lodging in cereals in high-input systems were shown to have negative side-effects (reduced resistance to fungal diseases, lower protein content, poorer nutrient-use efficiency, scarce competition against weeds) on the performance of varieties under organic and low-input agronomic conditions. The main aim of the present work was to determine the quantitative and qualitative performances of a not-dwarf soft wheat germplasm collection grown under organic agronomic conditions.

Materials and Methods

The study was carried out on a collection of 32 soft wheat (*Triticum aestivum* L.) accessions, including not-dwarf varieties and ecotypes cropped in Italy before the Green Revolution. In the 2016/2017 growing season, the wheat accessions were grown in triplicate in small plots (1.1 x 6.5 m) according to organic farming. The plots were sown at the seed density of 180 kg/ha. The soil was a clay-loam. The following parameters were recorded in each single plot: plant height, spike length, number of spikelets per spike, number of seeds per spike, weight of seeds per spike, test weight, percentage of lodging, yield. From each accession whole flour samples were obtained and analysed for: total (TDF), insoluble (IDF) and soluble (SDF) dietary fibre contents (Megazyme assay kit, Prosky et al.1988); free (FP), bound (BP) and total polyphenol (TP) and flavonoid (FF, BF, TF) compounds as previously described by Dinelli et al. (2011); anti-oxidant activities according to the DPPH and FRAP assays (Benzie & Strain, 1996; Floegel et al. 2011).

One-way analysis of variance (ANOVA) in conjunction with Tukey's honest significant difference was performed for comparing the 33 accessions. Significance between means was determined by least significant difference values for $p < 0.05$. Discriminant analysis was applied to the standardized data matrix of TDF, SDF, IDF, FP, BP, TP, FF, BF, TF, DPPH and FRAP activities of the investigated accessions and carried out by using Statistica 6.0 software (2001, StatSoft, Tulsa, OK, USA).

Results

Although significant differences in filed yield were observed (from a minimum of 21 t/ha for Andriolo to a maximum of 43 t/ha for Piave), the average yield of the 12 varieties compared to the 20 ecotypes is not significantly different. (Table 1).

In contrast, significant differences were observed for plant height, lodging, spike length, numbers of spikelets per spike, number and weight of seeds per spike (Table 1). These data highlight the breeding improvement done on the varieties compared to the ecotypes.

Tabella 1: Agronomic parameters averaged over the 12 varieties and the 20 ecotypes of soft wheat

	Yield (t/ha)	Plant height (cm)	Lodging (%)	Spike lenght (cm)	Number of spikelets	Number of seeds	Weight of seeds per spike (g)
Varieties (12)	3.36 (a)	119 (b)	16.7 (b)	10.4 (a)	19,0 (a)	46.5 (a)	2.3 (a)
Ecotypes (20)	3.10 (b)	125 (a)	62.8 (a)	10.2 (a)	18,1 (b)	37.1 (b)	1.8 (b)

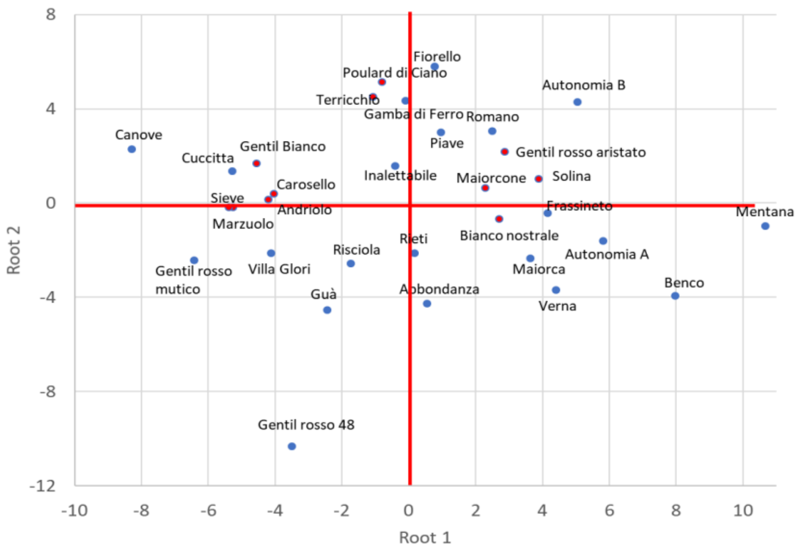

Figure 1. Scatter plot of the 32 investigated wheat accessions according to the nutritional/nutraceutical composition defined by the first two canonical functions.

Figure 1 shows a scatter plot of the wheat samples on the space defined by the first two canonical functions. As revealed from the values of canonical functions standardized within variance, the distribution of cases (genotypes) along Root 1 was strongly influenced by FRAP, free polyphenols, free and bound flavonoids, while along Root 2 was mainly determined by DPPH, bound polyphenols, SDF and IDF. The multivariate technique showed high discrimination power as indicated by the Wilks' lambda value of each variable (< 0.000001), significant at p < 0.005. In addition, 26 of 32 wheat genotypes (81.2%) were discriminated by the model with an accuracy value higher than 94%.

Conclusions

The characterization of soft wheat germplasm represents a strategic activity to identify and improve genotypes suitable for organic farming or for the development of new populations, as expected by the New Regulation of the European Parliament on organic production and labelling of organic products. Further years of investigation are needed to assess the robustness of these preliminary results.

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Grain Legumes Root Exudates Facilitate Wheat In Intercropping Systems Exploiting Phosphorus From The Soil

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Introduction

Sustainable intensification (SI), is considered an interesting strategy to sustain crop production conserving resources, reducing negative impacts on the environment and enhancing natural capital and the flow of ecosystem services (FAO, 2011). In arable cropping systems, SI is related to agrobiodiversity and its potential to improve soil physical stability and resilience of microbial processes mediating nutrient cycling (Peres et al., 2013). When plants interact positively, facilitations and complementary can occur and productivity increases with biodiversity. An agronomic measure to enhance agro-biodiversity is intercropping (Willey, 1990). In intercropping some facilitations at rhizosphere level occur, as nutrients availability improvement, depending on root exudates that can play a role of ecological tool. In a grain legume/cereal intercrop the legume root exudates (carboxylates and phosphatases) are involved in phosphorus (P) soil availability that represents a facilitation for the cereal (Cu et al., 2005; Hinsinger et al., 2011). Phosphorus in fact is characterized by a low availability in soil even when added by chemical fertilization. As a consequence, the exceeding amount of P fertilizer usually provided may reaches the water table thus, causing water pollution and eutrophication (Carpenter, 2005). On the other hand, global P reserves are close to depletion and P fertilizer cost is estimated to increase (Cordell et al., 2009).

The aim of this research, carried out on "living" soil in climate chamber, is to evaluate in intercropping benefit and facilitation of different grain legumes species on intercropped wheat. The effects of legume root exudation (quantity and composition of exudates) on the wheat phosphorus uptake was particularly focused.

Materials and Methods

Under controlled environment wheat (W), lupin (L), faba bean (F) and pea (P) were grown in pot as sole crop (SC) and in intercrop (IC) combining each grain legume with durum wheat at two levels of phosphorus soil supply: natural content in soil (P0) and adding 50 mg of phosphorus per kg of soil (P1).

Pots were destroyed at legume full flowering time, plants and soil samples were collected for the analysis. Phosphorus (total, mineral, organic and available fractions), phosphatase activity and organic acids in rhizospheric soil were detected; pH, total N and C, $NH4^{+}$-N, $NO3^{--}$-N were also determined. In root and shoot of wheat and legumes, growing in IC and SC, dry matter, P and N content were analysed and total plant accumulation was calculated.

Results

Data showed that IC absorbed phosphorus more than sole crop when no phosphorus was added and a significant contribution of wheat, especially in pea and lupin IC, was highlighted (56 and 61% of total P amount in mixture respectively).

Among IC, wheat/pea absorbed phosphorus much more efficiently than other mixtures due to high contribution of pea (Fig.1). At P0 P uptake was significantly higher in wheat intercropped with pea than respective SC (142 and 95% more in P0 and P1 respectively) (Fig. 2).

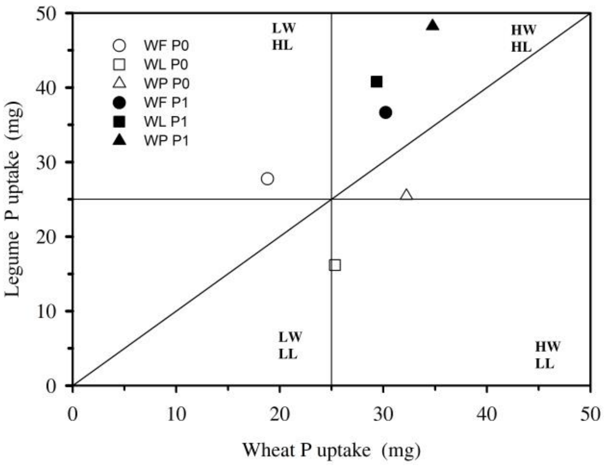

Fig. 1. P uptake (mg plant^{-1}) of legumes and wheat in IC. The bisector line represent the points in which P uptake is the same in wheat and legumes; the four quadrants represent the contribution of each partner to the IC: LW: low wheat; HW: high wheat; LL: low legume; HL: high legume; WF, WL, WP are intercropping of wheat with faba bean, lupin and pea respectively.

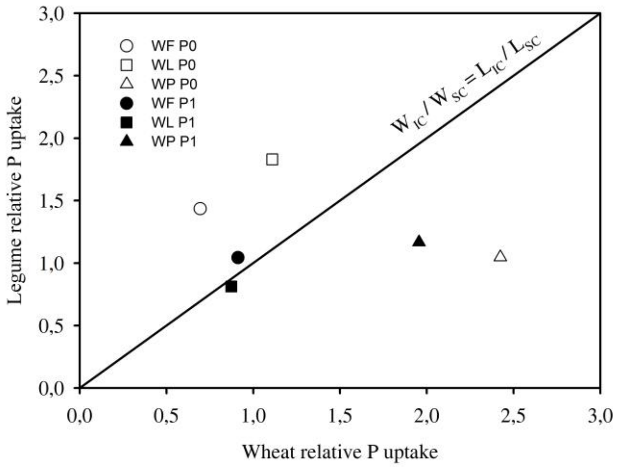

Fig. 3. Relative P uptake (IC/SC) of wheat and of legume are compared. The bisector line represent the points in which the relative P uptake is the same in wheat and legumes. WF, WL, WP are intercropping of wheat with faba bean, lupin and pea respectively.

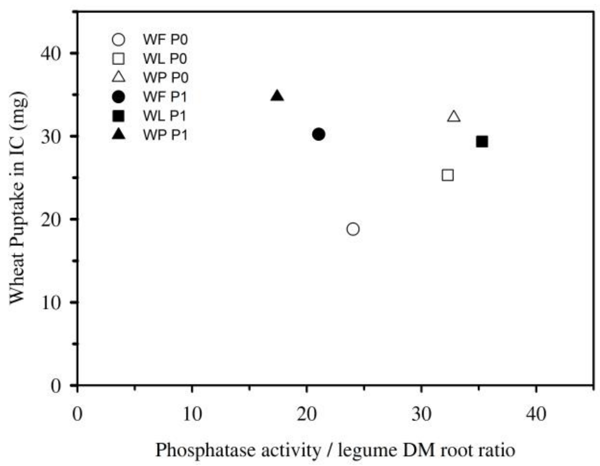

Fig. 3. P uptake (mg plant^{-1}) of intercropped wheat compared to acid phosphatase activity at two P level. Phosphatase activity is expressed as ratio by legume dry matter roots (µg p-nitrophenol g^{-1} h^{-1} root g^{-1}). WF, WL, WP are intercropping of wheat with faba bean, lupin and pea respectively.

When phosphorus was not added, the P uptake by the intercropped wheat is increased as the phosphatase activity increase, resulting highest in wheat/pea (Fig. 3).

Conclusions

Our results show that, under low available phosphorus condition, the root facilitation in intercropping with legume is beneficial to wheat P uptake and this is added to the benefit produced by N fixation in increasing N mineral soil availability.

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The Role Of Agronomic Research In The Management Of Constructed Wetlands For Wastewaters Treatment In A Mediterranean Environment

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Introduction

The functioning of a constructed wetland (CW) depends on the interaction between plants, substrate and microorganisms in relation to the type of structure and wastewater treatment being used. Many studies tend to give greater weight to engineering and design aspects of a CW. However agronomic aspects are also very important in a CW, such as the choice of the plants, the plant density and crop systems, the management of aboveground biomass and water balance, the reuse of treated wastewaters (TWW). Hydraulic conditions are differently influenced by single-species and multi-species systems. CWs produce biomass that can be harvested for the production of fodder and fuel. TWW can be reused for irrigation of open field and horticultural crops. This paper reports the main results from a set of experiments carried out in two pilot CWs in Sicily (Italy), during the past 15 years.

Materials and Methods

Tests were carried out from 2000 to 2015 in the experimental areas of the pilot Horizontal Sub-Surface Flow systems (HSSFs) in Piana degli Albanesi and Raffadali in the West of Sicily. The technical and functional characteristics of the pilot HSSFs have been described by Leto et al. (2013) and Tuttolomondo et al. (2015). *Arundo donax* L., *Cyperus alternifolius* L. and *Typha latifolia* L. were the macrophytes under investigations. During the test period, 5 experiments were mainly carried out. In all the experiments, the analysis of chemical/physical parameters of TWW were carried out using Italian Water Analytical Methods. Plant growth analysis was carried out by determining plant height and through an examination of the plant biomass. Nitrogen levels in the above/belowground biomass parts of the macrophytes were also measured. The water balance of CW was calculated in agreement with IWA (2000). The crop coefficients values were determined for each growth stage of the macrophytes in the study. The effects of irrigation with urban TWW on the yield and qualitative characteristics of three open field crops and on chemical-physical soil properties were compared to irrigation with freshwater. In the experiment concerning to tomato TWW irrigated-plots, we estimated the amount of N, P, K supplied by irrigating with TWW and evaluated nutrient savings compared to traditional agronomic management methods. In the last experiment, single-species and multi-species systems affected differently the treatment efficiency of dairy parlor wastewaters in two CWs.

Results

1. Effects of plants species on the pollutant removal efficiency (RE) of a CW.

The biomass yields and the N levels in plant parts were found significantly different for the macrophytes in the study. Chemical-physical and microbiological pollutants were found to be significantly lower in *Arundo* and *Typha*-planted units compared to *Cyperus*-planted unit (Table 1).

Table 1. Removal efficiency (%) of the most important chemical and microbiological parameters in the two CWs.

Species	[1]BOD_5	[2]COD	[3]TKN	[4]TP	*E. coli*
Arundo donax	72.5	67.5	49.9	45.1	87.4
Cyperus alternifolius	67.3	64.0	41.6	37.5	85.1
Typha latifolia	72.4	75.7	51.6	47.9	89.5

[1]BOD = Biochemical Oxygen Demand; [2]COD = Chemical Oxygen Demand; [3]TKN = Total Kjeldahl Nitrogen; [4]TP = Total Phosphorus.

2. Effects of evapotranspiration on water balance and pollutants removal efficiency of a CW.
The findings of the research showed that when ET reached average values of over 20 mm d^{-1}, water loss increased and increases in BOD_5 and COD concentrations in the final effluent were observed. This resulted in a decrease of apparent RE.

3. Effects of urban TWW irrigation from CW on open field crops and soil.
TWW irrigation affected the yield and quality of the crops and increased the N, P, K levels in the topsoil, but not significant differences were found for N content in the short-term application. TWW irrigation decreased the need for mineral fertilization of the crops (Table 2.).

Table 2. Agronomic management of N fertilization program of the crops in the study.

Crops	N fertilizer (kg ha^{-1})	FW-irrigated plots	[1]TWW-irrigated plots	[2]TWW-irrigated plots	[3]TWW-irrigated plots
Arundo donax	Total N	120.0	76.0	64.0	120.0
Cynodon dactylon	Total N	300.0	252.1	259.2	223.8
Paspalum vaginatum	Total N	300.0	263.2	260.2	231.2

[1]TWW from *Cyperus* planted-unit; [2]TWW from *Typha* planted-unit; [3] TWW from unplanted-unit.

4. Effects of FW and TWW irrigation from CW on characteristics of tomato plants.
No significant differences in total yield were recorded between FW and TWW-irrigated plants. The pH of the fruits was significantly influenced by the different irrigation treatment (Table 3). Microbial contamination was found to differ in the two parts of the fruit and was greater in fruit skin.

Table 3. FW and TWW irrigation on the productive and qualitative parameters of tomato fruits.

Treatments	Total yield (t ha^{-1})	pH	SSC (°Brix)	Titrat. acidity (g 100 ml^{-1})	Dry matter (%)
FW	69.4 ± 1.15^A	4.7 ± 0.02^A	4.8 ± 0.02^A	0.3 ± 0.02^A	5.5^A
TWW[1]	72.3 ± 0.93^A	4.5 ± 0.03^B	4.7 ± 0.01^A	0.2 ± 0.01^A	5.4^A
TWW[2]	73.4 ± 0.45^A	4.5 ± 0.01^B	4.8 ± 0.02^A	0.2 ± 0.02^A	5.4^A
TWW[3]	74.2 ± 0.36^A	4.5 ± 0.01^B	4.7 ± 0.03^A	0.2 ± 0.01^A	5.4^A

Means sharing the same superscript are not significantly different from each other according to the Tukey test ($P \leq 0.05$). [1]TWW from *Cyperus*-planted unit; [2]TWW from *Typha*-planted unit; [3]TWW from unplanted unit.

5. Effects of crop systems on the removal efficiency of dairy parlor wastewaters in a CW.
In single-species system, *Phragmites australis* showed significant N uptake and good tolerance to high wastewaters loads. In multi-species system, *Lolium* sp. and *Pennisetum* sp. showed significant BOD_5 removal and a better capacity to adapt to substrate conditions than *Brassica* species.

Conclusions

The comparison of macrophytes has permitted to highlight differences in terms of plant growth and ability to treat the main pollutants of wastewaters. TWW from CWs can represent a source of water and nutrients in the irrigation of open field and horticultural crops. It is possible to sustain that TWW can permit FW and fertilizers savings with respect to traditional agronomic management. Further research is needed regarding other topics such as the reuse of plant aboveground biomass for energy purpose.

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Can Digestate From Biogas Production Improve Soil Suppressiveness And Support Crop Yield?

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Introduction

The European Renewable Energy Directive of 2009 (2009/28/EC) along with the Italian public policy to support biogas production, led to a logarithmic increase in the number of anaerobic digestion plants from2008 up to 2013 (Carrosio et al., 2014). Biogas production should maintain that rising trend at least up to 2020 according to the EU projections (Molinari and Donati, 2015). Limits imposed by the European Nitrate Directive (91/676/CEE) were another driver for fast increase of anaerobic digestion biogas plants managed by farmers in Northern Italy. Such important Italian agricultural area is characterized by intensive livestock production with high nitrogen surplus. Silage maize (*Zea mays*), livestock manure, and energy crops are the feedstock for biogas anaerobic digestors, which currently covers 75% of total national biogas production in Italy.

The largest part of agricultural soils in the Po Valley is characterized by low soil organic matter content (SOM <2%) and these soils are subjected to further SOM decline due to climate change and intensive agricultural practices (Zdruli et al., 2004). Furthermore, SOM decline in the Po Valley is linked to crop yield decline of main field crops. Crop yield decline is an overall reduction of plant vigor and resistance to abiotic stress, due to loss of soil resilience and loss of microbial diversity which affect intensive growing area such the Po Valley (Manici and Caputo, 2009). Soil microbial activity reduction and increase in soil borne fungal pathogens, with a consequent rooting ability reduction of crops, are two out of the main biological factors involved in crop decline. In this context, benefits from incorporation of digestate of anaerobic biogas production were assessed in digestate-amended soils close to a series of biogas plants. The final aim of this study was evaluating in which extent soil amended with digestates can improve biological soil fertility and crop health.

Materials and Methods

The impact of soil amendment with digestate was assesses near biogas plants in three representative sites of the Po Valley (Cremona, Modena and Forlì provinces, respectively in central west, central and east Po Valley). Top soil was sampled in fields amended with digestate during the last six years and in non-amended fields. Sampling was performed in the middle of May 2017; at that time maize was growing in all the fields. Soil samples were partially air dried and subjected to 30 day-growth assay using maize as target crop. The trial was organized with a randomized block design. Plant growth was assessed as dry matter of the above ground part of plants, while roots were subjected to analysis of root fungal endophytes. Data were subjected to two-way ANOVA.

Results

Overall, sampled soils showed a SOM varying from 0.98 to 1.52%. Soils amended with digestate from anaerobic biogas production showed in general higher SOM compared to the non–amended soils, albeit this difference was not significant.

Plant growth and root infection frequency highly significantly differed both for sites and for soil amendments, even if significant interaction among those factors suggested that plant response to the diverse soil amendments varied according to the sampled sites. Soils amended with digestate determined higher plant growth than non-amended soil in all locations. Nevertheless, only in the Forlì site, this difference was significant (Fig. 1). Root colonization frequency by soil fungi was significantly lower in amended soils (Fig. 1). Root colonization and plant growth were negatively correlated (r = -0.69, P<0.001, 18 counts), suggesting that root colonization in amended soil was diminished.

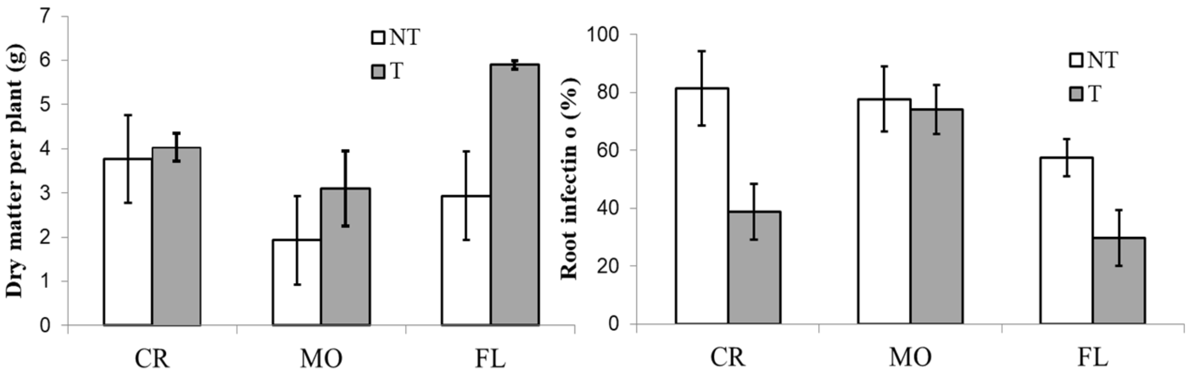

Figure 1. Plant growth (average dry matter produced by each plant) and root colonization in amended soils (T) and non-amended original soils (NT). CR (Cremona), MO (Modena) and FL (Forli) were the provinces in which the experimental sites were located.

As root endophytic fungal communities, occurring in both amended and non-amended soils, were represented by a series of potential root rot agents of maize, the observed lower root colonization in amended soils was consistent with an increase of maize crop health. Indeed, the main fungal populations isolated from roots were: *Fusarium moniliforme, F. oxysporum* and other *Fusarium* spp. which cause root necrosis and *Setophoma terrestis* causing 'red root rot'.

Conclusions

The first year results of this study show that soil amendment with digestate from anaerobic biogas production has increased crop health, even though a significant increase of SOM content was not observed in the digestate-amended soils. The impact of soil borne pathogens impairing crop growth was reduced in the soil amended with digestate from biogas production. This suggested an overall ability of digestate to improve soil suppressiveness, namely the complex of biotic factors able to optimize plant growth by suppressing soil borne pathogens.
In the further part of this study, the effect of digestate amendment on rhizobacteria involved in soil suppressiveness will be investigated, whilst another cycle of plant growth test will be performed to assess the effect of digestate amendment on plant growth response as observed in the first year of the study.

Acknowledgements

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Poster

“Agricoltura biologica e Agroecologia”

Compost As N Source For Field Crop Fertilization

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Introduction

The fertilization with organic matter is one of the practices to maintain or increase soil fertility and also it represents an alternative for the sustainability of agro-ecosystems, although environmental impact of this practice should be also carefully evaluated (Takakai et al. 2017a). Compost is a biosolid with favourable characteristics, e.g. content of stable organic N (Horrocks et al. 2016) and stabilized organic matter, and its use can allow soil fertility maintenance and/or recovery (Fecondo et al. 2008) and sustain crop yield (Takakai et al. 2017b). Compost characteristics are influenced by composition of the organic matter source. Therefore, different types of organic materials can determine the production of compost with different composition, especially in terms of nutrients. Although several studies have been carried out to evaluate the effect of compost application on field crop yield, only few papers focused on more than one type of compost with contrasting results. For this reason, the main aim of this study was to compare different compost types as total or partial mineral nitrogen fertilization substitution in an herbaceous crop succession (maize, wheat and sunflower) set in North-East Italy.

Materials and Methods

The experiment was carried out at the University of Padua "L. Toniolo" Experimental Farm, North-East Italy (Lat. 45°11'N, 11°21'E, 6 m a.s.l.) during a three-year research program, from 2006 to 2008. Three different crops were cultivated during the experimental period: maize (*Zea mays* L.) (16^{th} May - 3^{rd} October 2006; 7.5 plants m^{-2}), wheat (*Triticum aestivum* L.) (3^{rd} November 2006 - 18^{th} June 2007; 250 kg seeds ha^{-1}) and sunflower (*Helianthus annus* L.) (28^{th} April - 2^{nd} October 2008; 9 plants m^{-2}). To partially or completely substitute the crop N mineral requirements, four different types of compost were used as organic fertilizer: i) compost derived from green cutting and depuration sludge (G+S), ii) from green cutting, organic fraction of municipal wastes and other organic materials (G+F+O), iii) from green cutting (G) and iv) from green cutting and organic fraction of municipal wastes (G+F). Eight different fertilization treatments, six times replicated, were compared in each cultural cycle, adopting a completely randomized blocks experimental design. The fertilization scheme included: i) 50% of N supplied through G compost and 50% of N supplied through mineral fertilization (MF) (T1), ii) 50% of N supplied through G+F+O compost and 50% of N supplied through MF (T2), iii) 50% of N supplied through G+S compost and 50% of N supplied through MF (T3), iv) 50% of N supplied through G+F compost and 50% of N supplied through MF (T4), v) 100% of N supplied through G+F+O fertilization (T5), vi) 100% of N supplied through G compost (T6), vii) 100% of N supplied through MF (T7), viii) un-fertilized treatment for comparison (T8). The P and K crops requirements were satisfied adding mineral fertilizers to the content of composts. Maize was the only irrigated crop, with 120 mm of water supplied, equally divided in three different applications in July to satisfy crop evapotranspiration.

Results

The highest (ANOVA, $p<0.05$) maize total biomass (stalk + grain) production was detected in the MF treatment (T7), whereas the lowest (ANOVA, $p<0.05$) ones in the G+F+O compost fertilization (T5) and un-fertilized treatment (T8) (Fig.1a). Both wheat total and straw biomasses showed the same statistical trend among the fertilization treatments. The significantly highest values were recorded in the treatments where mineral fertilizers were used at both 50% (T1 to T4) or 100% (T7), without any significant differences among them, whereas the significantly lowest ones (ANOVA, $p<0.05$) were obtained in the un-fertilized treatment (Fig.1b). Despite sunflower average total biomass, straw and grain yields showed high differences among the treatments, the ANOVA statistical test did not indicate any significant differences among them, probably attributed to the high variability within each treatment (Fig.1c). At the end of the three-year crop succession the significantly highest (ANOVA, $p<0.05$) cumulate dry biomass productions were harvested for 50% compost+50%mineral fertilization (on average 58.3 Mg ha^{-1}) and 100% mineral fertilization (58.7 Mg ha^{-1}) treatments. Instead, the significantly lowest (ANOVA, $p<0.05$) biomass productions were obtained for the treatments where the 100% of N fertilization was supplied through compost (on average 50.7 Mg ha^{-1}) which were similar to those of un-fertilized treatment (Fig.1d).

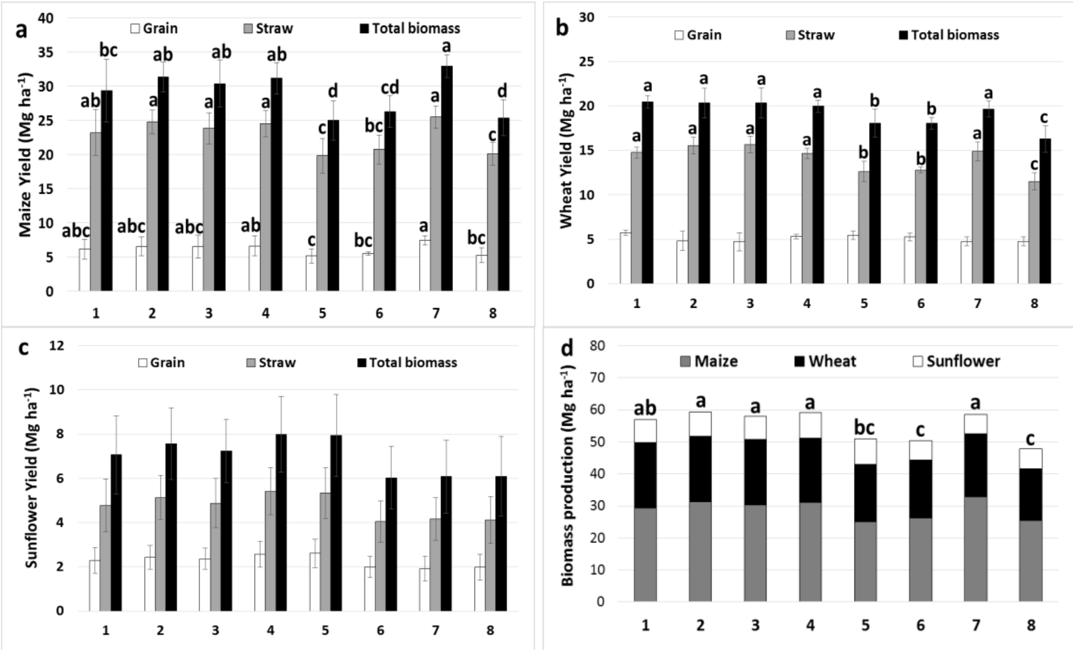

Figure 1. Crops dry biomass production (a, b, c) and cumulative dry biomass production (d). Histograms indicate average values, bars indicate standard deviation. Different letters indicated significant differences according to Tukey' HSD test at $p<0.05$. When letters are missing (Fig. C for grain, straw and total biomass and Fig. 1B for grain) no significant differences were found among treatments.

Conclusions

In the short-term period the crops response to compost fertilization is not unique. The organic fertilization with compost represents a valid substitute to mineral fertilization to maximize only autumn-winter crop yield (wheat), whereas it should be complemented by mineral fertilization to maximize spring-summer crop yield (maize).

Acknowledgments

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Carbon And Nitrogen Footprint In A LTE Comparing An Organic And A Conventional Low Input Cropping System

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Introduction

Crop cultivation greatly affects the dynamics of greenhouse gases (CO_2, NO_x, N_2O, …) as well as the carbon (C) and nitrogen (N) stocks in the soil (Dignac et al., 2017; Sanz-Cobena et al., 2017). The effects widely change depending on the cropping system and cultivation practices and deserve to be studied in the long term.
The aim of this work is to evaluate changes in soil C and N stocks after 15 years in a long term experiment (LTE) where an organic and a conventional low input cropping system are compared.

Materials and Methods

A LTE (BIOSYST) was started in 1998 at the Experimental Station of Agronomy and Field Crops (FIELDLAB) in Papiano (Central Italy, middle Tiber Valley, 42.956 °N, 12.376 °E, 165 m a.s.l.) to compare an organic system (ORG, EU reg. 2092/91) and a conventional low-input system (CON, EU reg. 2078/92). The two systems are laid down in two contiguous fields originally homogeneous for soil properties (Fluventic Haplustept clay loam, with same initial contents of SOM, total N, available P and exchangeable K). Details on the general design are reported in Benincasa et al. (2016). Briefly, a 6-year rotation was adopted with a same basic sequence of cash crops for both systems: summer cereal (grain maize) –summer vegetable (processing tomato) - winter cereal (durum wheat) - grain legume (in most cases faba bean) - summer vegetable (in most cases muskmelon) - winter cereal (soft wheat). In order to reproduce the steady-state running of the basic 6-year rotation in a farm and test all the six crops of the sequence in each year, six different orderings were realized for both ORG and CON, each ordering starting with a different crop of the sequence.
The main differences between the two systems concern N fertilisation management and crop protection. N fertilization for summer crops in ORG relies on previous fall-winter green manures with pure legumes or barley-legume mixtures, integrated, when necessary, by organic fertilizers (poultry manure or leather by-products). N fertilization of winter wheat in ORG is carried out by pre-sowing application of organic fertilisers, in CON by urea or ammonium nitrate split half at tillering and half at early stem elongation. Green manure crops and grain legumes do not receive N fertilisation. Weed control is mechanical in ORG, integrated mechanical-chemical in CON. Pests and diseases control is carried out by “natural” chemicals (pyrethrins, rotenone, copper salts and sulphur) in ORG and by “synthetic” chemicals in CON. Other agronomic practices (ploughing, PK fertilisation, cultivar, sowing dates, crop densities, …) are the same in both systems.
Apparent C balance (ΔC= C in organic fertilizers + C in crop biomass – C in marketable yield) and N balance (ΔN= N in fertilizers + estimated Ndfa in legumes – N in marketable yield) were calculated at the end of each crop cycle. In 2013 (i.e. after 15-years of cultivation) the soil bulk density, and the C and N contents of the soil were determined in the 0-0.4 m soil layer.

Results

The total organic C input into the system (C in total above ground crop biomass plus C in organic fertilizers) was higher in ORG than in CON (86.0 vs 78.1 t ha-1, SEM 1.94***, as a 15-year total). The C removed with the marketable yield was in most cases significantly lower in ORG than in CON (Figure 1). Thus, the C incorporated into the soil (i.e., ΔC) was constantly higher in ORG than in CON (Figure 1, Table 1). About 30%

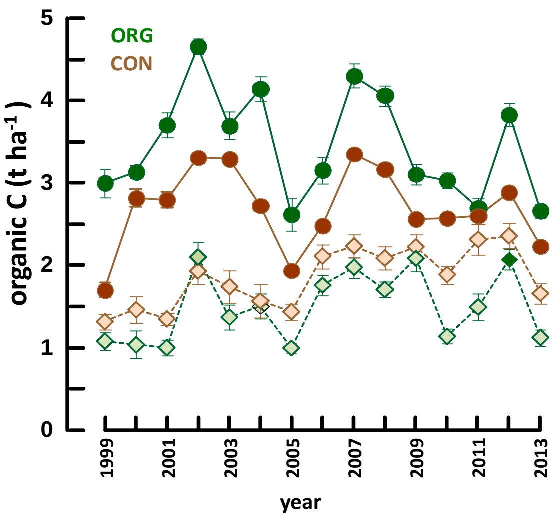

Fig. 1. Yearly variation of C incorporated in the soil, (ΔC, circles) and C removed with marketable yield (diamonds) in an organic (green) and a conventional (red) cropping system over 15 years.

of the C incorporated in ORG derived from green manures biomass with low C/N ratio (17, SEM 0.81, on the average), 66% derived from crop residues with high C/N ratio (42, SEM 1.04) and 4% from organic fertilizers (C/N=4). In CON, crop residues were the only organic C incorporated into the soil. The soil C content in ORG after 15 years was significantly higher than in CON (Table 1) while the two systems did not affect soil bulk density (1.362 ORG vs 1.359 CON, pooled SEM=0.011). The efficiency of C sequestration in the soil (i.e. C sequestered in soil/ΔC) was much higher in ORG than in CON (9.9% vs 1.7%, respectively, pooled SEM=1.43).

As far as N is concerned, the two systems did not differ significantly for ΔN over the 15 years (Table 1), while the organic N content in the soil after 15 years was markedly higher in ORG than in CON (+530 kg ha^{-1}). From data in Table 1 (neglecting soil mineral N as a minor issue), it comes out that in 15 years CON lost (probably by leaching more than volatilization) a total of 392 kg N ha^{-1} (i.e., 530-138) more than ORG, corresponding to a mean of +26 kg N ha^{-1} year^{-1}.

Conclusions

Results indicate that the organic system increased the carbon and nitrogen stocks in the soil but also reduced marketable yield. In front of the many ecological services provided the by organic systems (improvement of soil quality, enhancement of CO_2 sequestration, reduction of greenhouse gas emissions and N losses) organic farmers should be supported to compensate for the lower profitability (higher cultivation costs, lower yield).

Table 1. Cumulated Carbon (ΔC) and Nitrogen (ΔN) balances over 15 years and final soil C and N contents in an organic (ORG) and a conventional (CON) cropping system.

Cropping system	ΔC (t ha^{-1})	Soil organic C content (t ha^{-1})	ΔN (kg ha^{-1})	Soil organic N content (kg ha^{-1})
ORG	62.7	53.8	1059	5951
CON	49.5	48.4	921	5421
ORG *vs* CON	+13.2	+5.4	+138	+530
SEM	*1.37*	*0.74*	*68.3*	*106.6*
F test	**	***	ns	***

Acknowledgements

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Topsoil Fertility Of Organic And Conventional Farming: A Case Study In North-Eastern Italy Over An 8-Year Period

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Introduction

Organic farming (OF) covered 13.5 million hectares in Europe in 2016 with a 65% increase of the cultivated surface in the decade 2006-2015. Italy is among the European countries with the largest share of OF land (14.5%) and with the higher number of organic producers in 2016 (64,210) (Willer and Lernoud, 2018).

The adoption of organic farming is suggested as a way to increase soil fertility, especially with well-planned crop rotations including legumes and manure (Mader et al., 2002). As OF requires adaption of peculiar management practices (e.g. mechanical weed control, the sole use of organic fertilizers), changes in soil fertility and nutrient dynamics are expected. In this regard, long-term monitoring of soil physical and chemical properties is needed to better understand soil dynamics and to assess soil health and fertility (Diacono and Montemurro, 2010).

The experimental farm of the University of Padova (north-eastern Italy) in 2003 converted part of its cultivated land to organic farming.

The aim of our experiment was to assess the changes in the main soil chemical properties in both conventional and organic farming systems over an 8-year span.

Materials and methods

The experimental farm "L. Toniolo" of the University of Padova is composed of two sectors, about 3.5 km apart, in the low-lying Venetian plain. One is cultivated according to conventional practices, whereas the other is managed following organic farming regulation.

The climate is sub-humid with average annual rainfall of 850 mm and average annual temperature of 13.5 °C in both fields. Soil is a Fluvi-Calcaric Cambisol that differs slightly in texture (0-20 cm): 50.92 ± 9.24 % sand, 35.62 ± 8.70 % of silt, and 13.46 ± 3.41 % of clay for the conventional site; 41.20 ± 8.08 % of sand, 42.14 ± 7.16 % of silt, and 16.66 ± 2.41 % for the organic site.

Organic farming has a strict 3-year rotation of wheat, soybean and maize. Conventional farming has a more flexible crop rotation that includes wheat, soybean, maize and sugar beet.

The main difference between the two sites is about tillage and fertilizer management. Since chemicals are not allowed in organic farming, weed control is carried out with frequent harrowing operations before sowing (usually 1-3), and with hoeing operations (1-2) during soybean and maize growing season. In the organic fields, chemical fertilizers are substituted by organic amendments. In particular, soybean and maize are fertilized with farmyard manure, and wheat with sugar beet vinasse.

A total of 120 soil samples were collected in the 0-20 cm layer in both organic and conventional fields during 2008 and 2017, in the same sampling points (60 samples per site, in 3 different plots each).

Soil samples were air dried and analyzed for pH, EC 1:2.5, SOC (soil organic carbon, Walkley-Black method), SON (soil organic nitrogen, Kjeldahl method), and available P (Olsen method).

Results

Soil pH was slightly alkaline in both the conventional (7.58) and organic (7.63) sites, on average. Electrical conductivity (EC) was 0.21 mS cm^{-1} on conventional and 0.22 mS cm^{-1} on organic fields. In the organic site, the EC did not increase over the 8-year study period, as opposed to what could be expected due to sugar beet vinasse applications (Moran-Salazar et al., 2016).

In the conventional site, both SOC and SON content remained stable during the study period (on average, SOC was 7.27 g kg^{-1}, and SON 0.88 g kg^{-1}. On the other hand, the organic site showed overall higher levels of both SOC and SON respect to the conventional system, but a decreasing trend for SOC (from 9.14 g kg^{-1} of 2008 to 8.37 g kg^{-1} of 2017) and a slight increase in SON (from 1.08 g kg^{-1} of 2008 to 1.12 g kg^{-1} of 2017).
The soil C/N ratio of the conventional site was stable over the monitoring period (on average, 8.30), whereas it decreased significantly from 8.45 (2008) to 7.75 (2017) in the organic site. These results suggest that a mineralization process was still ongoing and that unstable soil conditions were likely despite the 8-year organic farming management. In this context, Diacono and Montemurro (2010) pointed out the need to refer to long-term data of more than 15 years to assess the effects of organic amendments on soil fertility.
As regards available P content, it increased significantly from 2008 to 2017 in both systems, but was generally lower in the organic site, probably due to the use of sugar beet vinasse (that has a negligible P content) for wheat fertilization.

Tab. 1. Main soil chemical parameters of the conventional (Conv) and organic (Org) farm (average ± standard deviation), for 2008 and 2017. Significant differences between the years in the same farming system are reported.

	year	pH	EC 1:2.5 (mS cm^{-1})	SOC (g kg^{-1})	SON (g kg^{-1})	C/N	Available P (g kg^{-1})
Conv	2008	7.48 ± 0.15 ^{b}	0.20 ± 0.03 ^{a}	7.12 ± 1.13 ^{a}	0.87 ± 0.13 ^{a}	8.22 ± 0.55 ^{a}	19.25 ± 7.51 ^{b}
	2017	7.69 ± 0.10 ^{a}	0.23 ± 0.23 ^{a}	7.42 ± 1.20 ^{a}	0.90 ± 0.10 ^{a}	8.38 ± 1.73 ^{a}	34.59 ± 13.93 ^{a}
Org	2008	7.68 ± 0.13 ^{a}	0.22 ± 0.03 ^{a}	9.14 ± 1.02 ^{a}	1.08 ± 0.10 ^{b}	8.45 ± 0.29 ^{a}	20.71 ± 7.88 ^{b}
	2017	7.57 ± 0.09 ^{b}	0.22 ± 0.18 ^{b}	8.37 ± 2.22 ^{b}	1.12 ± 0.09 ^{a}	7.57 ± 2.23 ^{b}	25.14 ± 6.83 ^{a}

Conclusions

Organic farming showed significant changes in soil chemical properties over an 8-year period. Soil in conventional farming had lower but stable SOC and SON contents, while soil in organic farming had better, although not stable, fertility conditions (with a decreasing C/N ratio). These results suggest the need to broaden our perspective for a better understanding of soil dynamics.
In this regard, it will be convenient to continue the monitoring of soil properties over time, to consider soil data in the light of farm management practices and crop production, and to use crop models to integrate field data, predict future developments, and simulate the effects of different management practices.

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Synergistic Agriculture Vs Organic Farming. First Results

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Introduction

In the last century there has been an evolution of agriculture through various stages, from a subsistence agriculture to an extensive agriculture, based on large land and crop rotation, reaching an intensive and specialized agriculture with marketing purposes on the agricultural market (Mazoyer, 2008), increasingly mechanized and characterized by the use of fertilizers and genetic engineering techniques.

This system of agricultural production showed that in the last 60 years agriculture has been interested in producing more income than food (Bonciarelli, 2008) creating a series of economic and environmental troubles (Benvenuti, 1995). The former is mainly linked to the sharp increase in the cost of the chemicals used, which are no longer able to guarantee economically viable returns. The latter concern environmental damage, such as excessive deforestation, extensive farms in fragile areas, irrigation in regions with strong evaporation that causes rapid salinization of the land, the use of heavy machines that plow deeper and deeper causing shortage of organic matter in the soil, the destruction of humus and the pollution of groundwater.

Between the end of the nineteenth century and the beginning of the 1920s, a new model of farm was born, through a cultural trend of return to nature, intended as a self-sufficient living organism, characterized by new cultivation techniques through the research of products that do not against, but in synergy with nature (Pittau, 2005). It was thanks to these principles that in the 80s the concept of synergic cultivation was born, elaborated by the naturalist Emilia Hazelip, who - starting from the studies of microbiologist Fukuoka - developed this method based on agronomic practices and precautions mainly aimed at the fertility of soil and the consequent better health of the whole soil-microorganism-plant system, rather than the increase in productivity. Just like organic farming, but with more incisive measures, which are based on the lack of the techniques of agricultural land work and on the association of plants (at least three different families) according to the relationships that contribute to the formation of a system based on a very wide biodiversity, which, in synergy, works for a good functioning of the whole system.

Currently, only a few studies have focused scientifically on the positive effects that this method has in plant development.

Synergistic agriculture is defined as "the most natural form of cultivation among those known, because it works with the natural fertility dynamics of the soil" (Hazelip, 2014).

Materials and Methods

The experimental test was conducted in farm located in central Italy 30 km North of Rome. The cultivation was carried out on raised beds, and as provided by synergistic agriculture, at least three botanical families were considered, in fact the system is based on the concept of soil self-fertility. At the fourth year of life of the synergistic garden, a comparison test was set up between the synergistic cultivation method and the organic farming.

In the synergistic garden, by arranging them in a completely randomized way, the following species of vegetable plants have been associated: tomato (var. Ponderosa di Belmonte), roman lettuce (var. Bacio), savoy cabbage (var. Sabrosa), parsley (var. Gigante d'Italia), red beetroot (var. Tonda di Chioggia) and courgette (var. Romanesco). The same crops were planted in the organic garden, placing them in specialized rows.

The experimental period started at april and ended at october. The plants were purchased in the nursery and then transplanted on the synergistic raised beds and on the organic farming at the beginning of the experiment.

The studies were made considering, in each of the two vegetable gardens, nine plants for each species taken randomly.
The results obtained with the two cultivation methods, related to different parameters, were compared. In particular, as regards the plants, chlorophyll was determined by using an *in vivo* measurer of this pigment (Konica-Minolta chlorophyll meter SPAD-502 PLUS), in order to evaluate the photosynthetic activity of the plants and their vegetative state, and the total nitrogen in the leaves, determined with an nitrogen analyzer, for the evaluation of the nutritional status and of the protein synthesis.
On the plants considered as final product, therefore at commercial ripening, the commercial fresh weight was taken into consideration, in order to evaluate the production, as well as the dry matter, with the dual purpose of defining the greater or less shelf life and the resistance to handling in post-harvest phases.
The calendar of ripening season was also examined.

Results
The analysis of the results obtained showed that the quantities of chlorophyll and total nitrogen present are greater in the species cultivated according to the synergistic agriculture with respect to the same species cultivated in the organic garden.
As far as production is concerned, there is an increase in the synergistic garden compared to the organic one, between 10 and 30%. In particular, it is equal to 30% for the Ponderosa di Belmonte tomato and savoy cabbage.
As for the ripening season, there is an advance of about twenty days in cabbage, parsley, lettuce and red beetroot grown in the synergistic garden with respect to the same varieties grown in the organic garden.
The tomato and the courgette from the synergistic garden, on the other hand, had a ripening delay of around twenty-one days compared to those grown in the organic garden.
As regards the harvest period, this was longer in the synergistic compared to organic, of about fifteen days.

Conclusions
The results obtained, even considering the importance of the pedoclimatic reality of the area where the trial was planted, show the great potential of this type of agronomic technique. It is still little known and used and is often considered a curiosity while the answers obtained are positive. In fact, through the data obtained it was possible to prove the efficiency of the synergistic cultivation technique compared to the organic cultivation. The plants cultivated by this method showed a higher chlorophyll content and a greater weight of the edible portions. All this thanks to a system in full synergy. Therefore, the choice to use this synergistic cultivation system can be a valid alternative to optimize the quality of the crops and to minimize the environmental damages that in conventional agriculture prove to be quite significant.

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"BioDurum" Project: Defining Innovative Processes For Organic Farming Through Open Dialogue

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Introduction

In European countries agricultural production is undergoing marked changes due to rapid shifts in consumer demands, input costs and concerns for food safety and environmental impact (Walters et al., 2016).
In Southern Italy, climatic concerns coupled with market volatility and non-remunerative farmgate prices are triggering reflections on how to reshape the food and farming system, yet still somehow revolving around key traditional crops for these regions.
In these Southern areas, organic agriculture represents a widespread, expanding and progressively consolidated farming system that, at farm level, successfully combines environmental and sustainability concerns with profitability and competitiveness aspects, in response to demand and requirement of the consumer about food wholesomeness. In particular, Sicily is the first Italian region for area and number of farms under organic farming, totaling 363,688 hectares (of which 44,869 hectares of areas under cereals) and 11,541 operators (SINAB, 2017).
Through a participatory research program, the "BioDurum" project intends to define innovative processes for organic farming systems centered on durum wheat, following the priorities identified by the "Italian strategic plan for the organic system development" (MiPAAF, 2016). These processes are designed to ensure i) adequate income for organic farmers, ii) product quality, iii) environmental benefits and iv) sustainable management of resources.
The project (financed by the Italian Ministry of Agriculture – MiPAAF and coordinated by the Council for Agricultural Research and Economics - CREA) is being implemented in collaboration with FIRAB (Italian Foundation for Research in Organic and Biodynamic Farming) with a multidisciplinary and multi-actor approach that values the involvement of organic farmers and other value chain stakeholders.
The objectives of the project are related to: i) development and implementation of diversified organic cropping systems, suitable for hot and drought environments; ii) agro-ecological and mechanical innovations; iii) identification of cultivars and landraces suitable for organic farming systems; iv) activation of a network of pilot farms and processing companies for the promotion of co-innovation; v) sustainability assessment of organic durum wheat production systems; vi) socio-economic analysis of diversified cropping systems.

Materials and Methods

The project is structured in different work packages (WP) and sub-WP:

1. Development and implementation of diversified organic cropping systems.
   - Assessment of different crop rotation routes suitable for semi-arid environments;
   - Response of durum wheat genotypes to the action of arbuscular mycorrhizal fungi (AMF);
   - Technological and health quality of organic durum wheat products derived from South Italy.
2. New agro-ecological methodologies and mechanical innovations.
   - Assessment of the efficiency of traditional and organic agro-technics;
   - Efficiency assessment of an innovative grain sowing device for weed control;
   - Methods for traceability of means of production (input) and of output product.
3. Genotype innovations and identification of cultivars/landraces suitable for organic farming systems.
   - Recovery and valorization of old local varieties, mix and durum wheat landraces;

- Varietal screening of genetic materials developed for organic farming systems.

4. Implementation of a network of pilot farms and processing companies for the promotion of co-innovation.
   - Selection of pilot companies;
   - Definition of agricultural practices and innovative crop plans;
   - Active participation in the co-innovation process through the constant exchange of experiences and results of experiments.
5. Sustainability assessment of organic durum wheat-based farming systems.
   - Identification of relevant sustainability indicators to highlight the effects of innovative practices;
   - Definition of the processing, weighing and aggregation of sustainability indexes;
   - Outputs production and evaluations with partners and actors involved in the project.
6. Socio-economic analysis of diversified organic cropping systems.

In the project, we adopted a qualitative methodology based on interviews research with relevant local actors and a case study approach with a combination of ethnographic methods, such as participant observations and in-depth interviews. The participatory research methodology appears to be useful in identifying more widely-accepted and rapidly applicable solutions. The field analysis is conducted by Semi-Structured Interviews (ISS) or in-depth interviews (Guala, 2003; Bichi, 2007), participatory workshop and participant observation during meetings with the stakeholders.

"On farm" and "on station" trials arranged with the project partners are carried out in several farms in two macro-regions (Sicily and Apulia-Basilicata), characterized by different environmental pedoclimatic conditions.

Results

The interviews allowed to identify a set of indicators useful to characterize the different areas or territorial contexts in which organic durum wheat is practiced, identifying the best practices of reference.

Field experiments, arranged with the project partners, concern the WPs activities, in particular: crop rotation suitable for Mediterranean environments, response of durum wheat genotypes to the action of AMF, evaluation of durum wheat landraces, old local varieties, mix of genotypes in organic farming systems. The agronomic results of the first year are being processed. The comparison of the "on farm" experiences and the results of the "on station" trials will allow scientific, practical and economic assessments of the innovative solutions introduced.

Several participatory workshops have been carried out and will be organized in the study areas to discuss the results and to identify the relevant sustainability issues. The sharing of the results obtained in the project with partners and with the pilot farms are allowing a greater awareness of the possible innovations that contribute to the strengthening of the organic durum wheat productive system.

Conclusions

The project, built by systemizing and enhancing the experiences of organic durum wheat in South Italy, can become a reference point for those producers who wish to improve the performance of organic farming in compliance with the environment.

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Analysis Of A Rice Germplasm Collection For The Identification Of Varieties Suitable For Organic Farming

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Introduction

The European and global market of organic products is rapidly increasing in the last years, boosting the rise of the agricultural land managed organically and the number of producers (Willer and Lernoud, 2018). Cereals including rice represent a main crop group for organic agriculture in Europe, with about 2,3 millions of hectares in 2016. Although the percent of this area dedicated to rice is very low because climatic conditions restrict this crop to Mediterranean countries, the interest for organic farming in the European rice area is also increasing. Variety choice in organic farming is an essential factor for successful production. Resistance to major diseases, nutrient-use efficiency, competitiveness against weeds, tolerance to mechanical weed control are important traits under organic production systems (van Bueren et al., 2011). In the case of rice cultivation, resistance to blast caused by *Magnoporthe oryzae* is essential (Titone et al., 2015), as well as a short and vigorous vegetative phase for a good competition against weeds and a short growing cycle for allowing green manure cultivation and/or the adoption of other organic practices such as dead mulching and “false seedbed”. Because of the lack of breeding programmes specific for organic farming, required traits should thus be individuated in crop varieties that were bred for conventional systems. In the present work, phenotypic data derived from different experimental activities carried out using a rice germplasm collection were utilized for the identification of accessions suitable for organic farming breeding.

Materials and Methods

The dataset utilized for the identification of varieties suitable for organic farming derived from a research project funded by AGER Foundation (RISINNOVA project grant no. 010-2369), in which about 300 temperate- and tropical-*japonica* rice varieties, adapted to the European growing conditions, were field evaluated in 2013 and 2014 for several agronomically relevant traits (Volante et al., 2017). A set of 26 phenotypic traits related to phenology, plant and seed morphology, yield and physiology under different water management conditions are available from this dataset. A further dataset for leaf blast tolerance evaluation, derived from other research projects (unpublished data), was utilized in the present work. The identification procedure consisted in the following phases: 1 – all available traits were hierarchically ordered on the basis of their relevance for the selection purposes, using literature analysis and experts evaluation, 2 – germplasm population was explored for the identification of selection criteria for each major traits, 3 – each criteria was then applied to the datasets using a step by step procedure using the ranking results from step 1.

Results

After literature analysis and experts evaluation, blast resistance was identified as the most important selection criteria, followed by short growing cycle, crop competitiveness against weeds and nutrient-use efficiency. For the first two traits, it was possible to directly use phenotypic results from the dataset for identifying the suitable selection criteria (i. e., respectively, a leaf blast resistance score modified from the Standard Evaluation System for Rice (IRRI 1996) and the number of days from sowing to flowering and maturation). On the contrary, indirect indicators had to be defined for competitiveness against stress and nutrient-use efficiency. A short duration period from sowing to flowering was considered a valuable trait for organic rice cultivation for expected correlation with a good competition behavior and tolerance to mechanical weed control, while for nutrient-use efficiency measured data of Nutrient Balance Index (NBI®) based on optically estimated chlorophyll and flavonoid content, was utilized. Also plant yield was utilized for a final evaluation of the identified selected varieties. As expected, blast resistance index for the entire germplasm was very weak (median SES value equal to 8). The lowest tenth percentile (i.e., equal or minor than 3.5 SES score), was selected, corresponding to the

30 most tolerant *japonica* varieties. Based on this short list result it was only possible to set a criteria of 155 days for the crop growing cycle which correspond to a medium maturity class. The list was further restricted to varieties with a maximum measured vegetative cycle of 98 days: the result was the identification of a first list of 12 accessions, of which 6 registered in Italy: three long B (Venere, Fragrance and Salvo), one long A (Jefferson), two round (Virgo and Krystallino). Moreover, this panel of 12 accessions showed an average NBI equal to 23.2, with only 5 accessions showing a value higher than the germplasm median.

Table 1. List of all main traits available from the datasets and their utilization in the present analysis

Trait category	Trait	Unit	Utilization	Germplasm median	Criteria value
Disease resistance	Blast resistance	SES score (IRRI 1996)	Variety identification	8.5	≤3.5
Phenology	Days to maturity	Days	Variety identification	152	≤155
	Days to flowering	Days	Variety identification	93	≤98
Plant morphology	Plant height	cm	Varieties evaluation	88.4	≥88.4
Seed morphology	Naked seed length and width	cm	Merceological grouping	-	-
	Seed width/length ratio	fraction	Merceological grouping	-	-
Yield	Number of tillers per meter	Number	Variety evaluation	88.2	-
	Yield of 50 panicles	g	Varieties evaluation	167.4	≥167.4
Physiology	Nitrogen balance index	Index	Varieties evaluation	23.4	≥23.4

Conclusions

The application of selection criteria to the germplasm collection showed several results. The blast tolerance criteria reduced the initial population to 10%, excluding from the following steps most of the varieties utilized in Italy, also in organic farming. The application of the other traits valuable for organic farming led to a strong selection, with the identification of six commercial varieties and six accessions not registered. Besides the need for direct evaluation of existing rice varieties appropriate for organic farming, the results highlight the importance of identifying the primary limiting factors of organic rice production for the breeding programmes.

Acknowledgments

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Agronomic Management Of ‘Early’ Potato Under Organic Farming System

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Introduction

Among the arable crops, potato (*Solanum tuberosum* L.) represents a major food crop in many countries where the demand for organic food is increased worldwide. Recent studies (Lombardo et al. 2012) highlighted the possibility to successfully produce the ‘early’ potato (harvested from March to June) under organic farming in the Mediterranean Basin, where its premium price offers a sufficient profit margin to growers targeting the export markets in northern and central Europe (Lunati, 2009). Yield levels are typically lower in organic farming systems than in conventional high-input ones (Lombardo et al. 2012) and, therefore, the current efforts of the scientific research are focused to establish an agronomic management system able to improve the crop performances. Hence, our aim was to identify the influence of the arbuscular mycorrhizal fungi (AMF) application, organic fertilization rate and cultivar choice on the physiology and yield of ‘early’ crop potato.

Materials and Methods

The trials were conducted over two growing seasons (2016 and 2017) at an organic farm located on the coastal plain of Siracusa, a typical area for ‘early’ potato cultivation in the southern Italy. A split plot design with 3 replications was adopted. The crop management treatments, representing the main plots, were summarized in Table 1. In particular, two treatments included the application of AMF (*Glomus* spp., *Gigaspora* spp.), at sowing time, with the aim to deliver the stimulation of root growth and an optimal nutrient plant absorption. The potato cultivars (‘Arizona’, Mondial’, ‘Universa’) were treated as sub-plots and selected since widely cropped in Sicily. Some physiological parameters (photosynthesis rate and chlorophyll content, indicated hereafter as Photo and Chl_{SPAD}, respectively) were monitored starting from the beginning of tuber formation. At harvest, the weight of marketable and unmarketable tubers (affected by greening, misshapen, pest and disease damages or small sized <20 g) per plant were determined and this allowed the calculation of the mean tuber weight (MTW) and marketable yield (MY). A representative sample per replicate was used to determine the tuber dry matter (DM) content. All the data were subjected to analyses of variance (ANOVA).

Results

Our results about Photo and Chl_{SPAD} highlighted a significant ‘*agronomic management treatment x season*’ interaction (Tab. 1). In particular, it is noteworthy to underline as T3 ensured highest values of these traits than T1 and T2, as especially evidenced in 2016. All the studied cultivars significantly decreased their Photo and Chl_{SPAD} starting from the beginning of tuber formation (Tab. 2). In 2016 they also showed an uniform trend in response to the AMF application (T2 and T3), which ensured higher MYs (Tab. 3). The efficiency of the AMF application was so high to allow the halving of the organic fertilizers used (T3) while obtaining both higher MTW and MY (Tab. 3). This was particularly evident for ‘Arizona’, that was the only one to take advantage of T3 treatment in 2017. These controversial results may be attributable to the meteorological conditions; indeed the 2016 growing season experienced unfavourable mean temperatures and total rainfall to ‘early’ crop potato growth (data not shown). The DM content was significantly influenced by the ‘*agronomic management treatment x cultivar*’ interaction (Tab. 3). In general, all the tested cultivars had higher DM content under T3, an important result in the perspective of improving home cooking quality.

Table 1. Photosynthesis rate (μmol CO_2 m^{-2} s^{-1}) and chlorophyll content (as SPAD units) as affected by ‘*agronomic management treatment x season*’ interaction. Different letters within each column indicate significant differences (LSD test, $P \leq 0.05$).

Agronomic	Product	Dose	2016	2017

management treatment			Photo	Chl_{SPAD}	Photo	Chl_{SPAD}
T1	Ricin-Xed[a] Xedaneem Pel[b] K_2SO_4 Biosin[c]	1 t ha^{-1} 1 t ha^{-1} 0.6 t ha^{-1} 150 cc hL^{-1}	10.6b	42.6c	12.3a	38.0b
T2	Ricin-Xed Xedaneem Pel K_2SO_4 Biosin Xedaopen[d]	1 t ha^{-1} 1 t ha^{-1} 0.6 t ha^{-1} 150 cc hL^{-1} 40 kg ha^{-1}	10.6b	45.4b	11.9b	40.3a
T3	Ricin-Xed Xedaneem Pel K_2SO_4 Biosin Xedaopen	0.5 t ha^{-1} 0.5 t ha^{-1} 0.3 t ha^{-1} 75 cc hL^{-1} 40 kg ha^{-1}	11.0a	47.9a	12.3a	39.9a

[a] Organic nitrogen (N) fertilizer derived from castor seeds after oil extraction; [b] organic fertilizer obtained from Neem seeds after oil extraction; [c] organic N fertiliser used as stimulant of plant growth; [d] soil conditioner containing AMF (7 active propagules/g). All these products adopted were kindly provided by XEDA Italia s.r.l. (Forlì, IT).

Table 2. Photosynthesis rate (μmol CO2 m^{-2} s^{-1}) and chlorophyll content (as SPAD units) as affected by '*cultivar x phenological stage*' interaction ($LSDint_{Photo}$ = 0.8; $LSDint_{ChlSPAD}$ = 1.3).

Phenological stage	Photo			Chl_{SPAD}		
	Arizona	*Mondial*	*Universa*	*Arizona*	*Mondial*	*Universa*
Beginning of tuber formation	11.59	12.55	12.85	43.34	41.37	42.96
~40-50% of total final tuber mass reached	10.45	10.57	9.97	42.50	42.03	44.11
~60-70% of total final tuber mass reached	10.19	10.42	10.18	37.95	40.30	40.12

Table3. Productive traits and dry matter (DM) content as affected by '*agronomic management treatment x cultivar*' interaction. Different letters within each column indicate significant differences (LSD test, $P \leq 0.05$).

Agronomic management treatment	Cultivar	2016			2017		
		MTW (g)	MY(t ha^{-1})	DM (%)	MTW (g)	MY(t ha^{-1})	DM (%)
T1	*Arizona*	52d	10.5e	17.1c	59f	30.6d	18.0d
	Mondial	52d	11.1e	18.1b	88d	33.3c	19.5b
	Universa	77b	7.9f	16.0e	135a	54.4a	16.3f
T2	*Arizona*	79b	17.9c	16.5d	68e	29.9d	18.7c
	Mondial	61c	17.5c	18.0bb	68e	28.7d	19.9a
	Universa	107a	15.0d	16.6cd	128b	53.5a	17.1e
T3	*Arizona*	101a	25.3a	16.3d	68e	43.1b	18.5c
	Mondial	78b	17.5c	19.2a	69e	33.2c	20.1a
	Universa	110a	18.9b	18.0b	106c	44.7b	18.0d

Conclusions

On the whole, the AMF application at sowing deserves specific consideration due to its phenological and yield potential under organic farming, as reported especially in the growing seasons with unfavourable meteorological conditions to 'early' crop potato growth. In addition, such agronomic management treatment also allows the halving of the organic fertilizers supply with undoubted economic and environmental advantages.

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Accumulation Of Heavy Metals And Response Of Wild Plant Species Grown In The Urban Area Of Palermo City (Italy)

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Introduction

In recent years, pollution from heavy metals has drawn attention in terms of risk to the environment and public health. Urban areas are known to be the main source of contaminants due to the high polluting emissions from various human activities and vehicular traffic (Wiseman et al., 2013; Zereini et al., 2007). Particularly worrying in built-up areas is an increase in air pollution due to numerous heavy metals, such as Co, Ni, Cu, Zn, As, Mo, Cd, Pb, and Hg. The ability of plants to absorb such elements in their tissues may be used as a method to monitor heavy-metal levels in urban soils (Malizia et al., 2012; Elekes et al., 2010). However, the effectiveness of this method is based on the sensitivity of a given species to a pollutant. The aims of this study were to evaluate the concentrations of heavy metals in the soil-plant system along the main road axis of the city of Palermo, within which two road sections were identified with different traffic intensity levels. Some spontaneous herbaceous species that vegetate along the road corridor of this road axis (urban area) and its extension towards the outermost area of the city (peri-urban area) have been monitored, in order to increase the knowledge on this vegetation for monitoring environmental impact on heavy metals in urban and peri-urban context.

Materials and Methods

The research was performed in 2017 in the city of Palermo. The sampling sites were identified randomly in two areas: one close to the urban area (Viale Regione Siciliana) and the other near the peri-urban area of Palermo (Tommaso Natale). The wild native herbaceous plants most commonly found at the sampling stations were *Plantago lanceolata* L., *Sorghum halepense L.*, *Verbascum sinuatum L.*, and *Daucus carota L.* Soil and plant samples taken at both sampling sites were subjected to chemical analysis at the Department of Food and Environmental Sciences of the University of Messina. The samples were subjected to a mineralization process executed using HNO_3 (65%) and H_2O_2 (30%) (JTBacker, Milan, Italy), using a closed belt microwave digestion system (Ethos 1, Milestone, Bergamo, Italy) equipped with sensors for temperature and pressure control. The determination of the elements in the samples was performed using ICAP-MS spectrometer of iCAPQ (Thermo Scientific, Waltham, MA), equipped with an ASX520 autosampler (Cetac Technologies Inc., Omaha, NE, USA). The sampling was carried out in the last week of May 2017. The concentrations of heavy metals measured on the plant tissues of the species were compared with those published in an integrated study in the EU "Soil pollution by heavy metals" (PE-SO 89.5a, Strasbourg 24 April 1989). For measurements performed on the soils, instead, reference was made to the legal limits established by Legislative Decree 152/2006, in order to verify whether the concentrations identified were within the Community regulatory limits.

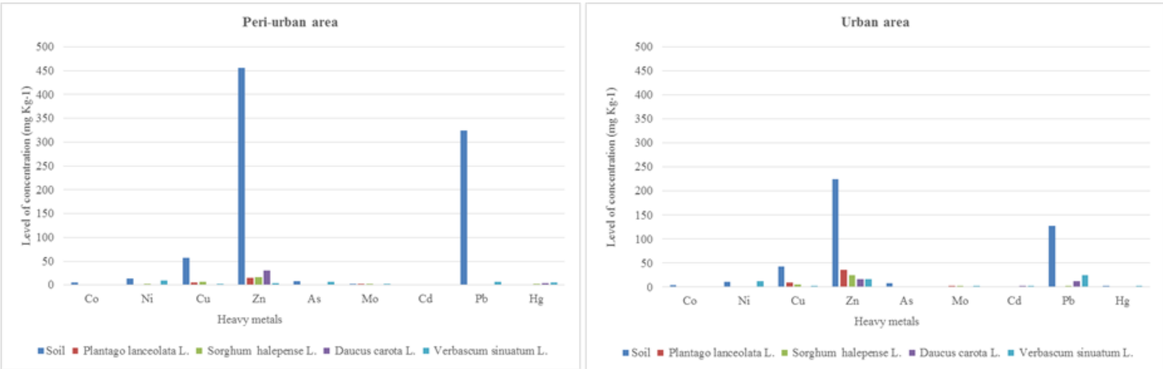
Results

Soils analyses showed a similar trend between the two study areas, with a high concentration of Zn, followed by Pb, Cu, and Ni. The soil taken in the peri-urban area showed higher concentrations than the soil taken in the urban area. Considering the level of risk of heavy metals of Italian Legislative Decree 152/2006, the Zn was the most common element (455,30 and 224,21 mg kg^{-1} in the urban and peri-urban areas, respectively), followed by Pb and Hg (Fig. 1). The concentration levels of Zn, Pb, and Hg found in both soils were higher than those expected in the Legislative Decree 152/2006, especially in the peri-urban area. The trend of heavy metals in plant tissues of samples of *P. lanceolata* L., taken from the two sites followed the same dynamics: Zn> Cu> Mo> Cd> Pb> Ni> Hg> Co. The most accumulated element in the tissues was Zn (36.31 – 14.82 mg kg^{-1}), followed by Cu (9.39 – 5.16 mg kg^{-1}), Mo (2.25 – 2, 20 mg kg^{-1}), Cd (1.66 – 1.60 mg kg^{-1}), Pb (1.37 – 1.22 mg kg^{-1}), while for the other elements (Ni, As, Hg, and Co) values were of about 1 mg kg^{-1}. It should be noted that for Zn, Cu, and Ni the highest values in *P. lanceolata* L. were found in the samples taken in the urban area where the concentrations of Zn in the soil were lower than those observed in the soils of the peri-urban area. In the case of *S. halepense* L., the trend in the concentration of heavy metals in tissues, in both samples taken in urban and peri-urban areas, showed the same dynamics: Zn> Cu> Hg> Ni> Mo> Cd> Pb> Co> As, with higher values in the tissues of the species taken in urban areas. In the case of *V. sinuatum* L., the concentration of the elements in its tissues, in both samples taken in urban and peri-urban areas, showed the same dynamics: Pb> Zn> Ni> Cd> Cu> Hg, with higher values in tissues of the species taken in the peri-urban area. In the case of *D. carota* L., the concentration of the elements in its tissues, in both samples taken in urban and peri-urban areas, showed the same dynamics: Zn> Pb> Hg> Cd> Co> Ni> Cu> Mo> As. The concentration values of heavy metals detected in the plant tissues of the four species, compared with the values reported in the EU study "Soil pollution by heavy metals" all fall within the threshold of the common values except for the Hg whose values, in all the species examined, exceed critical values (0.5 – 1 mg kg^{-1}).

Figure 1 - Concentration levels of heavy metals in plant tissues and soil in peri-urban and urban area.

Conclusions

The concentration values found in the soils of the present study showed higher concentrations in the peri-urban area compared to the urban area. In terms of environmental risk, the Zn was the most common element, followed by Pb and Hg. The environmental monitoring carried out with the four wild native herbaceous plants was interesting, highlighting variations in the selective absorption of heavy metals. In particular, the study shows that *V. sinuatum* L. has a good storage capacity of Pb, Zn, Ni, and Hg. *P. lanceolata* L. and *S. halepense* L. for Zn and Cu. *D. carota* L. for the Zn and the Pb. Critical values were found for Hg in all four species.



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Intraspecific Variability Of *Cynara Cardunculus* L. Seed Germination Across Domesticated And Wild Varieties

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Introduction

Cynara cardunculus L. is a perennial species native to Mediterranean basin. It comprises two botanical varieties *C. cardunculus* L. var. *altilis* DC. (domestic cardoon) and *C. cardunculus* L. var. *sylvestris* Lam. (wild cardoon), considered to be the wild ancestor of globe artichoke, *C. cardunculus* var. *scolymus* (L.) Fiori [1,2,3]. It sprouts at the end of summer, remains as winter leaf rosette in autumn, with a stem elongation in spring, full blossom in early summer, fruits ripening in summer and fully dried aerial biomass in late summer. As a result of this cycle, seed germination capability during a precise time window represents a crucial trait to select in agronomical lines, while tolerance to abiotic stresses is of prominent importance for Mediterranean crops exposed to vulnerable climate. Here we analysed the seed germination behaviour of domesticated and wild *C. cardunculus* varieties through a range of drought stress, dormancy induction and oxidative stress.

Materials and Methods

Wild cardoon, domestic cardoon and globe artichoke mature achenes were from CNR ISAFOM Bank of Cynara germplasm. To test the effects of oxidative stress on germination behaviour, seeds were sowed at Constant Temperature (CT) of 15 °C in presence of H_2O_2 at concentrations of 0, 0.4, 0.8 and 1.2M (Sigma Aldrich, Italy). Moreover, in order to observe any correlation between oxidative stress preservation and seed dormancy induction, achenes were incubated at alternating temperatures (AT) of 10/20 °C with concentrations of 0, 2.5, 5, 10, and 20mM of N-acetyl-cysteine (NAC) (Sigma Aldrich, Italy), which is a powerful antioxidant [4] and ROS scavenger [5]. Furthermore, the drought stress effect on seed germination was investigated sowing achenes at 10/20 °C with osmotic potential of -0.15, -0.3, -0.6, and -0.9MPa using Poly-Ethylene-Glycol (PEG) (Sigma Aldrich, Italy).

Results

Seed germination of wild and domesticated *Cynara carduncululus* varieties showed a clear differentiation where wild cardoon exhibited seed dormancy at constant temperatures, while domestic cardoon and artichoke varieties showed always a ready germination (Fig.1A and B).

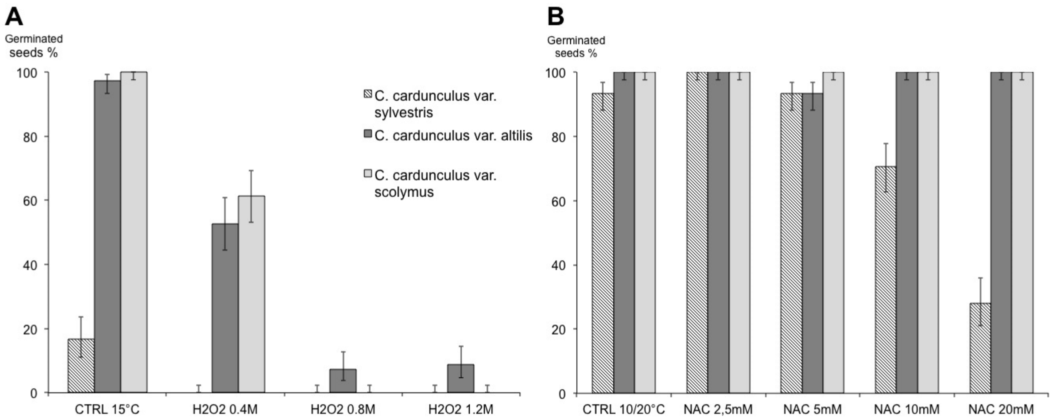

Fig. 1. Seed germination of wild and domesticated cardoon under (**A**) increasing oxidative stress (H_2O_2: 0.4M, 0.8M, and 1.2M) sowed at 15°C, and (**B**) subjected to dormancy induction (NAC: 2.5, 5, 10, and 20mM) conditions.

Alternating regimes allowed full germination in wild cardoon, while it appeared to be more sensible to hydrogen peroxide addition (Fig.1A). Oxidative stress lowered the germination performances in all the varieties, but cardoon was able to germinate at maximum stress conditions. N-acetyl-cysteine addition significantly affected germination only for wild accession, while domesticated lines exhibited normal performances (Fig.1B).

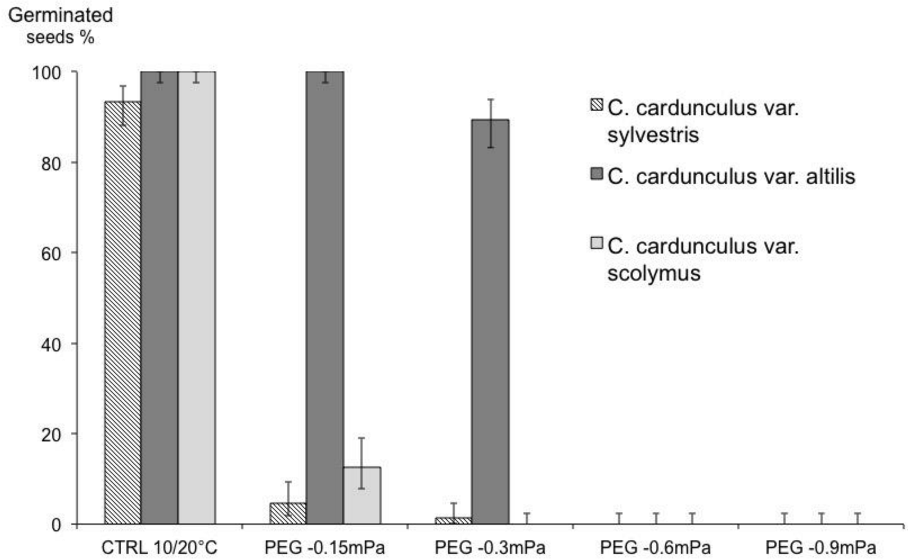

Fig. 2. Seed germination of wild (*C. cardunculus* var. *sylvestris*) and domesticated (*C. cardunculus* var. *altilis* and *scolymus*) under increasing drought stress (PEG: 0.15, 0.3, 0.6, and 0.9MPa) conditions.

Drought stress, even at lower concentration of PEG, resulted in a significant reduction of seed germination both in wild and in artichoke varieties, while domestic cardoon germination decreased drastically only at higher PEG concentrations (Fig.2).

Conclusions

Across the wild and domesticated varieties of *C. cardunculus*, only wild cardoon showed dormancy trait retention. In this variety, temperature alternation resulted in dormancy relief, while addition of NAC produced a dormancy induction. On the other hand, across the domesticated varieties domestic cardoon showed the best performances even in presence of drought and oxidative stress. These findings are of primary importance for genetic trait selection towards abiotic stresses tolerance and plant line quality assessment in *C. cardunculus* species.

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The Life Regenerate Project: Revitalizing Multifunctional Mediterranean Agrosilvopastoral Systems Using Dynamic And Profitable Operational Practices

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Introduction

The Quercus-based silvopastoral systems of the Mediterranean basin are recognized as priority by the "Habitats" Directive 92/43/EEC (type 6310 ''Dehesas with evergreen Quercus spp"). These systems are declining because of both abandonment and intensification trends (Sales-Baptista et al., 2016). Grazing practices could inhibit the tree regeneration processes thus compromising their long-term preservation (Rossetti and Bagella, 2014). Some studies evidence that the profitability of these systems is also under threat (e.g. Escribano et al., 2018). There are clear needs to transform current production systems and to identify alternative sources of income, to recycle the local resources, to stimulate natural tree regeneration, to improve soil fertility and increase farm productivity, so that these systems can become economically and environmentally sustainable.

The main objective of the LIFE Regenerate project (http://regenerate.eu/) is to provide ground evidence that silvopastoral farms can become self-sufficient and profitable relying on resource efficiency principles and incorporating in the farm income the added value of local products, and to upscale results to a wider scale. The project will take place in two phases: the demonstration and the replication activities. In this abstract, the experimental design set up of the Italian demonstration site is reported. The experimental hypothesis is that multiple species and multi-paddock grazing can be more effective than current grazing systems in supporting the biodiversity and ecosystem services in wooded grasslands.

Methods

In Italy, the demonstration activities are carried out at the "Elighes Uttiosos" farm, in Santu Lussurgiu (Sardinia, Italy, 40°8'N, 8°35'E). The main farm activity is the beef cattle and goats breeding. The farm consists of two distinct areas located at 850 m a.s.l. and 400 m a.s.l. Grazing of cattle and goats is organized on the basis of a seasonal short-transhumance among the two main plots.

Evolving from the actual grazing management, a grazing management based on the Adaptive Multi Paddock (AMP) system (e.g. Teague et al., 2011) will be adopted. A group of 5/6 cattle and 15/20 goats will be selected as experimental units. The AMP rotational grazing will be conducted in the mountain area (Figure 1a) from June to December and the hill area (Figure 1b) from January to June. The AMP grazing will be compared with a business as usual grazing scheme on both areas, according to their land use (*dehesa* type and permanent grassland). These areas will be grazed continuously during the grazing season.

Expected Results

The AMP rotational grazing applied within the framework of the LIFE-Regenerate project was designed to demonstrate the potential beneficial effects of AMP rotational grazing on: soil carbon sequestration, water retention capacity, soil nutrient availability, microbiota, and prevention of water erosion; pasture production and botanical composition, ultimately aiming to assure farm self-sufficiency in animal feeding and a higher profitability of livestock-raising practices; plant biodiversity and ecosystem services provision.

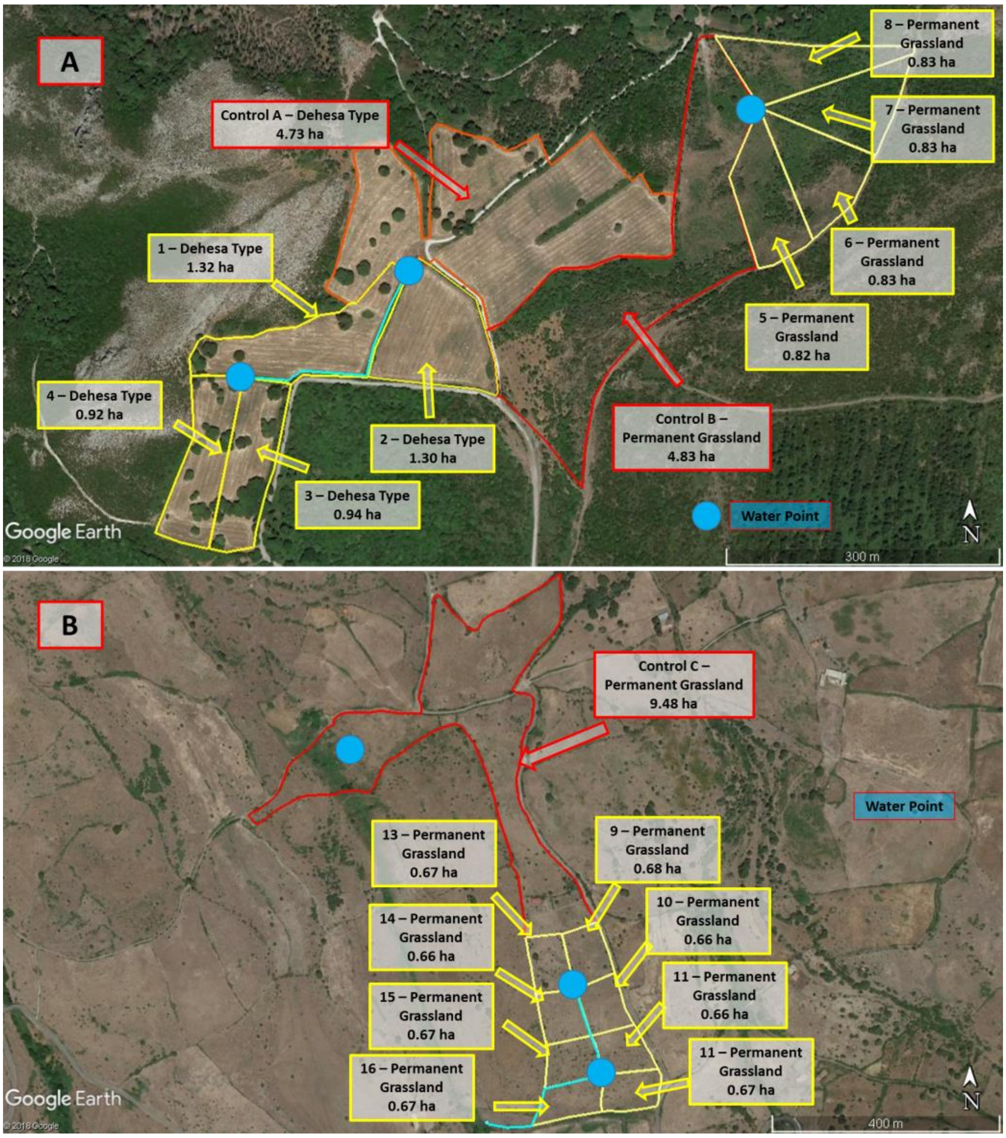

Figure 1. Experimental design of the trial at the Sardinian Demonstration Site ("Elighes Uttiosos" Farm) in the mountain (A) and valley (B) area. The yellow plots represent the Adaptive Multi Paddock (ADP) plots, while the red ones represent the control.

Acknowledgments

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Agronomic Assessment Of Durum Wheat Genotypes Cultivated Under Organic System In A Mediterranean Area

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Introduction

Durum wheat (*Triticum turgidum* L. spp. *durum*) is the most widespread crop in the Mediterranean area. An important increment of the areas cultivated under organic farming system has been observed in the last years. In Italy, the size of organic durum wheat areas increased by 44.7% in 2016, compared with the previous year (www.sinab.it) as consumers have become more aware of healthy and safe food produced with low environmental impact. The quality of organic durum wheat depends on the agronomic choices that must be dictated by the need to prevent the factors limiting production, including competition with weeds, the attack of pathogens and improve the efficiency of nutrient use. For these reasons, the choice of genotypes to be cultivated is crucial and must fall, properly, on genotypes well adapted to the cultivation environment and tolerant to the main biotic and abiotic stresses. In general, the production of durum wheat under organic farming conditions is lower than that obtained in conventional agronomic systems due to the lower nitrogen supply (Fagnano et al. 2012). These results suggest the importance of genotype selection for adaptability to organic farming. Furthermore, grain quality is strongly influenced by environment and genotype x environment interactions. The aim of this study was to compare modern and old durum wheat genotypes in order to evaluate their suitability to be grown under organic farming conditions in Mediterranean areas.

Materials and Methods

The study was conducted at field scale during the 2016-17 growing season. Six modern cultivars (Lesina, Natal, Nadif, Saragolla, Iride, Svevo) and eight old durum wheat cultivars and landraces (Russello, Scorsanera, Biancuccia, Timilia, Margherito, Perciasacchi, Madonie, Cappelli), were grown under organic cropping systems at Foggia, in Italy (41°29'02.4"N 15°33'41.0"E). The experiment was arranged in a completely randomized design with three replicates. Fertilization has been done at sowing (50 kg ha^{-1}of organic fertilizer with 14.5% N) and at booting (7 kg ha^{-1} of organic fertilizer with 4% N). At physiological maturity, grain yield and thousand kernel weight were determined. Moreover, the morphometric analysis of kernels (grain roundness, length, width and thickness) was performed by using the SeedCount SC5000 Image Analysis System (Next Instruments Pty Ltd, New South Wales Australia). Finally, protein content and yellow index were determined by using the Infratec 1241 Grain Analyzer (Foss) while gluten index was estimated using the Glutomatic 2200 (Perten). The differences among the means were determined by Tukey's honest significance difference post hoc tests. Cluster analysis (Ward's methods) was used to find truly homogeneous groups of genotypes. To compare differences among clusters, ANOVA and Tukey's tests were used for all continuous variables (5% probability level).

Results

The cluster analysis was performed using all traits analyzed (yield, quality and morphometric parameters) for the 14 genotypes under study identifying three clusters (Figure 1). Cluster 1 comprises the genotypes Biancuccia, Russello, Timilia, Scorsonera and Madonie that are typical old Sicilian durum wheat landraces; cluster 2 comprise five modern genotypes Iride, Natal, Saragolla, Svevo and Nadif and cluster 3 comprises three old landraces, Margherito, Senatore Cappelli and Perciasacchi and one modern cultivar, Lesina. In this last group, Margherito and Senatore Cappelli derive genetically from the same North African population (De Cillis, 1927), while Lesina contains in its genetic background a significant proportion of Senatore Cappelli.

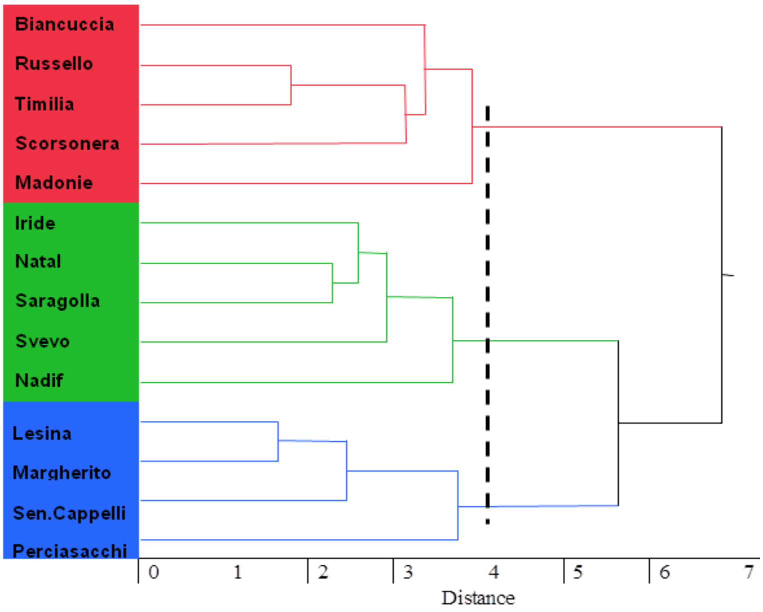

Figure 1 - Dendrogram constructed from the cluster analysis

As a result of this analysis, the mean of each parameter as well as the significance level of the ANOVA for each variable were represented by each cluster in table 1. The three clusters did not show significant differences for the grain yield confirming that under organic crop system old and modern genotypes have similar yield performance. The cluster 1, comprising old Sicilian durum wheat genotypes landraces, associated to good yield performance (2.34 t ha^{-1}), had also the highest protein content (17% d.m.), grain roundness and whole seed dimension demonstrating high suitability to be grown under organic condition in Mediterranean areas.

The cluster 3, comprising three old and one modern genotype, was characterized by higher grain yield, thousand kernel weight and width mean but the lowest protein content (15 % d.m.). Finally, cluster 2 comprising five modern genotypes was characterized by the highest gluten and yellow index as consequence of 20th century breeding activity (De Santis et al., 2017).

Table 1 - Analysis of variances (ANOVA) results performed on all qualitative parameters and different cluster groups

Parameter	Cluster 1 (n=5)	Cluster 2 (n=5)	Cluster 3 (n=4)
Grain yield (t ha^{-1})	2.34 ^{a}	2.22 ^{a}	2.40 ^{a}
Thousand kernel weight (g)	42.70 ^{b}	45.38 ^{b}	54.47 ^{a}
Gluten index (-)	13.28 ^{b}	45.02 ^{a}	22.00 ^{b}
Yellow index (-)	5.78 ^{b}	7.86 ^{a}	6.37 ^{ab}
Protein (% d.m.)	17.14 ^{a}	15.62 ^{b}	15.07 ^{b}
Roundness (mm)	0.60 ^{a}	0.59 ^{ab}	0.58 ^{b}
Length Mean (mm)	6.88 ^{b}	7.08 ^{b}	7.70 ^{b}
Width Mean (mm)	3.14 ^{b}	3.28 ^{ab}	3.32 ^{a}
Thickness Mean (mm)	2.94 ^{a}	3.00 ^{a}	3.05 ^{a}
Whole Seeds (mm)	602.60 ^{a}	563.46 ^{a}	470.65 ^{b}

Conclusion

The fourteen genotypes investigated showed a different behavior under organic cropping system. In particular, the old genotypes seem to show a greater adaptability to organic cultivation. No significant differences were found among the three cluster groups for grain yield while cluster 1 showed the highest protein content values, with Madonie showing also the best technological performance.

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Yield And Competitive Ability Against Weeds Of Mixtures Between Old And Modern Wheat Varieties

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Introduction

Durum wheat is the keystone of the agro-ecosystems in the arable land of the Mediterranean environments and an important part of its area falls within organic farms. For this crop competition exerted by weeds for the use of resources (natural and auxiliary) can determine drastic yield and quality reductions (Ruisi et al., 2015). In organic farming such critical issue is often addressed through a remodelling of several techniques such as soil tillage management, sowing time, plant density and genotype choice. With regard to the latter, there is a growing interest by organic farmers towards the old varieties as they, compared to the modern varieties, have a definitely greater competitive weed abilities thanks to some morpho-physiological plant traits (establishment speed, tillering capacity, plant height) (Röös et al., 2018); moreover, the old varieties/landraces are often characterized by a greater protein and gluten content and for peculiar sensory properties (Newton et al., 2010; Vita et al., 2016). On the other hand, the new varieties have a much higher production potential and technological characteristics of the grain often more responsive to the needs of the processing industry (De Vita et al., 2007). This study, carried out in a organic farming system, aimed to answer the following questions: 1) can the mixture of old and modern durum wheat varieties offer advantages over the monovarietal crop, combining the qualities of the different genotypes? 2) Which mixing ratio should be used in order to maximize the potential advantages of the mixture?

Materials and Methods

The experiment was conducted during the 2016/2017 growing season at the experimental farm Pietranera, located about 30 km north of Agrigento, Italy (37°32’N, 13°31’E; 178 m above sea level). The soil has a clay texture (518 g kg^{-1} clay, 217 g kg^{-1} silt, and 265 g kg^{-1} sand; pH 8.2; 20.5 g kg^{-1} total carbon; and 1.17g kg^{-1} total nitrogen), and is classified as a Vertic haploxerepts. The climate of the experimental site is semiarid Mediterranean; during the growing season annual rainfall was 555 mm mostly in the autumn/winter (September-February; 85%) and in the spring (March-June; 15%). The mean air temperatures was 16.7 °C in autumn, 9.8 °C in winter, and 16.9 °C in spring.

The experiment was set up in a randomized block design with six replications. The size of each plot was 1.5 × 6.0 m (8 rows, spaced at 0.18 m). Plots were planted with 4 genotypes of durum wheat (2 old Sicilian genotypes [O]: Scorsonera and Perciasacchi; 2 modern varieties [M]: Iride and Simeto) that varied widely in their morpho-phenological traits. Twelve different binary mixtures (1 old and 1 modern genotype) with three substitutive intercropping ratios (25:75, 50:50 and 75:25) and four pure stands were evaluated. Here, for brevity, only the average data of the two old varieties, the two modern varieties, and their four mixing combinations are reported. The previous crop was berseem clover (*Trifolium alexandrinum* L.). Before the experiment began, the soil was plowed in August and harrowed after the first autumn rainfalls. Organic nitrogen fertilizer (N =11%, C/N = 3.64) was applied before sowing at 400 kg ha^{-1}. Plots were sown at the end of December, using 400 viable seeds m^{-2}. No weed and fungal diseases control was performed. At maturity, grain yield and aboveground weeds biomass were recorded. Nitrogen contents were determined in the grain flour using the Dumas methods. The data recorded and those derived from them were submitted to the analysis of the variance according to the experimental design. Treatment means were compared using Tukey's test ($P \le 0.05$).

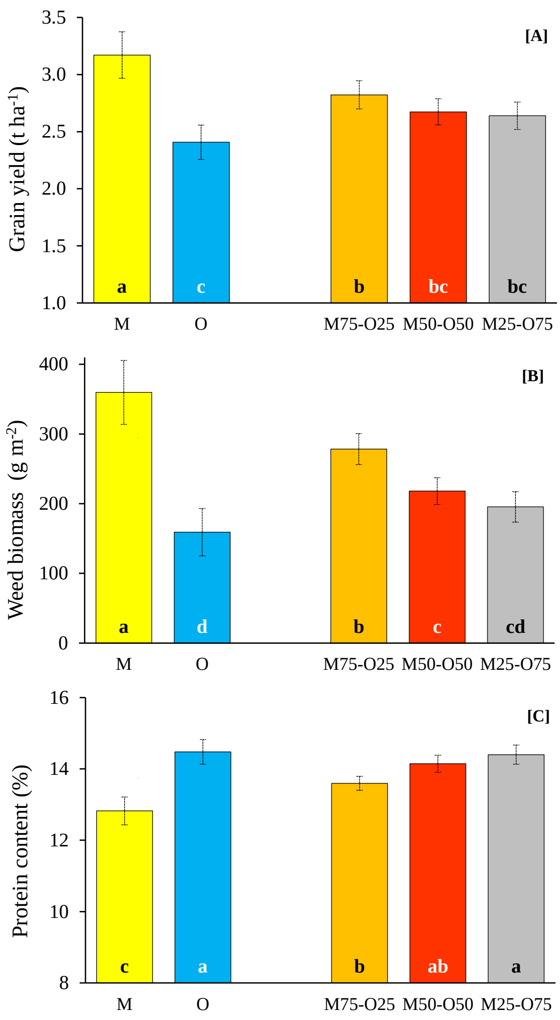

Fig. 9. Grain yield (A), weed biomass (B) and grain protein content (C). Mean values ± s.e.. M, modern varieties; O, old varieties; M75-O25, M50-O50 and M25-O75 indicate the mixtures between modern and old varieties and the percentage of each component. Different letters at the base of the histograms indicate significant differences at P<0.05.

Results

The old varieties, compared to the modern ones, showed a lower grain yield (on average, 2.41 *vs* 3.17 t ha^{-1}; Fig. 1A). Grain yields obtained with binary mixtures were proportionally reduced as the incidence of the old genotypes increased in the mixture (by 10, 16 and 18% compared to the average of modern varieties).

The weed biomass at wheat harvest was 1.59 t ha^{-1} in the pure crops of old genotypes and 3.61 t ha^{-1} in modern varieties (Fig. 1B). The competitiveness against weeds of the mixtures increased as the old varieties presence increased, so that in the mixture M25-O75 the weed biomass was statistically the same as the average of the pure crop of the old varieties.

Lastly, as expected, the grain protein content of the old varieties was significantly higher than the modern ones. (14.5 *vs* 12.8%; Fig. 1C). It is interesting to note that even when the incidence of the old genotypes was equal to 50%, the grain protein content was not significantly different to that observed in the pure stand of the old varieties.

Conclusions

The preliminary results of this study have shown that, in organic farming, wheat variety mixtures can represent a valid alternative to the monovarietal crops. In fact, the yield decreases were counterbalanced by: 1) a reduction in the incidence of weeds with obvious benefits for subsequent crops and for the efficiency and sustainability of the entire crop system and 2) the achievement of good grain quality. The latter assumes a particular relevance as often the organic cereal production is characterized by a low protein content and not suitable for the manufacture of high quality processed products.

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Nitrogen Transfer Is Enhanced By AMF Fungi In A Faba Bean/Wheat Intercropping

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Introduction

Intercropping is an agricultural practice that can offer several benefits allowing a better native resources use efficiency and, consequently, a restraint of the auxiliary inputs and often a greater production compared to the monocultures (Brooker et al. 2015). Several authors observed that, in a legume/non-legume mixture, one of the benefits could be the N transfer (up to 80 % of the non-legume N demand; Thilakarathna et al. 2016). The transfer may occur via different pathways: legume rhizodeposition, plant tissue decomposition and direct transfer through arbuscular mycorrhizal fungi (AMF) (Bedoussac et al. 2015). The latter, can simultaneously establish symbiotic relationship with different plant species creating a common mycorrhizal network, which serve as a preferential pathway for exchange among plants (He et al. 2003). However, contrasting results have been reported about the contribution of the AMF on N transfer; for instance, Li et al. (2009) showed that N transfer from mung bean to rice increased from 5.4% to 15.7% due to hyphal linkage, whereas Ikram et al. (1994) showed no significant differences with or without AMF inoculum. This experiment aimed to investigate the role of AMF on N transfer from faba bean to durum wheat grown in mixture, using the stem ^{15}N injecting method.

Materials and Methods

Durum wheat and faba bean in intercropping in presence (+MYC) or absence (–MYC) of AMF have been grown in pot in semi-protected conditions (natural temperature, light and air humidity but protected from atmospheric precipitations). Each treatment was replicated 5 times and the experiment was set up in a completely randomized design. Each pot (d=20 cm; h=50 cm) was filled with 14 kg of a substrate consisting of 30% agricultural perlite (1-2 mm diam.) and 70% of 2 mm sieved agricultural soil (486 g kg^{-1} sand, 247 g kg^{-1} silt, 267 g kg^{-1} clay; 10.8 g kg^{-1} organic matter, pH 8; 0.86 g kg^{-1} total N; 65 ppm P_2O_5; 135 ppm K_2O). The substrate was heat sterilized at 130 °C for 72 hours. Before the substrate sterilization, the natural soil microbial community except AMF was extracted (through filtration of a soil suspension with a 11 μm filter mesh) and added to all pots after sowing. The sowing was done on mid-January; the final density was 6 plants for wheat and 1 plant for faba bean per pot. At the sowing the AMF inoculum was applied in the +MYC treatment using a mix of 8 AMF species (equally present), at the density of 2000 spores pot^{-1}. Simultaneously, the original soil community extracted (excluded AMF) was added in all pots (320 ml of solution pot^{-1}). To evaluate the N-transfer from faba bean to wheat, the faba bean plants have been enriched with ^{15}N using the stem injection method (Chalk et al. 2002): NH_4NO_3 (enriched with 98 atom % of ^{15}N) was directly injected in the faba bean stem in 3 equal applications (55, 66 and 73 DAE) of 200 µl each at the concentration of 115 mM, for a total of 1.925 mg N/pot^{-1}. During the experiment, the soil moisture was continuously maintained above 70% of the holding capacity. At wheat flowering (85 DAE), the aboveground biomass was harvested, oven dried, and ^{15}N content was determined using a Roboprep-CN and 20-20 isotope ratio mass spectrometer. A root sample was stained using the method described by Phillips and Hayman (1970) and the percentage of AMF root colonization (Giovannetti and Mosse, 1980) was determined. The ^{15}N content was used to quantify the N transfer through the direct labelling plant method (Ledgard et al. 1985).

Results

In the inoculated pots (+MYC) the AMF root colonization was 30.3% in durum wheat and 64.4% in faba bean, whereas in –MYC pots root colonization of both species was always lower than 5%. Nitrogen transfer from faba bean to wheat was detected both with and without AMF inoculum. The presence of AMF significantly increased the percentage of faba bean N transferred to the cereal as well as the %N in the wheat directly derived from faba bean (Fig. 1A and 1B). The amount of N transferred from legume to the non-legume was 2.46 and 2.94 mg pot^{-1} in –MYC and +MYC, respectively (P<0.1; Fig. 1C).

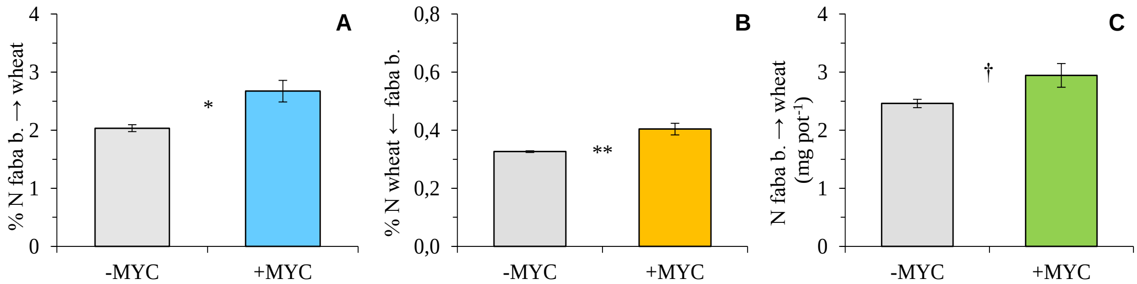

Fig. 1. A) Percentage of N transferred from faba bean to wheat; B) percentage of wheat N derived from the faba bean; and C) amount of N transferred from faba bean to wheat in absence (–MYC) or presence (+MYC) of AMF. †, *, ** P value < 0.1, 0.05, 0.01 respectively.

Conclusions

Results highlighted, thanks also to the method used (^{15}N labelling via stem injection) particularly sensitive and yield-independent (Ledgard et al. 1985), the occurrence of N transfer from faba bean to wheat even if the magnitude of N transferred was relatively low. The short growing period (85 days) and the relatively short time from labelling to harvest may have contributed to the low values of N transfer. Inoculation with AMF increased by 20% the amount of N transferred from faba bean to wheat. This effect can be ascribed to the roots linked by common mycorrhizal networks between the intercropped species, facilitating the N movement from the legume to the associated non-legume crop. Furthermore, AMF can favor the non-legume intercropped species by improving the acquisition of N released by root exudates and mineralization of legume nodules and fine root. In addition, AMF could also have contributed to N transfer indirectly by stimulating the activity of soil bacteria involved in the mineralization processes of plant tissues and nodules. Overall, this experiment confirms that AM symbiosis can have an important ecological role since it can positively drive the biological interactions among neighboring plants by promoting nutrient exchanges and thus limiting competition among plants for the available resources. A deeper comprehension of the importance of each pathway involved in the AMF mediated N transfer is essential to accurately defining management strategies of the soil-plant system to improve this important ecological process. This will require new and creative research approaches.

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Biodynamic Priming: Seed Bath In Preparation 500

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Introduction

Biodynamic agriculture, developed by Rudolf Steiner in 30's, is a system similar to organic farming. The Biodynamic techniques includes hints of homeopathy and organic farming following lunar and astrological influences on soil and plant growth (Masson, 2011). These practices aim to maintain soil fertility, the plants in good health and improve quality and yield. One of the practices is based on the use of the Biodynamic preparation 500 for seed soaking as an hydropriming technique. This technique is used to stimulate seed germination and the growth of more vigorous roots. The objective of this experiment was to highlight the effectiveness of seed bath with preparation 500 on quantitative and qualitative parameters of germination and to test the homeopathic effects using different concentrations.

Materials and methods

The experiment was carried out in the laboratory of seed analysis of CREA-DC in Palermo. The cow horn manure, known as preparation 500, is made by filling a cow horn with cow manure and burying it in the soil for about 6 months. For this research was used a preparation 500 bought by agribioshop (Dogliani - CN - Italy). It was diluted in water to reach 1‰ concentration and dynamized (von Wistinghausen et al. 2009). The dynamization is done during one hour by stirring the solution and making a vortex deep enough to see the bottom of the container and afterward reversing the stirring direction to break the vortex and make a new one. Similarly, a dynamized preparation with a concentration of 1% of cow horn manure (x10) was prepared. Two hundred seeds of cucumber (*Cucumis sativus*), melon (*Cucumis melo*) and carrot (*Daucus carota*) were soaked for an hour in distilled water (H_2O), in the dynamized preparation (Bio), in the 10x dynamized preparation (Bio x 10) or left unsoaked as control (Test), to test the effect of water hydropriming and of different homeopathic concentration. For each species and treatment, four replicates of 25 seeds were placed in Petri dishes on germination paper (carrot) or pleated paper (cucumber and melon). Seeds were allowed to germinate at the condition (temperature, light, humidity, substrate etc.). and for the time stated by official seeds analysis methods (ISTA,2006). Seeds were considered germinated only when radicles and cotyledons were fully formed. The seedlings with short, thick and spiral formed hypocotyls and a stunted primary root were considered as abnormally germinated (ISTA, 2006). The number of germinated seeds was recorded every day along with plantlet fresh and dry weight and their hypocotyl and root lengths (only for cucumber and melon). At the end of the trial, germination and dry weight percentage and mean germination time (MGT) were also calculated. MGT was determined according to the following formula: $MGT = \Sigma(g\times d)/G$ where g is the number of seeds germinated on day d and G is the total number of germinated seeds at the end of the germination trial. A completely randomized design was performed. For each species, data represent the mean of four replicated samples for each treatment. Statistical analyses were performed using ANOVA and the means were separated according to Duncan's Multiple Range Test at a significance level of 0.05.

Results

The biodynamic priming treatment with preparation 500 did not influenced the percentage of germination of cucumber, melon and carrot seeds (Fig. 1).

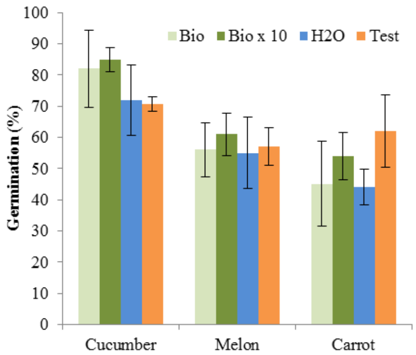

Fig. 1 - Percentage of germination.

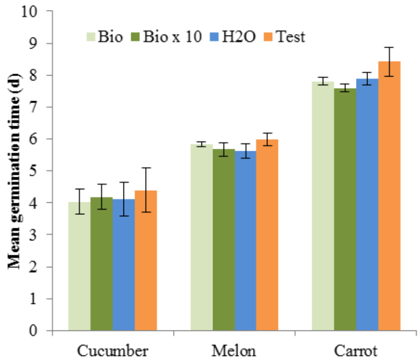

Fig. 2 - Mean germination time.

Similarly, the MGT of cucurbits was not affected by the seed baths, while unsoaked carrot seeds had a significantly longer MGT than soaked seeds (Fig. 2).
The morphological characteristics of germinated seeds were also evaluated. The fresh weight of seedlings (Fig. 3) showed variation due to treatments only in cucumber; the seeds treated with the biodynamic priming produced seedlings with a significantly higher fresh weight than untreated seeds. Nevertheless, cucumber seeds soaked in H_2O showed no significant differences with both preparation 500 treatments and with test. Dry matter percentage (Fig. 4) was affected by treatments only in cucumber seedlings that had a significant lower dry matter percentage when soaked in the biodynamic baths.
Significant variations due to treatments were also found in cucumber hypocotyls and roots, that showed an increase in their length when the seeds were soaked in the biodynamic baths (Fig. 5).

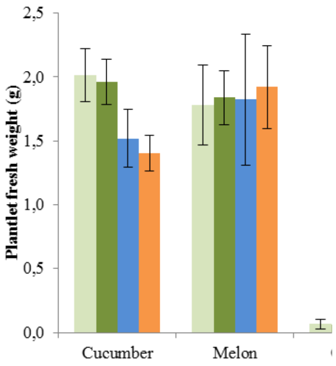

Fig. 3 – Seedling fresh weight.

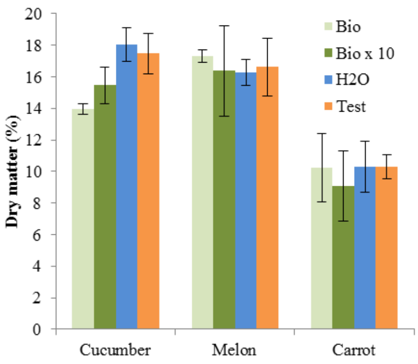

Fig. 4 – Seedling dry matter.

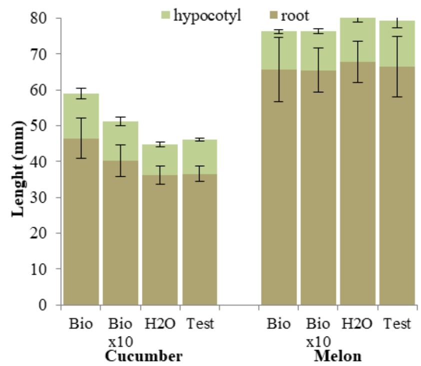

Fig. 5 – Length of root and hypocotil.

Conclusions

The use of preparation 500 for seed biodynamic priming did not prove to be effective in enhancing the germination of cucumber, melon and carrot seeds. The variation recorded were often due to a general effect of water soaking more than to the biodynamic preparation even if used at the higher dose.

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Comunicazioni orali

“Agricoltura per altri servizi ecosistemici”

Allelopathic Effect Of *Cynara cardunculus* Leaf Extracts On The Seedling Growth Of Two Cosmopolitan Weed Species

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Introduction

In order to find new eco-friendly strategies for weed control, the scientific community is increasing its interest towards the manipulation of allelopathic mechanisms. In the last years, the C_3 Asteraceae species *Cynara cardunculus* L. was studied for its allelopathic activity (Scavo et al. 2017; 2018), determined by sesquiterpene lactones such as cynaropicrin, aguerin B and grosheimin (Rial et al., 2014) and polyphenols such as chlorogenic acid, luteolin- and apigenin derivatives. The aim of this study was to evaluate the phytotoxic activity of globe artichoke [var. *scolymus* (L.) Fiori], cultivated cardoon (var. *altilis* DC.), and wild cardoon [var. *sylvestris* (Lamk) Fiori] leaf aqueous extracts on the seedling growth of two cosmopolitan weed species (*Amaranthus retroflexus* L. and *Portulaca oleracea* L.). In addition, the autoallelopathic effect on wild cardoon was investigated too.

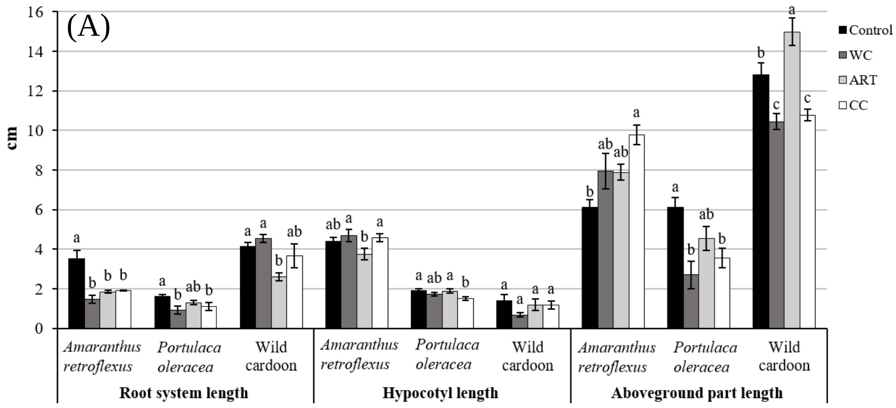
Materials and Methods

Fresh leaves of globe artichoke 'Violetto di Sicilia' (ART), cultivated 'Verde de Peralta' (CC) and wild cardoon ecotype 'Marsala' (WC) at the 25th visible leaves growth stage were sampled, randomly, in the Catania University experimental station farm situated in Catania Plain. Leaves from each botanical variety were washed, cut, ground and soaked with bidistilled water at 25°C in the dark. Then, the mixtures were filtered through filter paper to eliminate the solid fraction and, from these solutions, the 80% dilutions were obtained for each botanical variety. Each extract was compared using distilled water as control (C). Growth tests were carried out in a completely randomized block design into 8 x 10 cm plastic pots. The substrate was a mixture fine sand/peat (50:50), with the addition of expanded clay (Combo) 8/15 mm, and the pots were moistened with 50 mL of extract, with others 25 mL added during controls. The pots were stored inside growth chambers at the optimal conditions of temperature and photoperiod for single weed species tested. Root system length (cm), hypocotyl length (cm), aboveground part length (cm) and total dry weight (mg) were measured. All data were subjected to ANOVA and means separated with Duncan's test at the 0.05 probability level.

Results

The influence of *C. cardunculus* leaf aqueous extracts on the seedling growth of weed species under study and the autoallelopathic effect on wild cardoon is shown in Fig. 1A. Our data on root system length revealed that all extracts had a better performance in *Amarantus retroflexus* where the length was reduced about 50% as compared to the control, while in both *Portulaca oleracea* and wild cardoon the effect was extract-dependent. In particular, on the former the extracts obtained by WC and CC were more efficient than ART and C extracts, on the contrary on wild cardoon only the ART extract revealed a negative response. Similarly, it was found on the hypocotyl length of *Amarantus retroflexus*. The least effective with 22% of reduction of hypocotyl length was reported in *Portulaca oleracea*, while no statistical differences were recorded on wild cardoon. Therefore, the root system length was relatively more sensitive to autotoxic allelochemicals than was hypocotyl length. These results agree with findings of Turk and Tawaha (2002), who reported that water extracts of allelopathic plants had more pronounced effects on radicle growth than on hypocotyl growth. Regarding the aboveground part length, the allelopathic effect was more pronounced as revealed in all studied species. Statistical differences were observed in both weed species, mainly in *Portulaca oleracea*, where cardoon extracts showed an inhibition of about 51% as compared to the control. In *Amarantus retroflexus* leaf aqueous extracts favoured the aboveground part length, as well as in wild cardoon treated with ART extract.

Similar trend was noted for the total dry weight, where the ART extract revealed the highest level in wild cardoon (Fig. 1B). The variability of *C. cardunculus* leaf aqueous extracts here observed might be attributed both to the different combination of allelochemicals profile present in each extract and their level. Our hypothesis is corroborated by Ambika (2013), who found as a compound may be inhibitory at high concentration, stimulatory at low concentration, or have no effect at other concentrations.



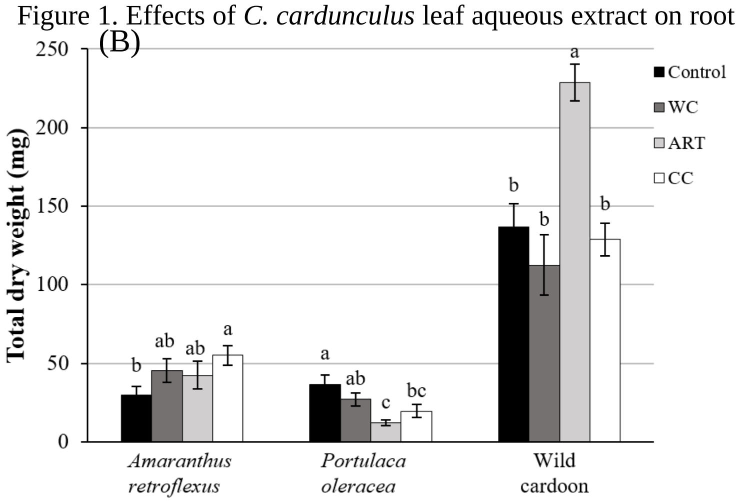


Figure 1. Effects of *C. cardunculus* leaf aqueous extract on root system length, hypocotyl length, aboveground part length (A) and total dry weight (B) of *Amaranthus retroflexus, Portulaca oleracea* and wild cardoon. WC: wild cardoon extract; ART: globe artichoke extract; CC: cultivated cardoon extract. Different letters for each parameter indicate statistical significance for $P \leq 0.05$.

Conclusions

The present study exploited the allelopathic effect of leaf aqueous extracts of *C. cardunculus* on two cosmopolitan weeds, as well autoallelopathic effect on wild cardoon. Overall, the inhibitory effect was extract-dependent, even if different behaviour was observed on the considered weed species. Nevertheless, the inhibitory activity revealed by our data could be used as a potential natural herbicide resource.

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Effect Of Innovative Organic And Organo-mineral Fertilizers On Yield Of Triticale Cultivated In Northern Italy

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Introduction

Biomass production for bioenergy purpose is increasing, especially as feedstock for biogas plant. Biogas crops shall be tolerant to biotic and abiotic stresses and be able to grow with low nutrient input (Scholz and Ellerbrock, 2002). Triticale is characterized by a high genetic potential yield and nutritive properties, thus it could be a very promising crop for biogas purpose (Horlein and Valentine, 1995).
Biomasses are mainly used in the biogas plant to produce green energy and a by-product called digestate is also obtained. Following the concept of circular economy, the identification of innovative organic fertilizers based on by-products might represents a strategic objective to increase the agricultural sustainability.
The fertilizing efficacy of digestates has been demonstrated (Möller and Müller 2012); however, to the author's knowledge there is scarce information in the literature on fertilizers obtained using digestate. Starting from these considerations, a study was set up to obtain and assess new fertilizers, enhancing digestates coming from biogas plants. The new fertilizers were assessed in triticale production and quality in Po Valley.

Materials and Methods

The investigation was carried out through field trial set in Reggio Emilia (44°47'31.2"N latitude 10°29'52.0"E longitude and altitude of 55 m a.s.l.), Italy, during the production season 2016/17. The trial was set in random complete block design with three replications. Two new experimental fertilizers were tested: organic fertilizer (pelleting solid digestate) (PELLET) and organo-mineral fertilizer with organic fraction contributed by the solid digestate (OMD). The two innovative fertilizers were compared with three controls: commercial organo-mineral fertilizer (COM), synthetic fertilizer (urea) (SYN) and zero fertilization (CTRL0). The digestate and the new fertilizers were chemically characterized by the protocols AOAC Official Methods of Analysis. Triticale (× *Triticosecale* Wittmark) cv. Tarzan was sowed in the end of October. Weeds and pests were controlled according to the cultivation protocols of the Emilia-Romagna Region, Italy. The amount of N supply was based on soil analysis, crop rotation and crop nutrients required. Fertilizers were applied following calculation of N balance to reach the same quantity of total nitrogen (100 N kg ha^{-1}). Harvest of triticale was carried out during dough and full ripe grain stages to record the main agronomical parameters. The treatments were separated by Bonferroni test after one-way ANOVA using GenStat 17 software.

Results

The analysis of the innovative fertilizers revealed interesting characteristics on their compositions compared to solid digestate (1.2 N - 1.0 P_2O_5 - 1.7 K_2O - 54% H2O). In fact, the pellet (1.5 N - 2.5 P_2O_5 - 2.0 K_2O - 7.8% H_2O) showed a strong reduction in content of water and greater concentration of the N-P-K, while organo-mineral fertilizer (10.0 N - 5.0 P_2O_5 - 15.0 K_2O - 7.0% H_2O) showed the same N-P-K content of the commercial one.
In general, the innovative fertilizers (PELLET and OMD) recorded values comparable with the traditional ones, showing the absence of negative effects on crop growth and yield both at the dough and full ripe grain stages (Table 1 and 2). In particular, the OMD performed better than other fertilizers in term of SPAD, total fresh weight and methane potential yield values when the crop was harvested at dough grain stage. Moreover, OMD performed as well as OMC and SYN in term of total dry weight and grain yield values at full ripe grain stage.

Table 1. Parameters recorded at dough grain stage

TREATMENT	HEIGHT (cm)		SPAD		TOTAL FRESH WEIGHT (t ha^{-1})		Nm^3 CH_4 ha^{-1}	
OMD	78.0	ab	52.8	a	42.0	a	6960.0	a
COM	85.5	a	54.0	a	39.4	a	5602.0	ab
PELLET	86.0	a	53.8	a	38.0	ab	5163.0	b
SYN	73.5	b	55.7	a	38.5	ab	5366.0	ab
CTRL0	72.0	b	43.5	b	34.0	b	4633.0	c
AVERAGE	79.0		52.0		38.4		5544.8	

Means followed by same letter do not significantly differ at P<0.05.

Table 2. Parameter recorded at full ripe grain stage

TREATMENT	HEIGHT (cm)		TOTAL DRY WEIGHT (t ha^{-1})		GRAIN YIELD (t ha^{-1})		HI
OMD	104.2	a	18.4	a	9.4	a	51.3
COM	104.0	a	18.6	a	9.1	a	48.9
PELLET	93.5	b	14.3	ab	6.9	ab	48.1
SYN	93.0	b	16.3	a	8.7	a	53.3
CTRL0	91.0	b	12.1	b	5.8	b	47.9
AVERAGE	97.1		15.9		8.0		49.9

Means followed by same letter do not significantly differ at P<0.05.

Conclusions

The results outlined interesting prospective for the use of the innovative fertilizers based on solid digestate. In fact, the innovative formulations seem to achieve agronomic performance comparable to the traditional fertilizers. The continuation of the research will be able to deepen the knowledge of innovative fertilizers, offering opportunities to valorize the digestates coming from biogas plants.

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Sunn hemp, a New Energy Catch Crop for Temperate Climates

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Introduction

According to the RED-recast (2016), it is estimated that in 2030 advanced biofuels should provide 27% of the total fuels required by the transport sector. This type of biofuels will be mostly derived from lignocellulosic biomass crops. The forecasted demand, however, will require a considerable expansion in the area dedicated to the production of lignocellulosic crops (about 100 Mha in 2050, IEA, 2011, RED-recast, 2016). In Italy it is estimated that about 4.2 Mha or one third of the national agricultural area would be needed to cope with the 2020 targets. It is therefore important to evaluate the technological and production potential of alternative crops and cropping systems that would allow to integrate the production of food and energy without land competition issues. Currently, for example traditional crop rotations leave the soil bare for several months, therefore it is possible to intensify the land use through the introduction of lignocellulosic catch crops. According to Dubois (2011), appropriate biofuel crops should have, among others, the following characteristics: i) fast growing rates, ii) high biomass yield, iii) high adaptability to current agricultural production systems, iv) high adaptability to adverse environmental and soil conditions, and iv) resistance to pests. Sunn hemp (*Crotalaria juncea*) is an interesting leguminous catch crop with nematocidal effects (Rotar and Joy, 1983; Yoshida 1995). Sunn hemp is not present in the European cropping systems, therefore, preliminary studies aimed at identifying its suitability and its specific agronomic requirements. The objective of this study was to characterize the productivity of two sunn hemp varieties under northern Italian conditions within a maize - wheat rotation.

Materials and Methods

The productive and physiological performance of two sunn hemp varieties (Ecofix and Crescent Sunn) was evaluated at 79 (HR1), 90 (HR2) and 105 (HR3) days after sowing (DAS), representing the beginning of flowering, full flowering, and the beginning of seedpod formation, respectively. Twenty four plots (2 varieties x 3 harvest times x 4 repetitions) of 5.4.x 8 m were arranged in a strip plot design. Sowing was carried out on 26 June 2017 after wheat harvest. Due to the extraordinary dry and hot 2017 summer season with temperatures above the seasonal average, five supplemental irrigations were applied. Biometric and productive parameters were evaluated in an area of 2 and 3 m^2, respectively at the corresponding harvesting dates (79, 90 and 105 DAS). At each harvest time, total green leaf area was measured with a leaf area meter (LI-3000; LI-COR, Lincoln, Nebraska, USA). Prior to each harvest, light interception (Sunfleck Ceptometer; Decagon, Pullman,WA), midday CO_2 gas exchange (CIRAS-2; PP-Systems, UK), and chlorophyll fluorescence (Handy PEA, Hansatech, UK) were measured. Biomass components and shoot dry matter were determined by oven drying to a constant mass at 105 ºC at the corresponding harvest dates.

Results

The two varieties tested here showed similar emergence rates; in both cases it was completed at 12 DAS. Moreover, plant height and biomass yields were similar between both varieties. Plant height, however, continued to increase from the beginning of flowering (HR1) till the beginning of seedpod formation stage (HR3). On the other hand, maximum biomass yield was reached between full flowering (HR2) and HR3. The mean biomass yield at these growth stages was 8.9 Mg ha^{-1}, that is 41% higher than at the beginning of flowering (HR1). As for the canopy cover, in terms of LAI and light interception, both parameters did not show differences between harvest times but only between varieties. The Ecofix variety showed 58 and 64% higher LAI and light

interception than Crescent Sunn, probably due to the higher total number of leaves, especially at the last two harvesting dates.
Even though no significant differences in photosynthesis and related parameters were found between both varieties, the trends with time were somehow opposed. In the case of the Ecofix variety the leaf gas exchange parameters tended to decrease towards the seedpod formation stage, suggesting an earlier senescence of this variety. Whereas in the case of Crescent Sunn, the photosynthetic rates were relatively stable at each sampling period. Moreover the photosynthetic efficiency, in terms of maximum quantum yield and photosynthetic performance index, tended to increase towards the end of the growing season in Crescent Sunn while remained constant on the case of Ecofix.

Conclusions

The agricultural sector is called to take action to find solutions capable of guaranteeing large quantities of lignocellulosic biomass for energy production purposes in a rational and sustainable manner without negatively affecting the main role of agriculture to supply food. An effective way to do that could be through the development of integrated cropping systems, where promising new catch crops could be introduced alongside traditional crop rotations, thus allowing on the one hand to increase crop diversification, and on the other, to increase the efficiency of land use in a sustainable manner. It has been shown in this study that sunn hemp, besides being a leguminous species with probable positive effects on the soil fertility, can arrive to produce acceptable levels of dry biomass in a relatively short time, especially if it is harvested at the full flowering (90 DAS). Even though the two varieties tested here appeared to respond differently to the harvest time, with Crescent sunn apparently being more suitable for late harvesting and Ecofix achieving maximum production at full flowering, both varieties were well suited (in morphological, physiological and productive terms) to the local pedoclimatic conditions. Therefore, it could preliminarily said that the best harvest time to maximize productivity is at full flowering (about 15 days earlier than the beginning of seedpod formation), which may render logistically feasible the cultivation of sunn hemp in between a traditional wheat - maize rotation.

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Modeling Camelina (*Camelina sativa* L. Crantz): A Promising New Multipurpose Oilseed Crop

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Introduction

Camelina (*Camelina sativa* L. Crantz) is a short-season oilseed crop belonging to the *Brassicaceae* family, native of Eurasia (Larsson, 2013). Recently the interest in this species has been highly increasing due to its wide environmental adaptability and to the versatile portfolio of biobased products sourced from its seeds (Berti et al., 2016; Zanetti et al., 2017). Furthermore, the cultivation of spring camelina biotypes as a winter crop, with a wheat-like cycle, demonstrated high yield potential (Berti et al., 2011; Schillinger et al., 2012; Masella et al., 2014) associated to many environmental benefits (e.g., protection from soil erosion, soil organic C (SOC) sequestration, reduction of nitrate percolation, provision of a food source for pollinators) in mild winter areas of the Mediterranean basin. The unique agronomic traits of camelina, together with its intrinsic capability of achieving sustained yields even in marginal land, led the European Commission to fund research projects targeting the development of integrated camelina-based supply chains across Europe (e.g. COSMOS, MAGIC, ITAKA, etc). As a consequence, this has pushed the demand for mid-term trend analyses of camelina productivity across Mediterranean countries, especially in light of changing climatic conditions. Biophysical models represent effective tools to tackle all these questions, due to their capability in reproducing interactions between plant, weather, soil and crop management, while performing in-silico experiments to carry out scenario analyses in current and future climatic conditions. In this context, the aim of the present study was to develop and evaluate a new model for the dynamic simulation of camelina production, oil and fatty acid accumulation in the seeds.

Materials and Methods

Ten plot trials were established at the experimental farm of the University of Bologna (44°54'N, 11°40'E) between spring 2015 and summer 2017, including both autumn and spring sowing dates. All the trials were rainfed and the spring camelina line Midas (Linnaeus Plant Science, Canada) was grown in all plots. Climatic data were recorded by a weather station located at the experimental farm. In all trials main phenological phases, total aboveground biomass at harvest (ABG), seed yield (SY), seed weight (TKW), seed oil content (SO) and fatty acid composition of oil (FA) were surveyed. The modeling solution (MS) developed for this study is composed by three interdependent models, targeting the simulation of crop development and growth, soil water dynamics and seed oil quality. The site-specific input data needed to feed the MS were organized in three information layers related to weather, farming practices and soil properties. The simulation of phenology, ABG and SY formation was carried out by the WOFOST_GTC model (Gilardelli et al., 2016). Soil water redistribution, evaporation and root water uptake were estimated using the UNIMI. SoilW component. The dynamic simulation of seed oil quality was performed via a logistic approach grounded on development stage code for SO and via enzymatic kinetic model based on Michaelis-Menten et al. (1913) for FA. The calibration of MS was performed automatically using the relative root mean square error (RRMSE) between simulated and observed data as objective function. Model performances were evaluated using mean absolute error (MAE, min. and opt. 0, max. +∞), RRMSE (min. and opt. = 0%; max. = + ∞), modelling efficiency (EF, -∞ ÷ 1, opt. =1) and coefficient of determination (R^2, 0÷1, opt. =1).

Results

Values of calibration and validation indices are presented in Table 1. Average errors in estimating emergence (EM), flowering (FL) and maturity (MA) dates were 8, 5 and 7 days respectively, with RRMSE ranging from 4.7% (MA) to 5.6% (EM) and EF values higher than 0.94 in all cases but one (MA). The simulation of growth variables confirmed the model ability in reproducing the inter-annual variability of field measurements (average MAE=0.62 t ha^{-1}; RRMSE=15.98%; EF=0.82; R^2=0.84), with best results achieved for final seed yield, as the model was able to explain 83-85% of the SY variability, with RMSE and MAE of 8.9% 0.15 kg ha^{-1} respectively. Although the overall goodness of fit was slightly penalized by the simulation of ABG, values of statistical indices were in line with literature data (Confalonieri et al., 2009; Gilardelli et al., 2016). The overall accuracy in simulating crop development and the dry weight of storage organs laid the basis for a correct simulation of seed oil quality, since the model herein presented is grounded on crop phenology and on seed weight estimation. Results denoted logistic and kinetic models ability to reproduce SO (EF=0.96; R^2=0.97) and FA composition (0.65<EF<0.85; 0.71<R^2<0.96) at maturity, with reduced error from stearic (RRMSE=12.23%) to linolenic acid content (RRMSE=8.6%). This proved the ability of the MS in modulating productivity and seed oil quality in response to the pedo-climatic conditions characterizing the crop cycle during the vegetative and ripening phases.

Table 1. Model performances in reproducing phenology, growth and seed oil quality.

Variable	Statistical indices			
	MAE (days*, kg ha^{-1})	RRMSE (%)	EF (-)	R^2(-)
	Phenology			
Emergence	8.30*	5.57	0.99	0.99
Flowering	5.10*	5.24	0.94	0.97
Maturity	6.80*	4.70	0.54	0.99
	Growth			
ABG	1.10	23.06	0.81	0.83
Yield	0.15	8.91	0.83	0.85
	Seed oil quality			
Seed oil content	29.62	3.96	0.96	0.97
Stearic acid	2.63	12.23	0.68	0.71
Oleic acid	13.00	11.68	0.83	0.85
Linoleic acid	17.20	11.96	0.74	0.81
Linolenic acid	22.23	8.60	0.85	0.96
Eicosenoic acid	10.76	11.36	0.65	0.76

Conclusions

This work presents a new model, specific for camelina, with high level of adherence between the real canopy, growth and seed quality dynamics and their model representation. The inclusion of dedicated algorithms for the evaluation of seed quality extended the potential for MS application as an integrated supporting tool to evaluate the competitiveness and sustainability of camelina-based cropping systems across different combination of management and agro-climatic conditions.

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Effects Of Soil And Water Salinity In A Sorghum Pot Experiment

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Introduction

Salinity is associated with reduced water availability because of the drop in soil water potential. Under salt stress, sorghum can lower leaf water potential to maintain water uptake and cell hydration, resulting in osmotic adjustment (Yang et al., 1990; Weimberg et al., 1984). The objective of this investigation was to determine the effects on sorghum growth and leaf water status at varying levels of soil and water salinity.

Materials and methods

The experiment was carried out in a greenhouse at DISTAL, University of Bologna, for 103 days from May to September 2017. *Sorghum bicolor* cv. Bulldozer (fibre sorghum) was cultivated in 7 L pots filled with a sandy soil (sand, 80%), previously sieved and mixed with salt (NaCl) to obtain three soil treatments: control with no salt (Ctrl), low (LSS) and high (HSS) soil salinity corresponding to a respective EC_e of 3 and 6 dS m^{-1}. Three salt concentrations of the irrigation water were established: control (Ctrl), low (LWS) and high (HWS) level of water salinity. In the first half of the experiment LWS and HWS were set at a respective EC_w of 2 and 4 dS m^{-1}, then at a respective 4 and 8 dS m^{-1}. Water was supplied manually, with an amount determined on gravimetric base. Half of the pots were kept at a soil moisture not exceeding the field capacity, to avoid percolation and salt leaching (No SL). The other half were over-irrigated to allow water drainage and, thereby, salt leaching (SL). The amount of drained water was assessed, and samples were taken for analysis. The three combined factors, soil and water salinity and salt leaching, were arranged in a completely randomized design with three replications, totalling 54 pots.

***Plant growth*.** Plant height, basal stem diameter and leaf number were weekly measured. At harvest, shoots were cut and weighed. Roots were separated from soil and weighed. Shoots and roots samples were oven-dried at 60 °C to determine the dry weight of plant organs and their sum. The root to shoot ratio (R:S) was also assessed.

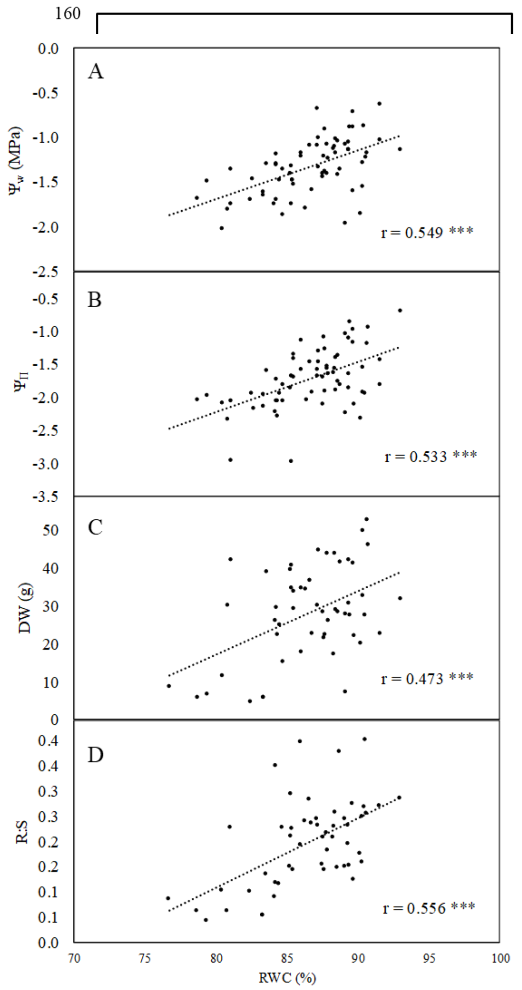
***Water status*.** Leaf water potential (ψ_w) and its components, osmotic potential (ψ_π) and turgor potential (ψ_T) were assessed in the uppermost fully expanded leaf before harvesting, *through a dewpoint potentiometer (WP4C, Decagon Devices). Relative water content (RWC) was also determined on the same leaf, based on Morgan's (1984) procedure.* Leaf osmotic adjustment (OA) was calculated according to Wilson et al. (1979). The bulk volumetric elastic module (ϵ) was calculated following the procedure of Steudle et al. (1977). Water use efficiency (WUE) was determined at the end of the growth cycle, dividing the total dry weight by the cumulated water consumption.

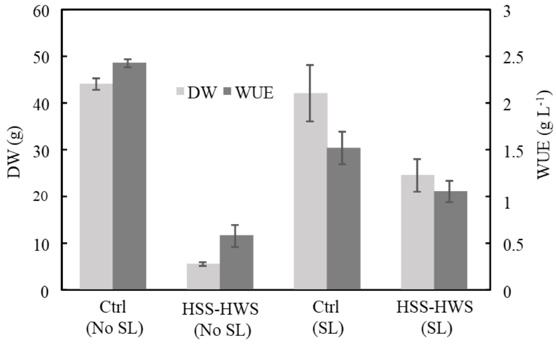
***Statistics*.** Data were submitted to a three-way ANOVA, using the LSD test to separate levels in significant sources.

Results

Plant growth. Plant height (Fig. 1) and, to a lesser extent, basal stem diameter and leaf number (not shown) decreased at increasing EC_e and EC_w during plant growth. This reduction was significantly mitigated by SL, irrespective of the soil and water salinity levels.

Total dry weight (DW) decreased at increasing EC_e and EC_w (Fig. 2). Water supply exceeding field capacity was uninfluential on DW under no soil and water salinity (Ctrl). Conversely, SL promoted higher DW accumulation under HSS+HWS, resulting in a mitigation of salinity effects.





L), Figure 2. Total dry weight (DW) and water use efficiency (WUE) in the same four treatments as Figure 1.

Although several studies recorded increased WUE under mild drought and salinity stress (Steduto et al, 1997; Bressan et al., 2016), a serious drop in WUE was observed with HSS+HWS in this study (Fig. 2). However, also in this case SL allowed WUE to be at least partially recovered.

The R:S was not significantly influenced by soil salinity, while being negatively and positively influenced by water salinity and SL, respectively (not shown). It is perceived that unfavourable soil conditions (HWS and No SL) constrained root growth more than shoot growth, affecting DW and WUE.

Water status: Salt stress induced a decrease in ψw fostering positive values of turgor potential in all the soil and water salinity treatments (not shown). Although SL did not bring significant change in ψ_π and ψ_T, the reduction of the total water potential (ψw) was significantly lower in the salt-leached treatments. At steady levels of water and soil salinity, the OA was boosted by the greater water supply in the SL treatments (not shown).

Lack of changes in ϵ with the decrease in ψw in the salt stressed treatments (not shown) indicates that salinity stress did not affect the elastic properties of sorghum leaf tissue. Conversely, RWC was found to be positively related with ψw (Fig 2.A) and its component $\psi \pi$ (Fig 2.B). This could be due to the fact that, although the plant accumulated solutes to maintain a water gradient, the amount of water absorbed in the stressed plants was lower, resulting in lower leaf water content. Alternatively, the decrease in RWC with ψw and $\psi \pi$ can be the signal of a passive concentration of solutes due to dehydration. Lastly, the positive relationships between RWC and DW (Fig. 3.C), and between RWC and R:S (Fig. 3.D) demonstrate how much plant growth (DW) and the balance between above- and below-ground portion (R:S) are associated with leaf water status.

Figure 3. Relationship between: water potential and RWC (A); osmotic potential and RWC (B); dry weight and RWC (C); root to shoot ratio and RWC

Conclusions

According to the FAO Paper 29 (Ayers and Westcot, 1976) the first drop in productivity of *S. bicolor* is expected at $EC_e > 6.8$ dS m^{-1}. In our experiment, sorghum showed a 12% DW reduction at a mere 3 dS m^{-1} of EC_e. In contrast to this, the plants managed to survive at an EC_w of 8 dS m^{-1}, a level very close to the "zero-growth EC_w" (8.7 dS m^{-1}) stated in the cited source. However, higher water supply in non-saline treatments (Ctrl (SL)) was not beneficial for DW, while being detrimental for WUE. RWC was the leaf trait more closely associated with morphological (height, stem diameter and leaf number) and biomass (DW and R:S) traits.

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Analyses Of Spontaneous Vegetation For A Detailed Characterization Of Soil Contamination

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Introduction

The composition of native flora can be affected by contaminated soils through a selective pressure that permits only potential toxic elements (PTEs) tolerant, "bioaccumulator" or "excluder" species to proliferate (Chowdhury et al., 2016). Changes in plant diversity are usually assessed by the application of diversity indices, the Shannon index being one of the most widely used. Phytoremediation is a technique for removing contaminants from soils or interrupting the exposure pathways that can be viewed as belonging to the general class of the bioremediation systems (Vidali, 2001). The effectiveness of this technique requires selected plants to uptake or immobilize PTEs and is linked to PTEs bioavailability in the soil. Therefore it is important to select plant species not only able to tolerate PTEs but also adapted to grow in the specific environmental conditions of the polluted sites. The aims of the present study were: (a) to assess the risks for biological communities and ecosystem due to PTEs pollution; (b) to identify the target PTEs for phytoremediation (c) to evaluate the effects of PTEs on plants diversity of the main plant communities; (d) to evaluate the potential for phytoremediation of native plant species growing on the site.

Materials and Methods

The test site was a 3.5-ha plot near an industrial plant for recycling automotive electric batteries classified by the regional authorities as contaminated, since risk analysis showed that there was a serious potential risk for workers due to inhalation or dermal contact with contaminated soil particles.

The analysis of the spontaneous vegetation that covered the site was carried out by using nine square plots (3 m x 3 m) selected according to the various vegetation types it presented. In each plot the presence/absence of the plant species, their abundance (expressed as percent cover) and overall vegetation cover was detected. The plant specimens were directly identified in the field except for dubious cases, which were later identified at the Herbarium Porticense (PORUN) according to Pignatti (1982), Pignatti *et al.* (2017) and Tutin *et al.* (1964–1980; 1993). The nomenclature follows Bartolucci *et al.* (2018) and Galasso *et al.* (2018). Within each plot, plant samples with the highest soil coverage were collected. Soil samples both from plots and from the rhizosphere of the most representative species were collected. Plants samples were separated in shoots and roots and analysed for PTEs content. Soil samples were characterized for texture, pH-H_2O, electric conductibility, organic carbon, nitrogen, carbonate content and PTEs concentrations.The bioavailable fraction of PTEs was estimated by a single extractions with DTPA solution. PTEs concentration in the solution was determined by inductively coupled plasma-atomic emission spectrometry (Perkin Elmer ICP-AES Optima 7300DV).

The parameters evaluated for each plot were: overall plant cover, total number of species and number of each species. The biodiversity indices (Shannon-Weiner index, Pielou equitability index) were calculated in each plot.

The potential Ecological Risk Index (ERI) was used for evaluating the potential risk for community diversity and richness from combined pollution of multiple PTEs (Hakanson, 1980):

$$\mathrm{ERI} = \sum_{i=1}^{n} E_r^i = \sum_{i=1}^{n} T_r^i \times C_f^i = \sum_{i=1}^{n} \left(T_r^i \times \frac{C^i}{C_n^i} \right)$$

where: E_r^i is the monomial potential ecological risk index of the PTE i; T_r^i is the toxic response factor for a specific PTE i (e.g. As=10, Cd=30, Cr=2, Cu=5, Pb=5, Tl=10 and Zn=1); C_f^i is the contamination factor of PTE

i; C^i is the content of PTE i in the samples (mg kg^{-1}), and C_n^i is the background value of PTE i in the study area (mg kg^{-1}).
The following indices were calculated for assessing the ability of plants to accumulate PTEs: bioaccumulation coefficient for shoots (BACs), bioaccumulation coefficient for roots (BAC_R) and translocation factor (TF). The BACs and BAC_R were calculated as the ratio between the concentration of PTEs in shoots and roots respectively and the concentration of PTEs in the rhizospheric soils. Translocation factor was calculated as the ratio between the concentration of PTEs in shoots and that one in roots (Baker and Brooks, 1989). For evaluating the capacity of plants to accumulate the bioavailable fractions of contaminants, a modified bioaccumulation coefficient (mBAC) was calculated for shoots and roots (Barbafieri et al., 2011) based on the bioavailable fraction of PTEs. To evaluate the presence of hyperaccumulator plants we also compared PTEs concentration in shoots with reference values given by Van der Ent et al. (2013). The statistical analyses were carried out by using MS Excel 2007 and SPSS 21. Pearson correlation analyses were made to investigate the relationships between soil factors and ecological parameters of each plot. Statistical significance in this analysis was defined at $p < 0.05$ and $p < 0.01$.

Results

The main soil factors influencing plant biodiversity were the total concentrations of PTEs while the bioavailable fraction of PTEs and other soil parameters did not affect plants diversity. The Cd, Pb and Zn concentrations were the driver of plants diversity showing a significant correlation for biodiversity and species richness (Tab. 1). The Ecological Risk Index (ERI) reported very high risk for biological communities and ecosystems in the majority of studied plots. The target PTEs according to the monomial ecological risk index were Cd and Pb. However all plant species accumulated Pb above legal PTEs thresholds in plants and all species except *A. vulgaris*, *D. viscosa* and *E. tetragonum* accumulated Cd above threshold for forage suggesting that there might be a potential transfer of pollutants to food chain, thus strengthen the necessity of a barrier to the dispersion of contaminated soil particles. From the bioaccumulation study of plant species growing on the site, *S. latifolia* was identified as a hyperaccumulator of Tl. The most frequent species on the site were *Holcus lanatus* and *Silene latifolia*, which also were well adapted to the site-specific conditions growing in very high-risk areas according to ERI. Furthermore, according to $mBAC_R$, *Holcus lanatus* for Cd and *Silene latifolia* for Pb were effective accumulating bioavailable fraction of respective PTEs.

Conclusions

Our findings indicate that the PTEs contents of the soil had negative effects on plant biodiversity (Shannon index, Pielou index and species richness). *Poaceae, Asteraceae and Fabaceae* were not influenced by the different PTEs levels, while the group of miscellaneous species resulted the best indicator of PTEs contamination. Cd and Pb were the target PTEs and most hazardous according to ERI. *H. lanatus* and *S. latifolia* were the most adapted species to soil contamination and the best candidate for phytostabilization of Cd and Pb respectively. These plant species can be used in association during the summer avoiding soil resuspension generally more intense during the dry season and protecting groundwater from pollutants leaching.

Table 1. Correlations between biodiversity markers for plant communities, ERI, pseudototal, bioavailability and other soil properties

	Shannon index	Evenness index	Species number	Poaceae	Fabaceae	Asteraeae	Miscellaneous species	Plant cover
ERI	-.84**	-.88**	-.71*	-.47	-.33	-.54	-.68*	.37
Cu***	-.58	-.53	-.58	-.33	-.33	-.55	-.47	.04
Cu DTPA***	+.20	+.21	+.14	-.01	-.22	.07	.27	-.54
Pb***	-.80**	-.84**	-.68*	-.46	-.30	-.51	-.65	.37
Pb DTPA***$^{-1}$)	-.41	-.46	-.18	+.48	-.48	-.49	-.16	-.05
Zn***	-.82**	-.79*	-.81**	-.66	-.23	-.59	-.73*	.32
Zn DTPA***	+.47	+.39	.46	-.03	-.35	.73	.39	-.47
As***	-.63	-.68	-.54	-.43	-.18	-.36	-.53	.37
As DTPA***	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cd***	-.85**	-.89**	-.72*	-.47	-.33	-.55	-.69*	.37
Cd DTPA***	-.22	-.23	-.07	.29	-.33	-.32	.01	-.32
Cr***	-.55	-.59	-.42	-.32	-.37	-.33	-.35	-.06
Cr DTPA***	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Tl***	-.13	-.07	-.09	.21	-.55	-.31	.00	-.31
Tl DTPA***	-.59	-.60	-.49	-.24	-.05	-.53	-.39	.16
Ph-H_2O	-.50	-.48	-.43	-.06	-.04	-.55	-.36	.22
EC (µS cm^{-1})	-.42	-.62	-.20	-.36	-.39	.12	-.24	.17
Carbonates (g Kg^{-1})	-.50	-.61	-.35	-.29	-.31	-.08	-.43	.41
OC (%)	+.38	+.30	+.46	.20	-.38	.56	.39	-.50
Total N (%)	+.48	+.50	+.35	-.12	-.17	.65	.25	-.29

*** mg Kg^{-1}; ** significant at the 0.01 level; * significant at the 0.05 level; n.d. = not detectable

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Poster

“Agricoltura per altri servizi ecosistemici”

Agro-Environmental Aspects Of Mycorrhizal Inoculation On Six Energy Crops Fertilized With Digestate

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Introduction

The ecosystem services provided by arbuscular mycorrhizal fungi (AMF) and the use of dedicated energy crops and digestate (as soil organic amendment and fertilizer) can be a viable possibility under the ongoing climate change. The application of organic amendments in agro-ecosystems has been widely recommended to improve the soil physical fertility and the soil carbon stock with positive fertilizer effects on crops, replacing inorganic fertilizer application with less environmental cost. Symbiotic mycorrhizal fungi, such as AMF, are a significant component of the soil microbial populations that influence soil fertility and crops yield and provide many functions, improving plants nutrition and water uptake, nutrient mobilization from organic substrates, soil carbon content, plants' resistance to abiotic stresses, soil aggregates stabilization and soil erosion reduction. The aim of this work was to evaluate the agro-environmental aspects of AMF inoculation on six energy crops fertilized with digestate liquid fraction (DLF).

Materials and Methods

The experiment has been carried out from January 2014 to March 2017 at the "L. Toniolo" experimental farm of the University of Padova at Legnaro (45° 21' N; 11° 58' E; 6 m a.s.l.), north-east Italy. Experimental design was a split-plot with AMF inoculation as the main-plot (AMF-Y = inoculated and AMF-N = un-inoculated) and crops as the sub-plots replicated four times, for a total 48 concrete growth boxes (2x2 m side) and 12 treatments. Studied plant species were *Arundo donax* L. (Giant reed), *Miscanthus x giganteus* Greef et Deu (Miscanthus), *Heliantus tuberosus* L. (Jerusalem artichokes), *Lolium perenne* L. (Lolium), *Zea mays* L. (Maize) and *Sorghum bicolor* (L.) Moench (Sorghum). The growth boxes, filled with fulvi-calcaric Cambisol soil, were installed with the top surface at 1.3 m above ground level, to avoid water table influence, and the bottom open, to allow water percolation. The DLF was distributed once a year (April 1st 2014, March 19th 2015 and April 1st 2016) at dose of 250 kg N ha^{-1} in all boxes. AMF inoculation (mix granular inoculum of *Rhizophagus intraradices*, *Funneliformis mosseae*, *Glomus etunicatum* and *G. clarum*) were carried out during sowing or plants transplanting at dose of 500 propagules m^{-2}, only in 2014 for perennial herbaceous crops, and in 2014 and 2015 for annual ones. No AMF inoculation was carried out at the beginning of 2016 crop season to evaluate the persistence and success of AMF inoculum in the experimental soil from previous two years' inoculation. Root AMF colonization was estimated according to Trouvelot (1986) in three randomly selected plants per box in June of each growing season. Plants harvest was scheduled considering plants species and meteorological conditions and dry biomass production was calculated drying it in a thermo-ventilated oven at 65 °C until constant weight. In dry biomass total Kjeldahl nitrogen and phosphorus (P) content were determined. Nitrogen (N) and P uptake were calculated as the product of nutrient concentration and dry biomass yield. Nutrient use efficiency indicates the total biomass produced per unit of nutrient absorbed, and it is expressed as the ratio of dry matter production and nutrient content (g g^{-1}). A porous ceramic plate (Ø 27 cm) was placed at 0.90 m depth in 18 boxes to collect percolation water. A total 223 percolation water samples were collected and analysed to detect ammonium nitrogen (NH_4-N) and nitric nitrogen (NO_3-N). Soil CO_2 emission was monitored in each growth box from April 2014 (1st DLF distribution) to April 2016 (3rd DLF distribution) through the static non-stationary chamber technique (Maucieri and Borin, 2017).

Results

The AMF root colonization was observed for all species, but it was variable during the experimental years, in Jerusalem artichoke it decreased from the first to third years while an opposite trend was observed for the other crops. AMF inoculation did not affect biomass production. Significant differences among crops on cumulative aboveground dry biomass production were obtained (Fig. 1). AMF inoculation, in all the studied crops, did not exert any effect on N and P biomass concentration, uptake per hectare and use efficiency. AMF treatment significantly reduced NH_4-N leaching (-32.8%) (Fig. 2a), but conversely, it increased NO_3-N leaching (+70.0%) (Fig. 2b). On species and measurements average, during the crop growing season, AMF inoculation significantly (Mann-Whitney test, $p<0.001$) increased (+23.1%) soil CO_2 emissions respect to un-inoculated plots (median value of 0.27 g CO_2 m^{-2} h^{-1}). Similarly, AMF inoculation determined a significant increase (+17.7%, $p<0.001$) respect to un-inoculated plots (median value = 1619.3 g CO_2-C) of the cumulative CO_2-C emissions at the end of the 25 monitoring months (5th May 2016).

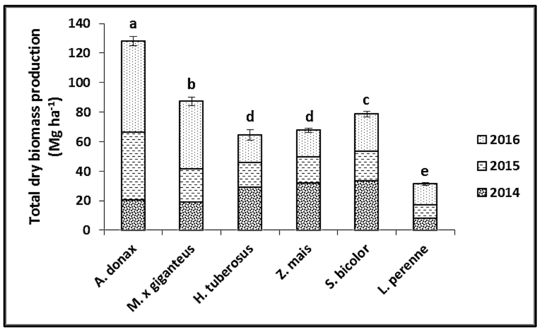

Figure 1. Crops cumulative total dry biomass production. Different letters show statistical differences at $p<0.01$ (LSD – Fisher Test).

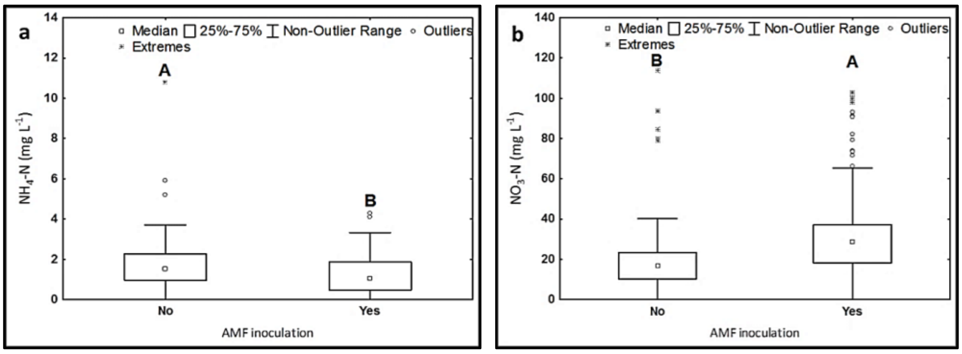

Figure 2. AMF inoculation effect on: a) NH_4-N and b) NO_3-N concentration in the water percolation. Different letters show statistical differences at $p<0.01$ and $p<0.001$(Test Mann-Whitney).

Conclusions

AMF inoculation was not able to enhance dry biomass production under studied conditions, but increased the NO_3-N leaching respect to un-inoculated plots. This last aspect makes necessary further in-depth studies considering its potential negative effect in nitrate-vulnerable areas.

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Agronomic Evaluation Of Camelina Genotypes With Improved Seed Qualitative Traits

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Introduction

Camelina [*Camelina sativa* (L.) Crantz] has recently been deeply evaluated by different EU (COSMOS, MAGIC, ITAKA, ICON, etc) and national (Ribitinnova) projects as one of the most promising new oilseed crops for Europe. In view of a peculiar fatty acid composition of its oil (Righini et al., 2016), characterized by increased content of polyunsaturated fatty acids (PUFAs), an elevate seed oil content and a limited amounts of noxious compounds, such as glucosinolates (GLS) and sinapine (Russo and Reggiani, 2017), camelina has attracted the attention not only of scientists but also food/feed/biobased industries which are looking for new raw materials. Furthermore, camelina is considered a low input species in view of limited nutrient requirements (Gesch and Cermak, 2011), resistance to common *Brassica* pests and diseases (Vollmann and Eynck, 2015), as well as tolerance to abiotic stress, such as drought (Hunsacker et al., 2013) and low temperature (Gesch and Cermak, 2011, Masella et al 2014). Recently new camelina lines with improved fatty acid composition have been released by Linnaeus Plant Science (Canada) and tested under several environmental conditions in Europe and Canada (Zanetti et al., 2017). Those lines, characterized by an increased oleic acid (C18:1) content and consequent decrease in linoleic acid (C18:2) content, show an improved omega-3/omega-6 ratio with valuable implications for biobased applications. The aim of the present study was to test the performances of these new camelina lines in comparison with a well diffused camelina line, Calena.

Materials and Methods

Camelina lines with improved seed oil compositions, namely 887 and 789-02, were grown for two consecutive years (2016 and 2017) in a side-by-side plot trial in comparison with reference camelina line, Calena, at the experimental farm of the University of Bologna (44°54’N, 11°40’E, 32 m a.s.l.). Experimental site is characterized by a silty clay loam soil and a mean annual precipitation of about 600 mm and a mean annual temperature of about 13 °C. Sowing took place on mid-March in both years and harvesting was done manually about 3 months later before the end of June. All plots were rainfed and a top-dressing application of 50 kg of N ha^{-1}, as urea, were applied before stem elongation. Main phenological stages were weekly surveyed along crop cycle. At full maturity, the central portion of each plot was manually cut and then threshed. Residual seed moisture content was determined on a representative seed sub-sample from each plot by oven drying at 105 °C; upon reaching constant moisture levels, and weighted. Seed yield, seed weight (TKW), oil and protein seed contents, fatty acid profile were determined in representative seed samples from each plot. Antinutritional compounds (GLS and sinapine) were assessed in mean representative samples obtained for each trial. In parallel, additional field trials were carried out by the CNR-IBBA in Casazza (BG) (45°44’N, 9°54’E, ~450 m a.s.l.) during 2009/10 growing season, testing only Calena in large strips, under real operational conditions, both in spring and autumn sowing. Seed yields and antinutrional contents obtained from those trials were considered as reference values for Calena under different environmental conditions.

Results

The new camelina lines, with improved fatty acid composition (887 and 789-02), were well adapted to Northern Italian climate and they were able to achieve comparable seed yields than the reference line Calena (Fig. 1). Interestingly the line 789-02 was also characterized by an increased seed oil content compared to the other two genotypes (Fig. 1), even if differences were not significant. When Calena was grown under different climatic conditions (Casazza) adequate seed yields for this line were confirmed with mean seed yield of 1.67 Mg DM ha^{-1} when sown in spring, while in autumn sowing it was able to achieve a seed yield of 2.18 Mg DM ha^{-1}. Fatty acid compositions of the new camelina lines confirmed significant differences compared to Calena (Tab. 1), in particular C18:1 content was significantly increased by 50% while C18:2 was decreased by 20% This lead the omega-3/omega-6 ratio increasing from 1.76 up to 2.23 in the new camelina lines, compared to Calena. Furthermore, the new camelina lines resulted also characterized by two additional positive features for future new feed/food applications of camelina seeds: *i*) reduced erucic acid content in the oil, *ii*) decreased GLS content (Tab. 1).

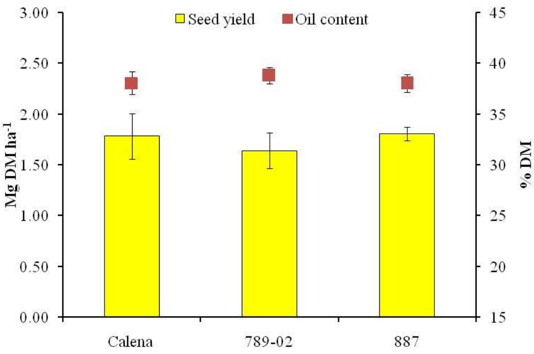

Fig. 1. Seed yield (yellow histograms) and seed oil content (red boxes) achieved by camelina line in Bologna in 2016 and 2017 screening trials. Vertical bars: standard error.

Table 1. Principal fatty acids (% DM) characterizing camelina oil and total GLS content (mmol Kg^{-1}) in the seeds. ** = $P \leq 0.01$, ns = not significant (LDS test).
[a] Antinutritional determination on Calena seeds were run on seed samples harvested in Casazza (BG).

	Principal Fatty Acids					Antinutritionals	
Cultivar	Oleic	Linoleic	Linolenic	Eicosenoic	Erucic	GLS (mmol Kg^{-1})	Sinapine (mg g^{-1})
			(% DM)				
Calena	14.2	18.3	32.2	13.9	3.5	32.0[a]	2.76[a]
789-02	20.4	15.4	32.8	13.6	2.1	26.7	3.86
887	22.3	13.7	32.0	13.7	2.3	27.7	5.00
Significance	**	**	*ns*	*ns*	**		

Conclusions

The identification of new camelina lines with improved seed qualitative traits (i.e., increased omega-3/omega-6 ratio and decreased erucic acid and GLS contents) will pave the way to further studies broadening both the possible applications of camelina oil and cake into livestock feeding diets. Furthermore, these new genetic materials will also represent a source of interesting traits for future breeding programs. Obviously, the definition of an optimized agronomic management for those lines would possibly further improve seed yield and presumably also seed quality.

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A Crop Model-Based Evaluation Of *Crotalaria juncea* Productivity Under Alternative Management Practices

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Introduction

Enhancing the multifunctionality of traditional agriculture is a key strategy to fulfill the Horizon 2020 targets. In general, traditional rotations leave the soil bare for lengthy periods, despite the chance to intensify the Land Equivalent Ratio (i.e. increase of the intensified cropping system yield compared to the sole-crop yield) by introducing fast growing, high biomass yielding crops. Sunn hemp (*Crotalaria juncea*) is a short-cycle and high yielding lignocellulosic legume crop with a great potential as a feedstock for advanced biofuels. Recent studies demonstrated that, as a cover crop, sunn hemp yielded from 7.5 to11.6 t ha^{-1} of dry matter in about 100-120 days in humid subtropical environments (Balkcom and Reeves 2005). Despite its tropical origin, sunn hemp is considered as a promising summer crop to design intensive, sustainable and multifunctional agricultural systems in European temperate climates, due to its low input requirements, its adaptability to a wide range of soils and its tolerance to water stress (Kamireddy et al. 2013). Furthermore, sunn hemp could increase crop diversification and soil fertility, while avoiding any competition with food crops. As a consequence, there is a large demand for in-depth analyses of the sustainability of integrated sunn hemp-based cropping systems (e.g. EU-BECOOL project, https://www.becoolproject.eu/) in the medium long-term. Biophysical models represent effective tools to answer these questions, due to their ability in reproducing non-linear crop responses to variable pedo-climatic and management conditions. The aim of the present study is the simulation of sunn-hemp productivity considering alternative plant density and harvest times in Northern Italy, in order to set-up a model to evaluate its suitability as potential advanced biofuels feedstock in different pedo-climatic and management contexts.

Materials and Methods

The model ARUNGRO (Stella et al., 2015) was adapted to simulate daily growth and development of sunn hemp via calibration of morpho-physiological parameters, assuming the number of stems as representative for the number of primary crop branches. A dedicated modelling solution (MS) was developed by coupling the crop model with soil water dynamics models, including the impact of agricultural operations on crop productions. The MS was then linked to a database including information on site-specific weather data, whereas soil properties and farming practices were defined according to experimental trials. The field level calibration of MS was automatically performed (multi-symplex method) using the Relative root mean square error (RRMSE) between simulated and observed data as objective function. AGB and LAI were selected as target variables for model calibration. Model performances were evaluated using RRMSE (min. and opt. = 0%; max. = + ∞), modelling efficiency (EF, -∞ ÷ 1, opt. =1) and coefficient of determination (R^2, 0÷1, opt. =1). The MS was done with field data collected from 2016 and 2017 experiments with an overall of 14 data points. The trials were carried out at the Cadriano experimental farm of the University of Bologna, (32 a.s.l., 44° 33' N, 11° 21' E). For that purpose 'Ecofix', a registered sunn hemp variety, was tested. In 2016, one sowing date (SD, 18th May) was evaluated at three harvesting times (HT, 75, 97 and 125 days after sowing, DAS) with three sowing densities (SWD, 104, 52 and 33 plants m^{-2} on 0.45 m row distance). In 2017, an early SD (26th June) was tested under three HT (79, 91, 106 DAS), and a late SD (5th July) was harvested at two different times (97 and 113 DAS). Basic agronomic parameters were measured in the two years, including phenological development, emergence rate (%), leaf area index (LAI, m^2 m^{-2}), plant height (m) and aboveground dry matter (AGB, t ha^{-1}).

Results

Figure 1 presents the performance of the ARUNGRO model as parameterized for sunn hemp and applied in six experimental trials during the 2016 and 2017 growing seasons (Figure 1a), and the overall correlation between measured and simulated AGB in the 14 available data points (Figure 1b).

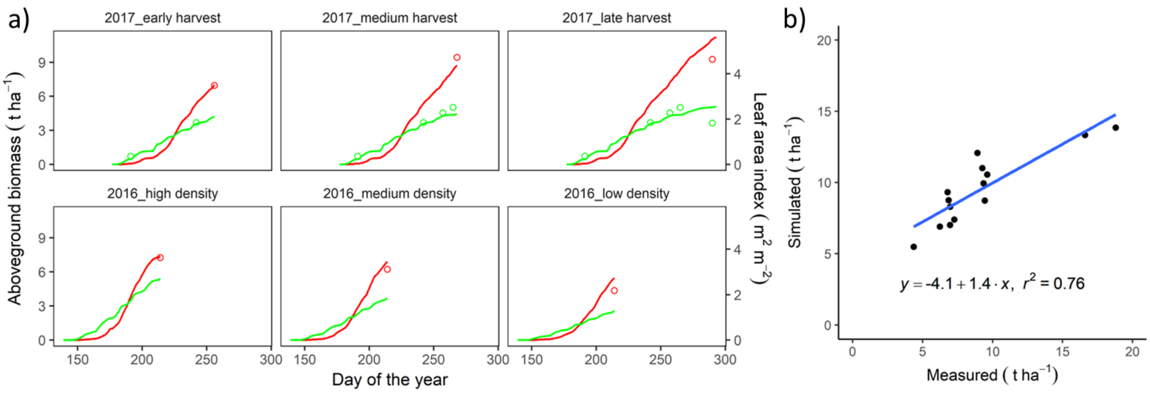

Figure 1. Dynamic simulation of aboveground biomass (red line) and leaf area index (green line, secondary y axis) as compared to field measurements (red and green circles) in two field experiments with variable harvest time (2017, Figure 1a, top charts) and sowing density (2016, Figure 1a, bottom charts); scatter plot of measured (x-axis) and simulated (y-axis) aboveground biomass in the 14 available data points (Fig. 1b).

The ARUNGRO model demonstrated its suitability in simulating AGB and LAI sunn hemp dynamics in 2017 growing season, when the crop was harvested from September 13rd (early harvest) to October 30th (late harvest). The LAI simulation denoted the model ability in reproducing field conditions, with maximum simulated and measured values around 2.5 m^2 m^{-2} (Figure 1a, top charts). When applied on datasets where different sowing densities were tested (from 33 plants m^{-2}, low density, to 104 plants m^{-2}, high density), the model coherently differentiated the growth dynamics of AGB and LAI, leading to AGB mean absolute errors of 0.65 t ha^{-1} (Figure 1a, bottom charts). When applied on the whole datasets, the model RRMSE was 23.4%, with modelling efficiency of 0.69 and an overall 76% of explained variability in measured data ($R^2 = 0.76$, $p < 0.001$).

Conclusions

Despite model improvements are needed to increase the adherence of the morphological peculiarities of sunn hemp, these results encouraged the further application of the MS in different growing environments, to provide quantitative information of the crop performances, which could be used to support the design of innovative rotations and the promotion of multifunctional agricultural systems in European temperate climates.

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The Effect Of Sowing Date And Genotype Choice On Crambe (*Crambe abyssinica*): A Promising Oilcrop For The Biobased Industry

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Introduction

Crambe (*Crambe abyssinica* Hochst x R.E. Fries) is an oilseed crop belonging to the *Brassicaceae* family, it grows spontaneously in the Mediterranean basin and its oil is characterized by a very high content of erucic acid (C22:1>55%) (Lazzeri, 1998). Thanks to the acidic composition of its oil and interesting agronomic features, i.e., low need for agronomic inputs and the tolerance to drought, crambe is currently considered a potentially sustainable crop for several biobased industrial applications (Righini et al., 2016). However, agronomic studies on this species are limited as well as the genetic material currently available (Zanetti et al., 2016), which still relays on varieties registered more than 10 years ago. The present study aims at increasing the agronomic knowledge on crambe. In particular, two field experiments were carried: in TEST 1 the interaction effect of sowing date and seeding rates was surveyed on a commercial variety of crambe called Galactica; in TEST 2 the productive performances of three recently released crambe mutant lines were compared to that of the Galactica.

Materials and Methods

The field plot trials were carried out in Cadriano (Bologna) at the experimental farm of the University of Bologna during spring 2017. In TEST 1 four sowing dates were carried out every two weeks (SD3, SD4, SD5, SD6) between 17/02/2017 and 29/03/2017. Within each date, two seeding rates were compared: high density (HD), corresponding to 220 seeds m^{-2} and inter-row of 13 cm vs. low density (LD), corresponding to 110 seeds m^{-2} and inter-row of 26 cm. In TEST 2, sowing took place on 29/03/2017, applying a density of 220 seeds m^{-2} with an inter-row of 13 cm and comparing Galactica (wild type) and three different mutant lines (M1, M2, M4). The mutant lines tested in TEST 2 were obtained by WUR (Wageningen University and Research) through chemical mutagenesis, which deactivates the functioning of the enzyme FAD2, which intervenes in the biosynthetic pathway of fatty acids catalyzing the conversion of oleic acid (C18:1) into linoleic acid (C18:2). In both trials, total biomass production, seed yield, seed weight (TKW), seed oil content and fatty acid composition of oil have been determined.

Results

In TEST 1, the ANOVA shown significant decreases in the total biomass production and the seed yield when sowing date was delayed. In particular, first and second sowing dates (SD3 and SD4) showed seed yields respectively of 2.82 and 2.63 Mg DM ha^{-1}, while SD5 reached only 2 Mg DM ha^{-1} and SD6 only 1.03 Mg DM ha^{-1}. Seeding rate, in contrast with Carlsson et al. (2007), did not show significant influence on the crambe productivity except for SD6 in which seed yield resulted higher in HD than in LD (about 40%). TKW decreased significantly and linearly in response to sowing delay, from 7.22 g in SD3 down to 4.85 g in SD6. Seed oil content differed significantly only between the first and last sowing date (36.08 vs. 31.24 % DM, SD3 vs. SD6, respectively). The positive responses in term of seed yield and seed oil content in association with anticipate sowing lead to significant higher oil production achieved in SD3 and SD4 compared to SD5 and SD6 ($P \leq 0.05$). Crambe oil profile resulted highly stable in response to sowing date, and in all the sowing dates the erucic acid content exceed 55% DM.

In TEST 2, interestingly, the crambe mutant lines showed same productive performances, in term of total biomass production, seed TKW and oil yield, compared wild type, Galactica. The only surveyed parameter that was affected by genotype choice the seed oil content, with all mutants presenting significant reductions in seed lipid content compared to Galactica (*P*≤0.05). As regards the fatty composition of oil, the mutant confirmed as expected a marked decrease in polyunsaturated fatty acids (C18:2 and C18:3) and an increase in the oleic acid content (C18:1, monounsaturated) compared to Galactica (Fig. 1). The content of erucic and eicosenoic acids showed significantly differences between M2 and M4 and Galactica. The increase in the content of one of these two fatty acids was counterbalanced by the specular decrease, in numerical terms, of the content of the other monounsaturated fatty acid- as easily understandable in the case of M4.

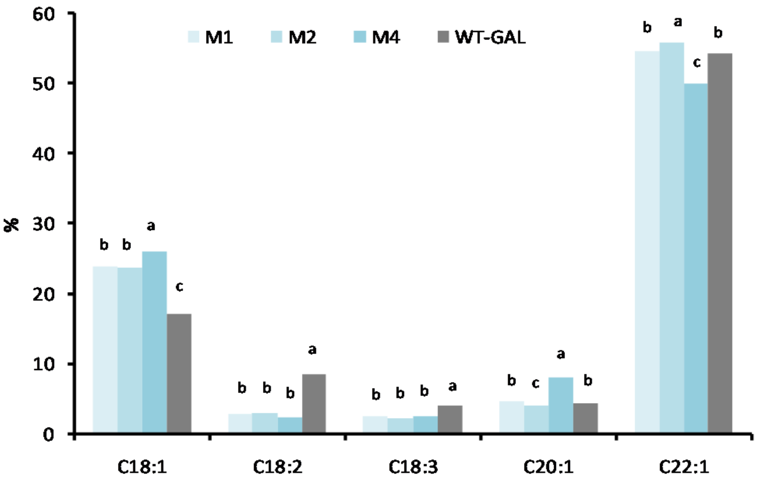

Figure 1. Main fatty acids of crambe oil in the TEST 2. Vertical bars: standard deviation. Different letters indicate statistically different values for P≤0.05 (SNK Test).

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Conclusions

Crambe confirmed to take advantages in response to anticipated sowing and its high adaptability to the northern Mediterranean climate characteristic of the Emilia Romagna region. Moreover, in light of the extreme drought, which characterized the studied growing season (-70% of usual precipitation for the study site), the aforementioned oil yields confirmed the high capacity of crambe to tolerate and satisfactory produce under water stresses. The mutant lines resulted performing similarly than Galactica. The achieved results on their fatty acid composition confirmed the stability of genetic mutation even in open field, and this would pave the way to new applications for crambe oil in the biobased industry, in relation to improved stability.

Acknowledgments

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Introduction Of Barley Hybrid And Maize At High Plant Density To Enhance Methane Production

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Introduction

In most cases the biogas plants request a feed integration with specific crops and a right combination of crops are often required to maximize the methane yield for hectare. In North Italy, the conventional cropping system for this purpose is triticale followed by maize harvested at dough stage.

The recent introduction of barley hybrids and new maize varieties could offer new opportunities for the supply chain for biogas. Barley hybrids are characterized by higher biomass yield and a lower predisposition to develop of foliar disease if compared to conventional cultivars (Muhleisen et al., 2014, Blandino et al., 2015). Recent maize hybrids are able to withstand higher plant densities and to show greater productive advantage with narrow inter-row spacing that enhance plant equidistance (Testa et al., 2016). In order to evaluate the above mentioned new introductions a research was set to compare different double cropping systems, based on winter cereals with different harvesting times followed by maize, cultivated under conventional and high plant population on yield and on methane production.

Materials and Methods

During 3 growing seasons (2014–2016), field trials were conducted in North West Italy (Carignano, TO) comparing different treatments according to a factorial design based on four cropping systems and two sowing densities. The tested cropping systems were maize (M) as single crop and maize sowing as double crop after barley (BM), triticale (TM) and common wheat (WM). Moreover, maize was sown at two different plant densities: standard density (StD: 7.5 plants m^{-2} sown at a 0.75 m wide inter-row spacing) and high density (HiD: 10 plants m-^{2} with a narrow inter-row spacing of 0.5 m). The treatments were assigned to experimental units using a split-plot design, with the cropping system as the main-plot treatment and the maize plant density as the sub-plot treatment. The experimental unit was replicated 2 times and it was represented by main-plots having a surface equal to 2000 m^2, in order to harvest the crop with conventional chopper machine.

The silage yield obtained for each crop and harvest was determined by weighing the forage harvested from all the plot surface. The specific methane yield per ton of volatile solid (VS) was measured through the biochemical methane potential (BMP) method. The methane production per hectare was calculated for each cropping system on the basis of the BMP results and the silage yield.

Results

Dough stage was reached earlier on hybrid barley compare triticale (+ 11 days) and wheat (+ 19 days). On the other hand, among winter cereals silage production was higher on wheat (14.9 t ha^{-1}), compare to triticale (13.0 t ha^{-1}) and to hybrid barley (10.3 t ha^{-1}); consequently the methane production was higher on wheat (4550 Nm^3 ha^{-1}) compare to triticale (-17%) and to hybrid barley (-28%).

As expected, the delay of sowing after wheat and, secondly, after triticale reduced the maize for silage yields: compared to the maize cultivated as single crop (21.8 t ha^{-1}) yields were on average -20%, -33% and -47% after barley, triticale and wheat, respectively. Plant density of maize affects yield but its effect was progressively less evident delating sowing time; therefore, as single crop the HiD significantly increased, on average, by 23% the silage yield compared to StD, while in the last two sowing after triticale and wheat, no significance differences were pointed out.

The analysis of cropping systems highlight that the double crop barley + maize(BM) has reached the highest biomass production (32 t ha^{-1}) and methane yield per hectare (9971 Nm^3 ha^{-1}) with a positive effect of maize at high plant density (Figure 1). This treatment showed an increase of methane production of 46% and 18%

compared to StD maize alone and triticale after maize (TM) StD, respectively. However, the use of high plant population in single maize crop system (M HiD) led to methane yield similar to the conventional system based on double-crop system triticale + maize (TM StD).

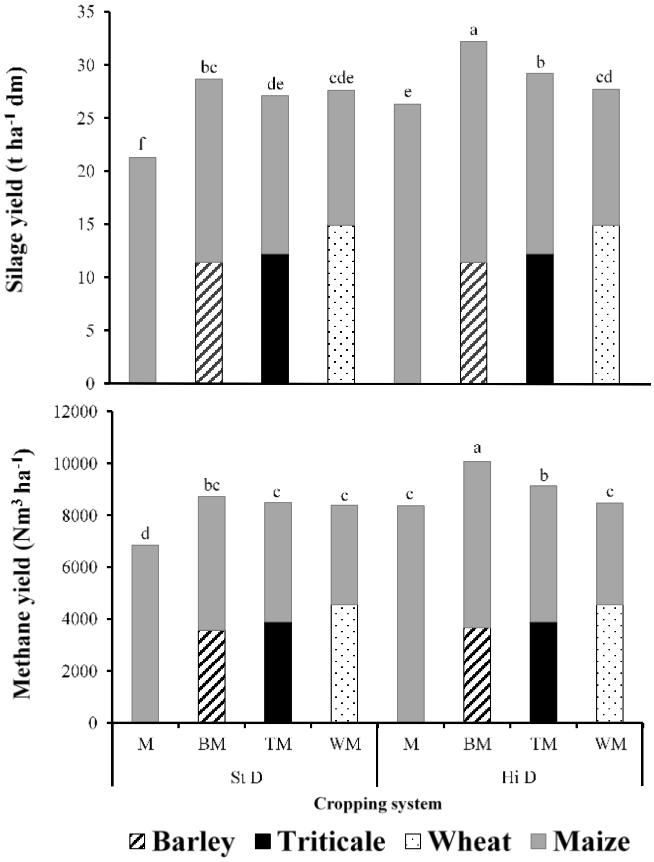

***Figure 1**. Effect of cropping systems based on different winter cereal - maize combinations[1] and maize plant densities[2] on silage yield per hectare. Different letters on bars indicate significant differences (P < 0.01).*

[1] M, single crop of maize planted in spring; BM, double crop with hybrid barley followed by maize; TM, double crop with triticale followed by maize; WM, double crop with common wheat followed by maize.

[2] StD, a standard planting density (7.5 plants m^{-2}) sown at a wide inter-row spacing of 0.75 m; HiD, a high planting density (10 plants m^{-2}) with a narrow inter-row spacing of 0.5 m.

Conclusion

The recent introduction of barley hybrids and maize hybrids able to withstand higher plant density can lead enhancement of silage and methane yield compare the more conventional double-crop system (triticale + maize) at standard density.

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Harvesting Management Influences Long Term Productive Performances Of Perennial Energy Grasses

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Introduction
Decisions about the harvest time of perennial energy grasses have important implications for economic and environmental objectives because there may be a significant trade-off between harvestable yield, qualitative traits for specific bioenergy processes, and environmental costs or benefits. Harvest time has been identified as a major determinant of biomass productivity (Hoagland et al., 2013; Monti et al., 2015), quality (Kludze et al., 2013; Monti et al., 2015) and stand longevity of perennial energy grasses (Heaton et al., 2009). Within Mediterranean environments decisions about harvest time result even more important in relation to uneven precipitation distribution and mild temperatures characterizing autumn and early winter period which often leads to increased biomass yield when harvest is delayed in winter, as reported for giant reed by Nassi o Di Nasso et al. (2010). In the present study the effects of the adoption of different harvesting times are reported on the productive performances of two long term side-by-side experiments: one including switchgrass (*Panicum virgatum* L.) and miscanthus (*Miscanthus* x *giganteus*) set in Bologna, the second including giant reed (*Arundo donax* L.) and miscanthus set in Catania.

Materials and Methods
Switchgrass and miscanthus were established at the experimental farm of the University of Bologna in Cadriano (44°54'N, 11°40'E, 32 m a.s.l.) in 2008. The trial site is characterized by a soil classified as Ustochrepts. The mean annual precipitation is about 700 mm, with nearly one half of it localized during the crop vegetative cycle (May to September). The mean minimum and maximum temperatures (avg. of last 20 years) are 8.6 and 19.0 °C, respectively. The climate at Bologna is defined as Northern Mediterranean (Metzger et al., 2005). Giant reed and miscanthus were established in 1997 and 1993, respectively, at the experimental farm of the University of Catania (37°24'N, 15°03'E, 10 m a.s.l.). The trial site is characterized by a soil classified as Xerofluvents. The mean annual precipitation is about 600 mm, with less than 20% of it localized during the crop vegetative cycle (May to September). The mean minimum and maximum temperatures (avg. of last 20 years) are 12.7 and 23.0 °C, respectively. The climate at Catania is defined as Southern Mediterranean (Metzger et al., 2005). In the present study the productive data (biomass yield) obtained in the last four growing seasons (2014/15, 2015/16, 2016/17, 2017/18) are presented, comparing the effect of autumn and winter harvest in switchgrass in Bologna, and in giant reed in Catania, furthermore the productive results of winter harvested miscanthus are also presented as reference in the two locations. Hemicellulose, cellulose and lignin content have been also determined on representative biomass samples from each trial following the methods reported on Scordia et al. (2017).

Results
In Bologna, switchgrass productivity (Fig. 1) was significantly influenced by growing season, harvest time and their interaction ($P \leq 0.05$, LSD test). Generally, delaying switchgrass harvest in winter (end of January/beginning of February) lead to a significant increase in biomass yield compared to autumn harvest (+60%). Otherwise, miscanthus productive performance resulted not significantly influenced by growing season, and it resulted more productive than switchgrass. When comparing productive data of the two perennial energy grasses within the same harvest time (winter), the mean biomass yield of miscanthus resulted significantly ($P \leq 0.05$) higher than that of switchgrass (16.60 vs. 12.00 Mg DM ha^{-1}, miscanthus vs. switchgrass, respectively). In Catania, the effect of harvest time on giant reed productivity was opposite (Fig. 2) than that

surveyed in Bologna for switchgrass, with significantly higher biomass yields associated to autumn (September) harvest (+~30% in comparison to winter harvest). As previously reported by Monti et al. (2015), giant reed confirmed its higher productive potential compared to miscanthus under southern Mediterranean environment (+90% of biomass yield in the 3 considered growing seasons). It is worth noting that the stand age of the two species is not the same and presumably the lower productivity of miscanthus could be partially explained by the "age" factor, even if the susceptibility of miscanthus to summer drought it is well document in the literature (Mantineo et al., 2009). If in the northern Mediterranean environment (Bologna) the studied perennial energy grasses could benefit from high precipitation and mild temperatures characterizing the late autumn/early winter

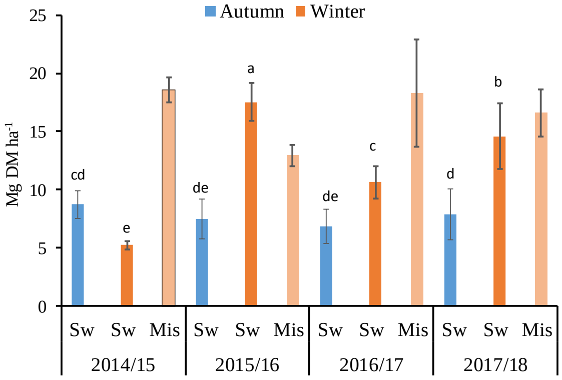

Fig. 1. Productive performances of switchgrass (Sw), in autumn and winter harvest, and miscanthus (Mis), only in winter harvest, in Bologna. Vertical bars: stardard deviation. Different letters: statistical different means for the interaction 'growing season x harvest date' ($P \leq 0.05$, LSD test).

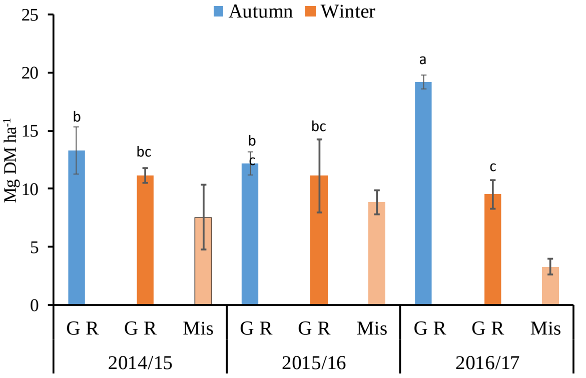

Fig. 2. Productive performances of giant reed (G R), in autumn and winter harvest, and miscanthus (Mis), only in winter harvest, in Catania. Vertical bars: stardard deviation. Different letters: statistical different means for the interaction 'growing season x harvest date' ($P \leq 0.05$, LSD test).

season, thus extending their vegetative growing season; otherwise in the southern Mediterranean environment (Catania) precipitation normally occurs when temperatures are already too low for crop growth or even when winter harvest has already been performed.

Conclusions

Switchgrass, giant reed and miscanthus confirmed their high suitability to Mediterranean environments also in the long term, being able to achieve sustained productions for more than 10 years. The full characterization of harvested biomass, actually still under evaluation, would permit a better understanding of the achieved productive results on the three studied energy grasses, since qualitative aspects assume a great impact on bioenergy production, limiting or expending their potential uses.

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Simulation Of Bioenergy Cropping Scenarios On Sediments And Nutrient Flows In A Mediterranean Watershed Using The SWAT Model

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Abstract
Biomass production for bioenergy using marginal and underutilized lands could be incremented in the near future to meet EU biofuel goals. A key issue is the environmental sustainability and impact of these new agro-ecosystems. The aim of this study is to simulate large-scale bioenergy crop production to determine sediment losses, nutrient flows and streamflow loadings in a Mediterranean watershed in the Sulcis area (Italy). The Soil and Water Assessment Tool (SWAT) model was implemented to assess the relative effectiveness of alternative new agricultural systems with respect traditional land use management taken as reference scenario. SWAT model prediction were compared against river discharge and non-point pollutant losses data recorded in the field. Our first results indicate that promoting perennial bioenergy crops production in the watershed could deliver reduction of sediment transport and nutrient losses under various bioenergy scenarios if compared with traditional row crops.

Introduction
Large quantities of cellulosic feedstock production are expected in the next years to meet European Union (EU) bioenergy policy. In this framework, the expansion of bioenergy crops on marginal, contaminated and underutilized areas in the Mediterranean basin could be a valuable pathway, avoiding competition with food resources and animal feed. One of the greatest challenges is to identify and evaluate potential impacts of these crops and agronomic management on water quality in order to implement best management practices for environmental sustainability. In this work, the Soil and Water Assessment Tool (SWAT) model was implemented to simulate the impact of planting bioenergy crops in the Sulcis area (Sardinia, Italy). This work attempts to: 1) implementing the SWAT model for a baseline scenario that represents the reference land use and identifying a set of best setting parameters; (2) simulating the growing of high yielding perennial energy crops in order to evaluate the effects land use change on discharge, sediments and nutrient flows by monitoring the water balance.

Materials and Methods
SWAT model is a is a public domain well-established hydrologic tool developed by USDA Agricultural Research Service (USDA-ARS) and Texas A&M AgriLife Research, successfully used for assessing soil erosion, water quality and non-point source pollution in a variety of applications (Chen et al., 2017). The model delineated the watershed into different sub-basins and further units on single Hydrologic Response Units (HRUs) that can be defined as homogeneous aggregation of soil, land use and slope for computing the water cycle dynamics. In this work, we used the ArcSWAT2012 version to manage all data in a GIS environment. The input data used to implement the model are Digital Elevation Model, soil map, land use map, meteorological data, water quality data and river discharge.
Firstly, all input data was set-up to delineate the watershed, sub-basins and new drainage network. Secondly, the model was run to assess the hydrologic effects of the actual land use. Finally, the model was set and run

incorporating and simulating the presence in the land use the perennial energy crops, in order to evaluate their growth and response compared with traditional crops.

Results

Climatic data show a typical bimodal pattern from the Mediterranean environments for rainfall distribution and temperature (mean rainfall 668 mm; mean temperature 17.3 °C). The model results in a watershed area of 254 km^2, 736 HRUs, 101 sub-basins, potential evapotranspiration of 1584 mm. The simulated stream discharge resembled with the observed discharge reasonably well for the observed period (years 1990-1992) (Fig. 1). The results of the simulation for a future planting of perennial energy crops in the lowland irrigated area shows a significant decrease with regard sediment deposition and nitrogen losses in the basin (Tab. 1). Less marked surface runoff for energy crops scenario depend on the presence of rainfed crops (especially durum wealth) in arable hill-slope areas on the watershed.

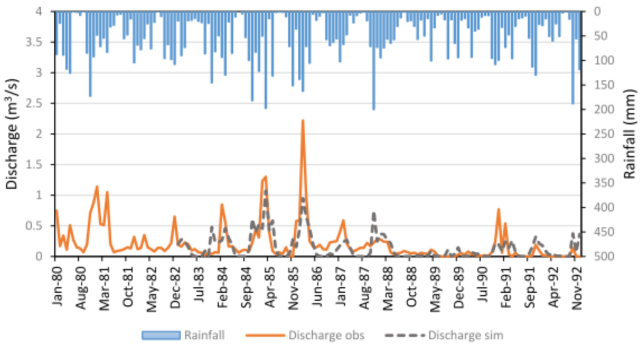

Fig. 1 - Stream discharge of the study area.

Tab. 1 - Scenarios of feedstock production.

Scenario	Sediment loading	N lossess	Surface runoff
Baseline scen.	2.4 Mg/ha	33.1 kg/ha	63.6 mm/yr
Energy crops scen.	1.6 Mg/ha	23.2 kg/ha	61.5 mm/yr

Conclusions

The work shows that the semi-distributed SWAT model is realistic predictor of hydrological flow, sediment and nutrient cycle in the study area. Preliminary results suggest positively impacts for future scenarios of bioenergy feedstock production with perennial crops on water quality and environmental sustainability. The slight decrease of surface runoff in the model due to row crops on rainfed areas suggests adopting conservation practices to avoid soil erosion and land degradation. Future work will be carried out to validate and calibrate the model. Data gathered from field trials and bibliography will help to identify the best setting parameters for testing new energy crops in the model (e.g. giant reed, cardoon, swichgrass). New scenarios of bioenergy feedstock production will be modeled and simulated for in-depth analysis of the impacts of different landscape scenarios comprising detailed management operations such as tillage, fertilizer, pesticide application, irrigation, and harvesting.

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Acknowledgements

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Nitrogen Use Efficiency Of Long-Term Plantations Of Arundo donax And Miscanthus x giganteus

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Introduction

Perennial, no-food grasses have been proposed as the most efficient species for biomass production due to their natural resource use efficiency, agronomic, environmental and social benefits. Species characterized by high water use efficiency and low nitrogen requirement, hence well adapted to use natural resources of a specific environment, can be recommended as ideal crops (Scordia et al., 2017). Along with irrigation water savings, nitrogen requirement is a significant issue in intensive agriculture and greatly affects the energetic balance of crops. Hence, reduced nitrogen fertilizer by means of low input crop-ping systems could directly mitigate greenhouse gas emissions (Cosentino et al., 2014).
In the present study long-term plantations of two perennial grasses (*Arundo donax* and *Miscanthus* x *giganteus*) grown in rainfed conditions under two nitrogen regimes were compared in terms of biomass yield and nitrogen use efficiency.

Materials and Methods

Miscanthus x *giganteus* and *Arundo donax* were grown at the Experimental farm of the University of Catania. *Miscanthus* was transplanted in summer 1993, while *Arundo* in spring 1997. During the first three growing seasons, both plantations received nitrogen fertilization (three-levels) and irrigation water (three-levels) (Cosentino et al., 2007; 2014), otherwise plants were maintained in no-input for the subsequent seasons and harvested only once a year in wintertime. From 2013, in each plantation, two levels of nitrogen (as ammonium nitrate) were compared: 80 kg N ha^{-1} (N_{80}) and 0 kg N ha^{-1} (N_0). The present study reports the biomass yield and nitrogen use efficiency of 2014/15, 2015/16 and 2016/17 growing seasons. Aboveground biomass yield was determined on a sampling area of 20 m^2 per plot in wintertime (February). Nitrogen use efficiency (NUE) was calculated as agronomic efficiency (kg crop yield increase per kg nutrient applied), according to Mosier et al. (2004). A two-way ANOVA using repeated measurements in time was adopted on biomass yield, while a one-way ANOVA on NUE. Duncan's post-hoc test was used for mean separation at 95% confidence level.

Results

Average yearly mean temperatures were similar among years (from 18.45°C in 2015 to 18.71°C in 2016), as well as average yearly minimum and maximum temperatures (13.5 and 23.6°C across growing seasons, respectively). Precipitations were higher than the long term trend (~550 mm) in both 2016 (765 mm) and 2017 (717 mm) and lower in 2015 (491 mm).
Biomass dry matter yield was significantly affected by the species, nitrogen fertilization and growing seasons ($P \leq 0.05$), while interactions of fixed factors were not significant. *Arundo donax* outperformed *Miscanthus* x *giganteus* in the present environment and cultivation practices applied (i.e., rainfed conditions). In 2015, *Arundo* and *Miscanthus* (N80) showed similar yields (11.9 and 10.4 Mg DM ha-1), while Arundo unfertilized produced 10 Mg DM ha^{-1} against 5.3 Mg DM ha^{-1} of *Miscanthus* (Figure 1). In 2016 *Arundo* and *Miscanthus* unfertilized produced 10.6 and 6.2 Mg DM ha^{-1}, while *Arundo* and *Miscanthus* N80 attained 15.3 and 8.7 Mg DM ha^{-1}. In 2017 a similar trend was observed, *Arundo* N80 shoed the highest yield (14.9 Mg DM ha^{-1}) followed by *Miscanthus* N80 (9.7 Mg DM ha^{-1}), *Arundo* N0 (8.4 Mg DM ha^{-1}) and *Miscanthus* N0 (5.9 Mg DM ha^{-1}).
Figure 2 shows the nitrogen use efficiency of both crops. The kg DM yield increase per kg of N applied was significantly affected by species and growing seasons effect, as well as by the interaction *species x growing season* ($P \leq 0.05$). *Arundo* showed the highest NUE across the average of growing seasons (54.7 kg DM kg^{-1} N),

while *Miscanthus* attained 43.1 kg DM kg^{-1} N. However, while *Arundo* showed the highest NUE at the wettest growing seasons (2016 and 2017, respectively), *Miscanthus* showed the opposite trend, with maximum NUE at the driest year as compared with *Arundo* (63.1 against 23.4 kg DM kg^{-1} N). Across species, 2015 showed a significantly higher NUE (58.2 kg DM kg^{-1} N) than 2016 and 2017, which were not significantly different (44.2 kg DM kg^{-1} N, on average).

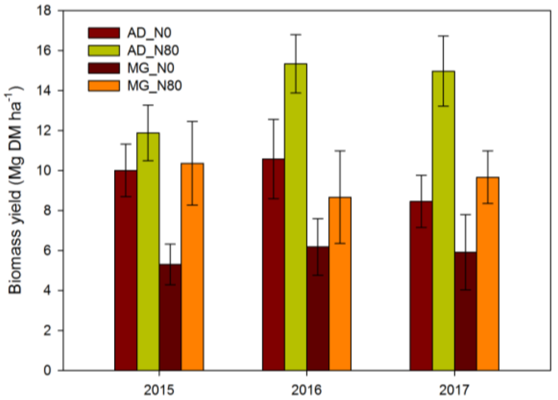

Figure 1. Biomass dry matter yield of Arundo donax L. and Miscanthus x giganteus under no-fertilization and nitrogen fertilization (N0 and N80, respectively).

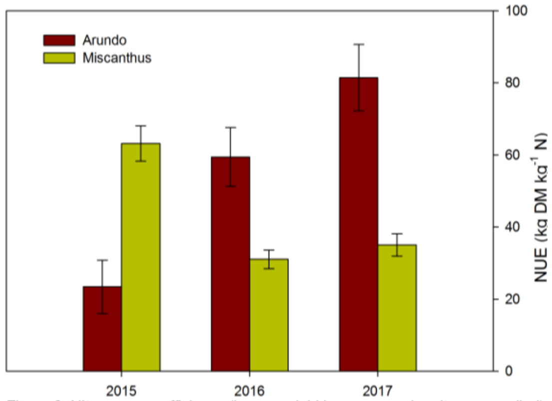

Figure 2. Nitrogen use efficiency (kg crop yield increase per kg nitrogen applied) in Arundo donax and Miscanthus x giganteus in three experimental years

Conclusions

The present study assessed the biomass yield and the increase of biomass yield per kg of nitrogen applied to long term plantations of *Miscanthus* x *giganteus* and *Arundo donax* (24 and 20 years, respectively) grown in rainfed conditions in a semi-arid Mediterranean area. *Arundo* outyielded *Miscanthus* in both fertilization and no-fertilization treatments. Biomass yield was well related to precipitations in *Arundo*, while it seems unconnected with the yield in Miscanthus, likely due to the end of its lifespan. *Arundo*, on the other hand, as widespread in the present environment looks more adapted to the changing meteorological conditions than *Miscanthus* that was introduced from more temperate environments.

Our findings showed that NUE is maximized when water availability is abundant in *Arundo*, while *Miscanthus* showed the opposite trend, with maximum NUE at the driest. Again, the age of the plantations might have biased NUE trend in *Miscanthus*. Further growing seasons might confirm our assumption. Given the low input requests, as water, nitrogen, pesticide, herbicides and the potential environmental benefits of its cultivation management, giant reed can be considered as a crop with high environmental sustainability in the long-term.

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A Follow Up Study Of Biomass Yield Of *Saccharum spontaneum* ssp. *aegypticum* Under Water Regimes

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Introduction

Mediterranean climates are characterized by long periods of drought during summer and short dry periods from autumn to spring, what limits plant CO_2 assimilation and biomass production to a great extent. More limiting scenarios are forecasted due to climate change in the coming years in the Mediterranean basin, due to increased evaporation and changes in the seasonal distribution of rainfall and its intensity, higher air temperatures and increased occurrence of extreme weather events. Under these circumstances, plants with excellent adaptation are needed. Perennial crops, and grasses in particular, have proved to be more efficient than annual crops for biomass production for several environmental and economic reasons. However, to avoid competition for land and food, harsh-prone environments, commonly known as marginal lands, should be devoted to the cultivation of energy crops. The JRC has set a series of thresholds to define marginal lands in terms of biophysical constraints. We focus on climate limitation given by the ratio between precipitations and potential evapotranspiration (P/ET). Areas with P/ET $\leq$0.60 are classified as affected by dryness. The present study follows up a long-term plantation of the C_4 perennial grass *Saccharum spontaneum* ssp. *aegypticum* under different water regimes in a semi-arid Mediterranean environment.

Materials and Methods

Saccharum spontaneum ssp. *aegypticum* was established in 2005 at the Experimental farm of the University of Catania. Materials and methods are extensively reported in Cosentino et al. (2015). Here we report the biomass yield following the study of Cosentino et al. (2015), namely 10^{th}, 11^{th} and 12^{th} growing season (2014/15, 2015/16, 2016/17, respectively). Through the growing seasons, meteorological conditions and potential evapotranspiration were continuously measured, then the P/ET ratio was calculated. The relative yield reduction (%) among irrigation treatments was calculated according to: $[(1 - (X_{0\text{-}50}/X_{100}) \times 100)]$, where X_0 and X_{50} are biomass yields at rainfed and 50% of the maximum ET restoration, and X_{100} represents biomass yields at 100% of the maximum ET restoration.

A one-way ANOVA using repeated measurements in time was adopted on biomass yield. Duncan’s post-hoc test was used for mean separation at 95% confidence level.

Results

Throughout the growing seasons, average yearly minimum temperatures ranged between 11.2°C and 13.9°C in 2012 and 2016, respectively. The former season showed the highest average yearly maximum temperature overall, 24.9°C. The average yearly mean temperatures were similar among years (from 17.6°C in 2011 to 18.7°C in 2015). The dryness index greatly changed among growing seasons: it was well above the threshold in 2011 (0.71), slightly higher in 2015 (0.62), slightly lower in 2016 (0.59) and well below in 2012, 2013 and 2014 (0.35, 0.34 and 0.38, respectively) (Table 1).

Biomass dry matter yield was significantly affected by irrigation treatment ($P\leq0.05$) and growing season ($P\leq0.05$), while the interaction *yield x time* was not significant at 95% confidence level. Biomass dry matter yield ranged between 29.9 and 37.1 Mg ha^{-1} in I_{100}, between 24.5 and 32.0 Mg ha^{-1} in I_{50} and between 19.1 and 27.4 Mg ha^{-1} in I_0.

Table 1. Meteorological conditions and dryness index at the Experimental farm of the University of Catania (37°25′N., 15°03 E., 10 m a.s.l.)

Year	Avg. yearly Tmin (°C)	Avg. yearly Tmax (°C)	Avg. yearly Tmean (°C)	P/ET
2011	12.64	22.63	17.64	0.71
2012	11.17	24.91	18.04	0.35
2013	12.57	23.56	18.06	0.34
2014	13.21	23.69	18.45	0.38
2015	13.59	23.82	18.71	0.62
2016	13.90	23.25	18.57	0.59

Across growing seasons, I_{100} produced 32.8 Mg ha^{-1}, I_{50} 27.6 Mg ha^{-1}, and I_0 22.7 Mg ha^{-1} (Figure 1). The highest yield was achieved at the wettest year (2011), while more variable trends were observed in dry seasons. The relative yield reduction was higher in I_0 as compered to I_{50} with respect to I_{100}. Figure 2 shows the maximum, minimum, median and interquartile ranges of both stress and mid-stress conditions. I_0 showed a median of 30.6%, and interquartile ranged from 28.0 to 34.1%. Maximum and minimum values ranged between 37.3 and 26.3%. I_{50} showed a median of 16.5%, interquartile from 13.8 to 17.6%, and maximum and minimum values between 11.8 and 19.5%.

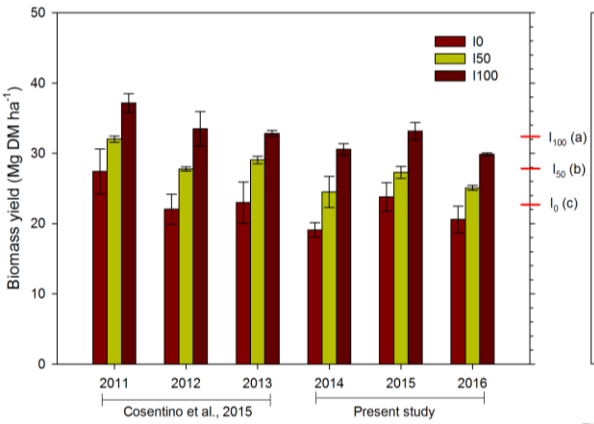

Figure 1. Biomass dry matter yield of Saccharum spontaneum ssp. aegyptiacum under different water regimes and growing seasons.

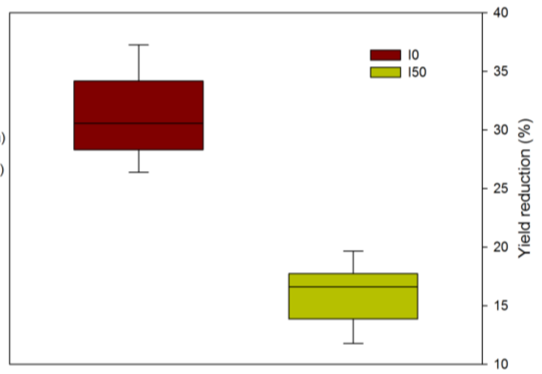

Figure 2. Percentage yield reduction of Saccharum spontaneum ssp. aegyptiacum in rainfed (I_0) and 50% ETm restoration (I_{50}).

Conclusions

The investigation of wild species well adapted to environments dominated by biophysical limitations is a strategy to develop resilient energy crops suitable to hash-prone environments. This study confirmed the desirable traits of the C4 perennial grass *S. spontaneum* ssp. *aegypticum* (Cosentino et al., 2015; Scordia et al., 2015). Biomass production was mostly driven by meteorological conditions through the growing seasons. However, even in the driest seasons, *S. spontaneum* ssp. *aegypticum* was able to maintain satisfactory biomass yield. The relative reduction was in the range of 28.0 to 34.1% in the most stress condition; nevertheless, when the irrigation level was raised to the 50% of the ETm, such reduction strongly reduced to 16.5% as median value.

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Effect Of Different Date Of Sowing On Cotton (*Gossypium hirsutum* L.) Varieties In Mediterranean Climate Conditions

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Introduction

Cotton is one of the most important commercial and industrial crop in many countries (Ganapathy et al. 2008). It is used both for the fiber, used for spinning and for the production of valuable paper and paper products, and for its seed, which is rich in oil and proteins (Chen et al., 2015). Therefore, a crop like this has a huge impact for the world economy and a great importance for agriculture, industry and trade in many tropical and subtropical countries. As a result, the genus *Gossypium* has long attracted the attention of many researchers. Cotton (*Gossypium* L.) is a shrub belonging to the *Malvaceae* family. It is a crop that requires warm-humid climates, with a great ability to adapt from the pedological point of view and good tolerance to salinity (Ahmad et al., 2007).The genus *Gossypium* includes about 50 species, but the most commercially cultivated are essentially two: *G. hirsutum* and *G. barbadense*, both originating in the New World. *G. hirsutum* is characterized by a short fiber (< 25 mm) and represents 90% of world production (Jenkins 2003), whilst *G. barbadense* is equipped with extra-fine fiber (> 34.9 mm), fine and resistant, and represents 5% of worldwide production of fiber (Wu et al., 2005). Today, cotton is also the subject of experiences aimed at the recovery and enhancement of the crop through sustainable farming techniques.
In this work the yield of two varieties of *G. hirsutum* L., *Juncal* and *Elsa* was evaluated, depending on the time of sowing.

Materials and Methods

The research was executed at the Agricultural Technical Institute "Calogero Amato Vetrano" of Sciacca experimental farm (N 37°30'39.86", E 13°07'35.55", 60 m a.s.l.). Soil in the test area was sandy clay loam soils (Aric Regosol, 54% sand, 23% silt and 23% clay) with a pH of 7.6, 14 g kg^{-1} organic matter, 3.7% of active calcareous, 1.32% total nitrogen, 18.1 ppm assimilable phosphate and 320 ppm assimilable potassium. The climate is Mediterranean with mild, humid winters and hot, dry summers. With reference to the year 2016, average annual rainfall was 539 mm, with maximum average temperatures of 27.02°C and minimum average temperatures of 10.6°C. A split-plot design was used with three replications, two different varieties of cotton (*Juncal* and *Elsa*) and three dates of sowing were compared. The plot area was 15.2 m^2, the soil was harrowed and fertilized in the month of march 2016 in order to provide a good seedbed. The sowings (I sowing date: 19 April, II sowing date 30 April, III sowing date 14 May) were performed manually on distant rows 0.95 m, with an investment of 12 plants m^2. During the entire cultivation cycle, the main phenological stages were observed and the main agronomic management concerned the fertilization at the time of sowing, in the phase in which the crop was with 50% of the plants in bloom and when the size of the capsules were about 2.5 cm in diameter; irrigation was performed by administering a volume of watering equal to 50% of the maximum evapo-transpiration and corresponding to a seasonal irrigation volume of about 1500 m^3/ha^{-1}. Harvesting has been staggered throughout the year in four different time. The number and the weight of the cotton balls per plant were determined at the harvesting stage for all the samples. At the end of the last harvest, the height of each plant and the height of insertion of the first fertile branch on the stem were detected on a sample of 10 plants selected randomly within each parcel. The four harvests have also allowed the calculation of agronomic precocity indexes, (MMD), (PRI) and (EI). The separation of the fiber from the seed of the raw product collected in the trial areas was performed by a cotton gin. Analysis of variance (ANOVA) was done on the data to determine the significance of differences between the means. The separation of means was carried out using the Tukey's test.

Results

Table 1 shows the results obtained. The factor "date of sowing" did not give significant variations for the main parameters examined. Between the two varieties examined, with exception of the parameters: plant height, height of insertion of the first fertile branch, MMD and EI, all the others, showed highly significant differences. In particular, the highest productivity was recorded for *Elsa* variety, which gave a greater number of capsules than *Juncal* (16.61 and 11.46 per plant respectively), a higher average weight of cotton balls (5.3 and 4.7 g/plant) and a higher yield in raw fiber (4.44 Mg/ha and 2.6 Mg/ha). Also the average trend in production had variations due to the variety effect. The index showed a significant decrease in production from *Elsa* variety (29.78 kg/ha/d) to *Juncal* variety (17.02 kg/ha/d).

Tab. 1 – ANOVA Effect of date of sowing and variety on production parameters

	Plant height (cm)	Insertion height I fertile branch (cm)	Capsules open (n/plant)	Medium weight flock (g/plant)	Yield of fiber raw (Mg/ha)	Fiber (%)	MMD (dd)	PRI (kg/ha/d)	EI (%)
Sowing date									
I date	106,4	13,4	15,0	5,1	4,0	41,1	158,5 A	24,7	28,5 B
II date	105,1	13,1	13,3	4,8	3,4	41,5	151,4 B	23,1	62,9 AB
III date	97,7	13,5	12,2	5,1	3,3	41,4	143,3 C	22,8	88,8 A
	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	**	n.s.	**
Variety									
Elsa	106,1	14,1	15,9 A	5,2 A	4,2 A	42,4 A	150,0	28,9 A	47,0
Juncal	99,2	13,9	12,4 B	4,7 B	2,8 B	39,8 B	152,9	17,5 B	71,5
	n.s.	n.s.	**	**	**	**	n.s.	**	n.s.
Variety*Sowing date	n.s.	*	n.s.	*	n.s.	n.s.	**	n.s.	**

Conclusions

The two varieties confirmed a good adaptability to the local conditions, however, *Elsa* variety showed a higher precocity of about 10 days compared to *Juncal*, irrespective of the sowing period. Regarding the raw fiber production, the parameter variety has determined the most significant increases in production regardless of the time of sowing. *Elsa* variety has in fact provided a production in raw fiber almost double compared to *Juncal*. The best sowing date was found to be the first, corresponding to the second decade of April; in fact, the temporal positioning of the crop cycle between the second decade of April and the third of September allowed to exploit the natural water reserves in pre-sowing and at the same time to obtain the best production performance, 4 Mg/ha against 3.39 and 3.21 respectively of the II and III date of sowing.

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Soil Greenhouse Gases Emissions In A Cardoon-Based Bio-Energetic Cropping System: The Role Of Compost Application At The First Year

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Introduction

Perennial bioenergy crops have a crucial role in climate change mitigation through their potential in reducing Greenhouse Gases (GHG) emissions and increasing Soil Organic Carbon (SOC) stocks (Robertson et al., 2016). Among these, cardoon (*Cynara cardunculs* L. var. *Altilis*) is considered an important crop for its drought tolerance under Mediterranean conditions, and high biomass production and multiple uses of biomass components (e.g. Mauromicale et al., 2014). The role of different organic fertilizers on soil GHG emissions dynamics is one of the key topics in the scientific debate on the contribution of agricultural systems to climate change mitigation (Sanz-Cobena et al., 2017). The use of compost as N fertilizer proved to have a positive impact on GHG emissions mitigation in annual crops (Forte et al., 2017), but there is little evidence of its impact on perennial cropping systems. The aim of this study is to preliminarily assess the impacts of different N fertilization systems (compost *vs* mineral fertilization) on GHG emissions under Mediterranean conditions in a cardoon cropping system for biomass production.

Materials and Methods

The field experiment was conducted at the experimental farm of the University of Sassari, Sassari (IT, 83 m a.l.m., 40°46′N, 8°28′34″E), in a first-year cardoon crop under Mediterranean climate and sandy-clay-loam soil. The N fertilizer target rate was 100 kg ha^{-1}. The experimental design was completely randomized with four replicates and a plot size of 24 m^2 (6 m x 4 m). The following fertilization treatments were compared: i) Mineral (MI), using urea; ii) Compost (CO) from organic urban waste and pruning residues (*Ammendante Compostato Misto*, D.lgs 72/2010) provided by Verde Vita s.r.l.; iii) Compost + Mineral (CM), (75% N from compost and 25% from urea,); iv) unfertilized control (NC). GHG emissions were measured applying a closed chamber technique (Smith et al., 2010). Soil Respiration (SR, g m^{-2} h^{-1} of CO_2) was measured using a portable, closed chamber system (EGM-4 with SRC-1, PP-Systems, Hitchin, UK) and 10 cm inner soil collar with perforated walls in the first 5 cm (Lai et al., 2012). N_2O and CH_4 fluxes (g ha^{-1} d^{-1}) were measured from 30 cm inner collars taking 30 mL of air samples, using a 60 mL polyethylene syringe and injected into 12 mL pre-evacuated vials at 10″, 10′ and 20′ after chamber closing. Concentrations of N_2O and CH_4 in air samples were analysed with a gaschromatograph (Agilent 7890 A). Fluxes were calculated from the rate of increase in GHG concentration. The effect of interaction between treatments and dates on GHG fluxes was tested by computing the ANOVA of the fitted generalized least square (gls) model. Pearson's correlation analysis was performed to test the relationship between N_2O or CH_4 fluxes and SWC and soil T for each treatment.

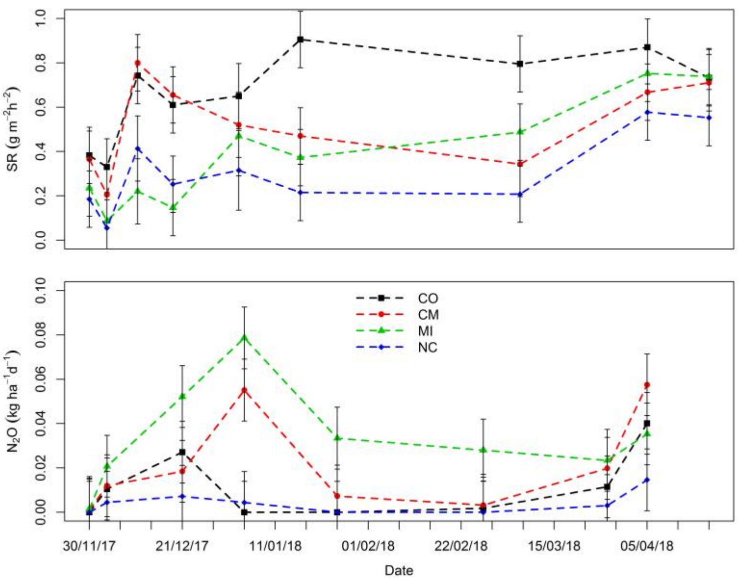

Figure 10. Soil Respiration (SR, g m^{-2} h^{-1}) and N_2O Fluxes (kg ha^{-1} d^{-1}) along the experiment. Bars represent the standard error of the mean (gls model). CO: Compost; CM: Compost+Mineral; MI: Mineral; NC: Control, unfertilized

Results

The maximum SR fluxes were observed in mid-January, when CO_2 emissions were higher in CO (0.91 g m^{-2} d^{-1}) than MI and NC (0.37 and 0.21 g m^{-2} d^{-1}, respectively). Minimum SR values were observed under NC (0.06 g m^{-2} d^{-1}) at the beginning of December (Figure 1). Maximum N_2O fluxes were observed at the beginning of January, when emissions under MI and CM (0.078 and 0.055 kg ha^{-1} d^{-1}, respectively) were higher than the very low CO and NC fluxes). The CH_4 fluxes, mostly uptake, were negligible across the experiment. Not significant correlations between both SWC and soil T and N_2O and CH_4 fluxes were observed (data not shown).

Table 1. Results of Analysis of Variance (ANOVA) of the fitted gls model for soil respiration (SR), N_2O and CH_4 fluxes. df: degrees of freedom.

	SR		N_2O		CH_4	
	df	P	df	P	df	P
Treatment	3	***	3	***	3	NS
Date	8	***	7	**	7	NS
Date*Treatment	24	NS	21	NS	21	NS

Conclusions

The fertilization systems of cardoon during establishment significantly influenced GHG emissions. SR and N_2O emissions were affected by treatments and season, but not significant effects of fertilization were observed on CH_4 fluxes. The compost played a positive role in mitigating N_2O emissions, but it further insights on soil organic C changes over the years are needed to better understand the potential of compost fertilizers in sequestering soil C and thus effectively mitigating the global warming potential.

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Evaluation Of An Hemp Genotype (Futura 75) For A Dual Purpose Production In A Semi-Arid Mediterranean Environment

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Introduction

In recent years it was observed a renewed interest for hemp (*Cannabis sativa* L.) cultivation, both as industrial and food crop. The interest as food crop lays in the nutritional values of hemp seeds mainly related to their high-quality oil and proteins contents. As reported by Amaducci et al. (2015), hemp fibre can also be used as reinforcement in composite materials, to produce insulation mats, car interior panels, and requested in bio-building sector to form concrete too. The possibility to cultivate hemp for a dual purpose use could improve the farmer revenue.

The information regarding the dual purpose hemp cultivations are poor and even more in Mediterranean environments. In this respect the present study evaluated the adaptability of Futura 75 hemp genotype under the Mediterranean conditions of Southern Italy (Sicily).

Materials and Methods

The field trials were carried out between spring and summer 2017 in seven private farms located in Gangi (Palermo province), Gela (Caltanissetta province), Caltagirone (Catania province), Petralia (Palermo province) and Vallelunga Pratameno (Caltanissetta province).

In order to evaluate the adaptability in different Sicilian areas, in the seven private farms that cultivated hemp in large fields, three plots (10 x 10 m each) were delimited in order to evaluate morphobiometrics parameters and biomass yield.

The locations, sowing and harvest time are reported in table 1.

In all sites the cultivations were carried out under rainfed conditions.

Tab. 1: Site, altitude, seeding rate, sowing and harvest time in the seven locations.

Site (Province)	Altitude (m asl)	Seeding rate (t ha-1)	Sowing time	Harvest
Gangi (Palermo)	650	50	24/03/2017	18/07/2017
Gela San Leo (Caltanissetta)	50	30	22/03/2017	19/07/2017
Gela zona Ind. (Caltanissetta)	50	30	22/03/2017	19/07/2017
Caltagirone Az.1 (Catania)	500	35	08/04/2017	27/07/2017
Caltagirone Az.2 (Catania)	450	35	04/04/2017	27/07/2017
Petralia (Palermo)	600	45	01/04/2017	10/08/2017
Vallelunga Pratamento (Caltanissetta)	400	45	28/03/2017	10/08/2017

In the different sites, harvest was performed at seed maturity. At harvest, edge plants were removed in each plot in order to weight the biomass within 16 m^2 (4 x 4 m). Dry biomass yield was calculated by weighing sub-samples of fresh biomass and after oven drying it at 65 °C until constant weight. The seed samples were air dried, cleaned and weighed for seed yield determination.

Results

Observing the height of Futura 75 in the seven sites, the highest height value was observed in Gangi while the lowest in Gela San Leo (145.5 and 81.3 cm, respectively) (Fig.1). The highest height of the plants observed in

Gangi was probably due to the highest seeding rate adopted in this location, and, as it is known, hemp at high seed density increases its height and reduces the production of seeds.

Across the experimental sites, the average stem dry biomass was equal to 3.93 t ha^{-1}. The highest value was observed in Caltagirone Az.2 (6.49 t ha^{-1}) followed by Vallelunga P. (4.82 t ha^{-1}), Caltagirone Az.1 (4.47 t ha^{-1}) and Gangi (4.35 t ha^{-1}). The lowest stem dry biomass was obtained in Gela San Leo (1.95 t ha^{-1}), Petralia (2.64 t ha^{-1}) and Gela zona Ind. (2.82 t ha^{-1}) (Fig.2). In previous experiments carried out by Cosentino et al. in Catania (Cosentino et al., 2012; Cosentino et al., 2013), the stem dry biomass yield of Futura 75 ranged from 6 to 10 t ha^{-1} in relation to the water availability, while in rainfed conditions, in relation to the sowing time, the stem dry biomass yield ranged from 1.8 to 8.7 t ha^{-1}.

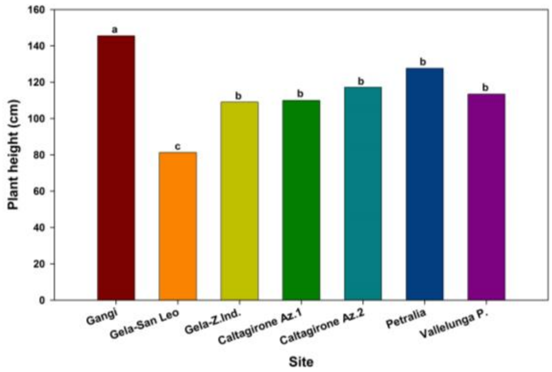

Fig. 1. Plant height (cm) in relation to the different sites and varieties.

Seed yield, averaged across the different locations and seed densities, was equal to 0.98 t ha^{-1}.
The most productive site was Vallelunga P. (1.76 t ha^{-1}) followed by Caltagirone Az.2 (1.37 t ha^{-1}), Caltagirone Az.1 (1.24 t ha^{-1}), Petralia (1.10 t ha^{-1}), Gangi (0.79 t ha^{-1}), Gela zona industriale (0.32 t ha^{-1}) and Gela San Leo (0.26 t ha^{-1}).

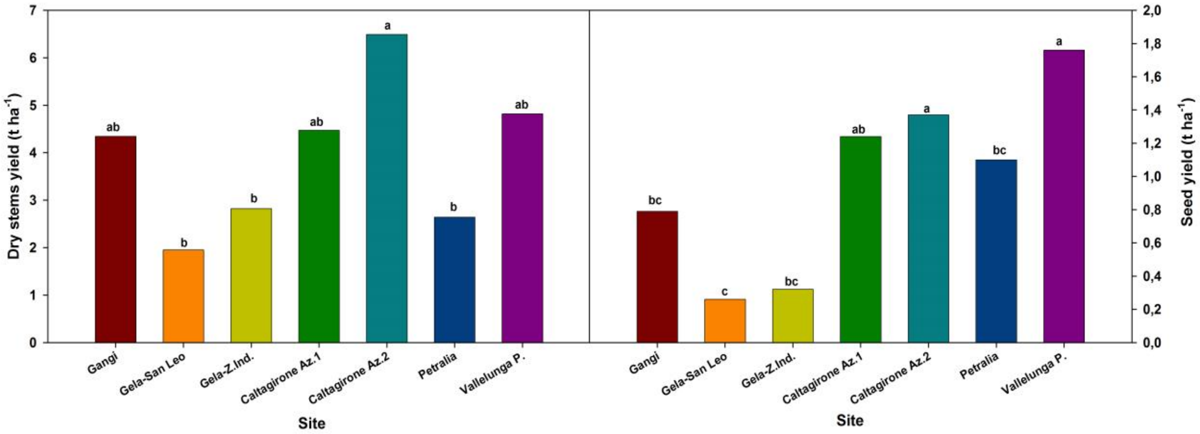

Fig. 2. Stem dry biomass (t ha-1) (left) and seed yield (t ha-1) (right) in relation to the different sites and varieties.

Conclusions
Futura 75 hemp genotype highlights a good adaptability to several Sicilian sites. Both dry stem biomass yield and seed yield varied in relation to the sites of cultivation. The differences were mainly related to the different water availability (data not shown). The obtained results suggest the possibility that hemp, in this environment, could be cultivated both for seed and fiber productions but attention to the water availability must be drawn. Moreover the difference in seeds and stems yields observed suggest to carry out further studies in order to evaluate the best sowing density to increase seeds yield.

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Evaluation Of The Methanogenic Potential Of Two Lignocellulosic Crops

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Introduction

Biogas production can be considered an important technology for the sustainable use of agricultural biomass as a renewable energy source even more when the substrates for anaerobic digestion are crop residues, livestock residues or energy crops that don’t compete with food crops for land use.

The aims of this study were to evaluate the production of biogas and biomethane from two lignocellulosic crops suitable for the Mediterranean environment (*Arundo donax* L. and *Saccharum spontaneum* subsp. *aegyptiacum* (Willd.) Hack) and the efficiency of a thermal pretreatment to increase the biomethane production. The purpose of the pretreatment is to break the recalcitrant lignin layer, so that the cellulose and hemicellulose present in the biomass are hydrolyzed by microorganisms and converted into simple sugars to achieve greater energy yield.

Materials and Methods

The qualitative analysis of the biomass was carried out through the extraction unit Fibertec Velp Scientifica, FIWE model using the Van Soest method which allows to determine the composition of the fibrous fraction of any vegetable matrix. A physical pretreatment of thermal type was carried out using an autoclave (model 1000 ML Zipperclave Assembly, Parker) at 160 °C for 10 minutes, distilled water as catalyst stirring at 160 rpm. For the estimation of the methanogenic potential of the different vegetable matrices (*Arundo* and *Saccharum*) was used the BMP test (Biochemical Methane Potential), and every BMP test lasted 30 days. The experiment was carried out using an automatic methanogenic potential detection system (AMPTS, Automatic Methane Potential Test System) of the different organic matrices (Fig.1).

Fig.1 AMPTS, Automatic Methane Potential Test System

Dry and volatile solids were determined both for the organic substrate and the inoculum in order to obtain an inoculum/substrate ratio equal to 3 inside the batch. The dry weight was obtained drying the biomass in a ventilated oven at 105 °C until constant weight. For the estimation of the volatile solids the dried samples were placed in a muffle furnace at 550 ° C for 5 hours.

Results

The heat treatment with water at 160° C resulted in an increase in the cellulose and lignin content. Hemicellulose showed a significant reduction in both species with the introduction of heat treatment. The Neutral detergent-soluble (NDS) has decreased with increasing temperature, more in Saccharum than in Arundo (Fig.2).

The speed of the digestion process was higher for the untreated biomass, which reaches the peak production within 5 days from the start of the process.

The increased speed of the digestion process in the case of non-pretreated biomass is ascribable to the higher content of hemicellulose, rapidly hydrolysed in soluble sugars by hydrolytic bacteria, and NDS, which is a readily available substrate for acidogenic bacteria. Cellulose, whose content is in greater proportion in the pretreated biomass, must instead undergo a slow hydrolysis process before it can be available for acidogenic bacteria.

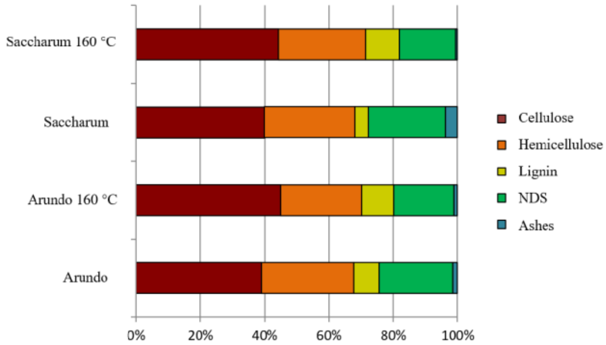

Fig.2 Fibre fractions in relation to the different treatments (species and temperature) determined by the Van Soest method.

The real methane yield was obtained considering the methane production per unit of volatile solid and multiplying it for the biomass yield of the crop expressed in volatile solid (tSV ha^{-1}). The difference in the theoretical methane yield are ascribable to the different biomass yield of the two species. The lower methane yield of the pretreated biomass was due to the increase in lignin content on the total of volatile solids (Fig.3).The real yield is greater for the pretreated biomass, despite the higher content of lignin and the lower total content of digestible fractions (hemicellulose, cellulose, and NDS) (Fig.4). The greater production is due to the physical transformation that undergoes the lignocellulosic matrix during the pretreatment.

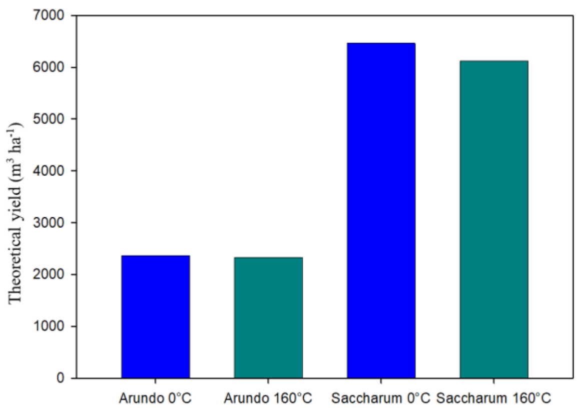

Fig.3 Theoretical methane yield (m^3 ha^{-1}) in relation to the different species and pretreatment studied.

The thermal pretreatment interrupts the continuity between cellulose, hemicellulose fibers and lignin. In this way the enzymatic hydrolysis is less obstructed and therefore a greater release of monosaccharides from the fibers is obtained with a consequent greater production of methane with the same biomass composition.

Conclusions

The experiment confirms the aptitude of *Arundo donax* and *Saccharum spontaneum* to different energetic exploitation. These two species show, in relation to their needs respect to the climate, environment and agronomic input, the traits of the ideotype biomass crops suitable to the cultivation in marginal Mediterranean semi-arid environment.

All the substrate under study highlighted high methanogenic potential that were confirmed by biomethane production tests (BMP test) carried out in laboratory.

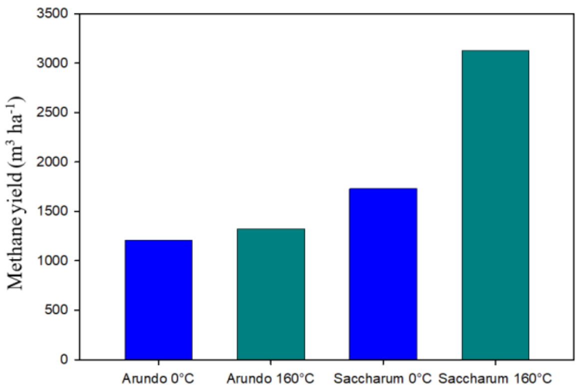

Fig.4 Methane yield (m^3 ha^{-1}) in relation to the different species and pretreatment studied.

Urban Agriculture: A New Perspective

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Introduction

In the sustainable soil management, the maintenance of the natural resources and the biodiversity, the production of environmental services among which the mitigation of the climatic changes with CO_2 reduction, the biodiversity protection and the promotion of a development urban eco-sustainable finalized to an increasing attention to the production of healthy foods and of elevated quality are of primary importance. The periurban agriculture is becoming an increasingly widespread phenomenon. The urban gardens in Italy and in Europe, are tripled in alone three years, turning an individual practice into a strategy of urban policy destined to cooperate for the development of future cities. Still there is no precise mapping that allows us to quantify the phenomenon, but the data available confirm a very rapid expansion that began in the 70s and accelerated above all in the last 15 years. Furthermore, a number of side effects have been identified, with a strong positive impact such as: the reduction of the heat island effect; the outflow of rainwater; nitrogen fixation; pest control and energy saving.
In this research, the possible impact of atmospheric pollution on the quality of a soil cultivated in urban garden has been studied, examining the content of micro-macro elements and heavy metals in the urban garden, adjacent to a road to intense vehicular traffic of Rome such as the Nomentana Street, in comparison with a vegetable garden located in the agricultural area "Estate of S. Leonardo", near Monterotondo, province of Rome, Lazio region.

Materials and Methods

In the present work two types of soils were studied: a vegetable garden and an urban garden. Analyzes of micro-macro elements (Fe, B, Mn, Ca, K, Mg and Na) and heavy metals (Cd, Cr, Cu, Ni, Pb, and Zn) present in different soils were carried out by means of Inductive Coupled Plasma Optical Emission Spectrometry, (ICP-OES), instrument the Thermo Fisher, ICAP 6000. Soil samples, collected from the 0-30 cm layers, were air dried, sieved (2 mm), and soil properties were determined according to laboratory methods (MiPAAF, 2000). Total soil heavy metals and micro-macro elements were determined by a total acid digestion of the soil according to ISO 11466 (1995). All results given are averages of three samples. The concentrations are expressed in mg kg^{-1}. Currently, in Italy is still under study legislation that indicates the limits of concentration of heavy metals for agricultural soil, at present we can indicate "orientation values".

Results

The processing of the analytical data of the two examined soils, the urban garden and the vegetable garden of Estate of S. Leonardo, near Monterotondo, province of Rome, Lazio region, showed a good degree of comparability between the two soils, both for heavy metals (Figure 1) - which in any case are always below the limits of attention - both for micro-macro elements (Figure 2). The soil of Estate of S. Leonardo has a greater content of macro elements, probably due to repeated fertilizations over the years, as well as the natural composition of the soil. In this paper the results obtained would confirm that the soil used for the cultivation of an urban garden, despite being located in areas at high risk of pollution represents a possibility to requalification of urban areas and of environmental improvement.

Figure 1

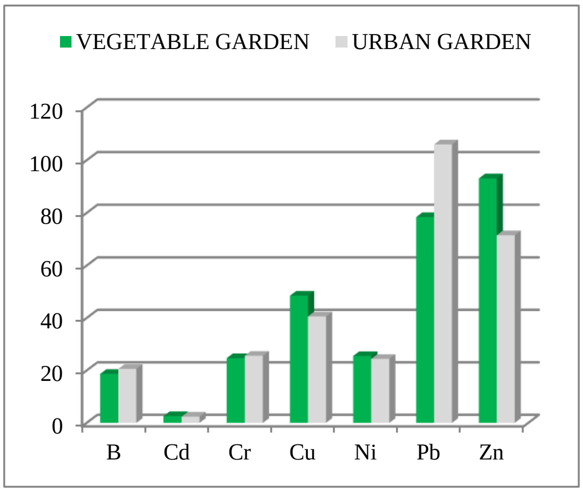

Figure 2

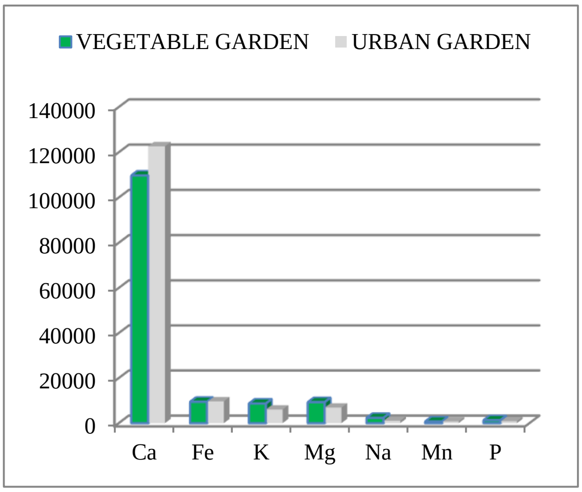

Fig. 1. Heavy metals and B content in soils of the vegetable gardens (mg kg^{-1}); Fig. 2. Macro-micro element content in soils of the vegetable gardens (mg kg^{-1})

Conclusions

In this work, preliminary data would confirm that urban agriculture plays a major role for the conservation of soils creating a link of continuity between city and countryside, according to a model of sustainable urbanization, of biodiversity, as a potential tool for the sustainability of supply chains and of agri-environmental policies.

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LIFE PASTORALP: A Project For Alpine Pasture Vulnerability Assessment

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Introduction

Alpine natural pastures are important ecosystems threatened by anthropic factors, such as abandonment or reduction of management, and by environmental drivers, nowadays mainly represented by climate change (Subedi et al., 2016). Socio-economic changes interest many mountain and marginal areas covered by permanent pastures, and this is causing remarkable effects on biomass production, forage quality, botanical composition and biodiversity issues (Orlandi et al., 2016). Climate change is affecting mountain ecosystems in different ways (IPCC, 2014): in the last century, the Alps have experienced a remarkably high temperature increase (about +2 °C). Moreover, a modification in precipitation patterns along growing season is expected, with high consequences on productive regimes that can affect animal utilization of these resources (Nettier et al., 2017).
Despite these factors, in many regions of the Alps an adoption of measures on pastures to face climate change is still lacking, even if some *ad hoc* policies for marginal areas to preserve mountain farming were adopted. To contribute to fill these lacks, the present LIFE funded project aims to produce information on how to reduce the vulnerability and increase the resilience of farming systems based on alpine pastures by assessing and testing adaptation measures, increasing capacity building and developing improved management strategies for climate change adaptation.

Materials and Methods

PASTORALP (Pastures vulnerability and adaptation strategies to climate change impacts in the Alps; October 2017-March 2022) is an EU-funded project in the Climate Change Adaptation LIFE program (LIFE16-CCA-IT_000060), coordinated by the University of Florence (Italy) and involving eight institutions operating in Alpine areas equally distributed across Italy and France. The actions will take place in two protected areas of Parco Nazionale del Gran Paradiso (Italy) and Parc National des Écrins (France), extending over more than 160,000 ha.

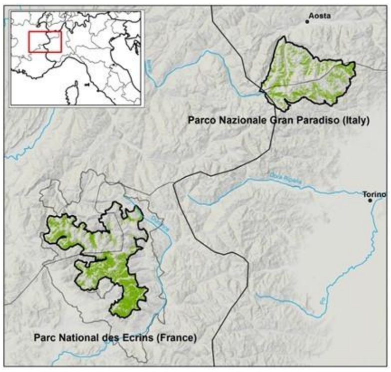

Figure 1. Protected areas (PNE and PNGP) interested by the PASTORALP project and pastures surface (in green).

PASTORALP actions reflect the usual design of the LIFE program. Preparatory actions are meant to create a stakeholder framework for the implementation of all project actions, the establishment of a communication plan, to disseminate activities and to analyze the legislation background. The outcomes of these actions will be used to identify feasible adaptation strategies. Data collection and climate scenarios will be assimilated into grassland simulation models for vulnerability analysis. Pastoral maps will be used in combination with climate scenarios for modelling or for vulnerability assessment. A large set of environmental and socio-economic indicators will be adopted to define feasible adaptation strategies. The outcomes from these actions will all be available via an online platform tools. Stakeholders/end users will then cooperate with potential beneficiaries in modulating and optimizing the tools platform, which is considered the most effective output of the project. A detailed set of communication activities will facilitate a participatory process of local stakeholders/end users alongside the project, through information, consultation and validation workshops and training. The final products of this co-construction process will be translated into an adaptation strategy and replication plan, that will be proposed to decision-makers at regional, national and EU levels for its replicability also in other alpine mountain environments.

Results

Expected results of the project will concern farming systems assessment, as estimation of the pastures vulnerability in the two National Parks and the integrated impacts of climate and socio-economic changes on pasture production systems. Characterization of forage resources will be performed by means of harmonized vegetation types maps. Modelling and climatic scenarios and the obtained outputs will in turn be used to propose climate change adaptation strategies for pastures management in the studied areas and to produce guidelines and recommendations for an enhanced decision-making in pasture management at different policy levels.

The involvement of local stakeholders (contacted during launching events, workshops, by direct connections, etc.) will be one of the key strategies of the project: to this aim, evaluation and demonstration of the technical and socio-economic viability of proposed management options will be performed in selected demonstration pilot areas and the adaptation strategies will be continuously refined with feedbacks from local stakeholders, involved during all the lifespan of the project. In this way, the project should promote an increased capacity building to local communities/actors for coping with climate change impacts and adaptation of farming practices.

Finally, one of the major impacts of PASTORALP will be the reduction of land abandonment through the promotion of improved EU, national and regional proofing policies, practices and incentives (RDPs, CAP, etc.) mainstreaming climate change adaptation for mountain pastoral resources.

Conclusions

LIFE PASTORALP will assess vulnerability of alpine pastures to face future climate changes, propose adaptive management strategies and ensure feasibility and sustainability of proposed practices. The Parks involved in the project should be considered as “open laboratory areas” in order to extend the knowledge on adaptive pastures management inside their territory and to replicate them across the entire alpine range, with further adaptive proposals that will continue after the end of the project.

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Nitrogen Balance Of A Low-tech Aquaponic System

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Introduction

Aquaponics (AP), the combination of hydroponics and recirculating aquaculture, is a promising atypical and complex food production technology (König et al., 2016). It can be considered a sustainable agricultural production system because does not undermine our future capacity to engage in agriculture (Lehman et al., 1993). The key aspect of AP is the nitrogen (N) balance because the fish low N use efficiency (NUE) well matches with the vegetable N requests with positive effect on environmental impact reduction. Indeed: 1) protein-rich fish feed (the major source of N) represents 50–70% of fish production costs; 2) only about 25% of the N input is harvested through fish biomass, whereas over 70% is excreted in the water by fish as ammonia. In view of this the aim of this study was to evaluate the N balance of a low technology AP system managed at two fish densities and comparing their performance with a hydroponic system.

Materials and Methods

The experiment has been carried out at the experimental farm of Padova University, North-East Italy (45°20′ N; 11°57′ E; 6 m a.s.l.) inside a plastic greenhouse 50% shaded. A randomized block experimental block design with the following three treatments replicated three times was adopted: aquaponics with low fish density (APL), aquaponics with high fish density (APH) and hydroponics (HP) as control. Each unit consisted of: 1) a tank (volume 500 L) in which fishes were farmed in the AP units or where the nutrient solution was present in the HP units; 2) two vegetable tanks (volume 275 L each), filled with 225 L of expanded clay, that received the same water flux from the 500 L tank and acted both as biofilter; 3) a water storage tank (volume 50 L) where the vegetable tanks output was collected before relaunch in the fish tank. The three parts of the system were connected by overflow actioned by a single pump (Newa Jet 1700) located in the accumulation tank that relaunched water to fish tank. The water flow rate was 120 L h^{-1} allowing a complete water recirculation every 5 hours. The experiment started on 19th June 2017 and ended on 7th November 2017. On 27th June fish were put in APL and APH treatments (which through their wastes acted as nitrogen fertilization), whereas in HP treatment 607 g $unit^{-1}$ of $Ca(NO_3)_2 \cdot 4H_2O$ were added. The other macro, meso and micro-nutrients were added in all systems at the same dose. The fish tanks were stocked with common carp (*Cyprinus carpio* L.) at a stocking density of 2.5 and 4.6 kg m^{-3} for APL and APH treatments, respectively. Fishes were manually fed once a day with a commercial pelleted feed (6.6% N content) at 2% of its weight. During the entire experimental period the vegetable tanks were cultivated in succession with catalogna chicory (*Cichorium intybus* L. Catalogna group - from 27th June to 25th July, 9 plants m^{-2}), lettuce (*Lactuca sativa* L. - from 26th July to 29th August, 12 plants m^{-2}) and Swiss chard (*Beta vulgaris* var. Cicla - from 29th August to 7th November, 10 plants m^{-2}) transplanted at 3rd true leaf.

The NO_2^-, NO_3^-, and NH_4^+ water content was monitored two times per week in the systems' water and one time per month in the fresh water used daily to refill systems' evapotranspiration. Fish weight was detected for each unit at the beginning and the end of the experiment. At harvest time all plants were harvested, divided into aboveground and belowground, and dry biomass production was obtained drying biomass in a thermo-ventilated oven at 65 °C until constant weight. In the dry biomass fractions total Kjeldahl nitrogen was determined. The N percentage content in the fish biomass (2.7% on fresh weight) was estimated using literature values (Fauconneau et al., 1995; Buchtová et al., 2011; Miroslav et al., 2011).

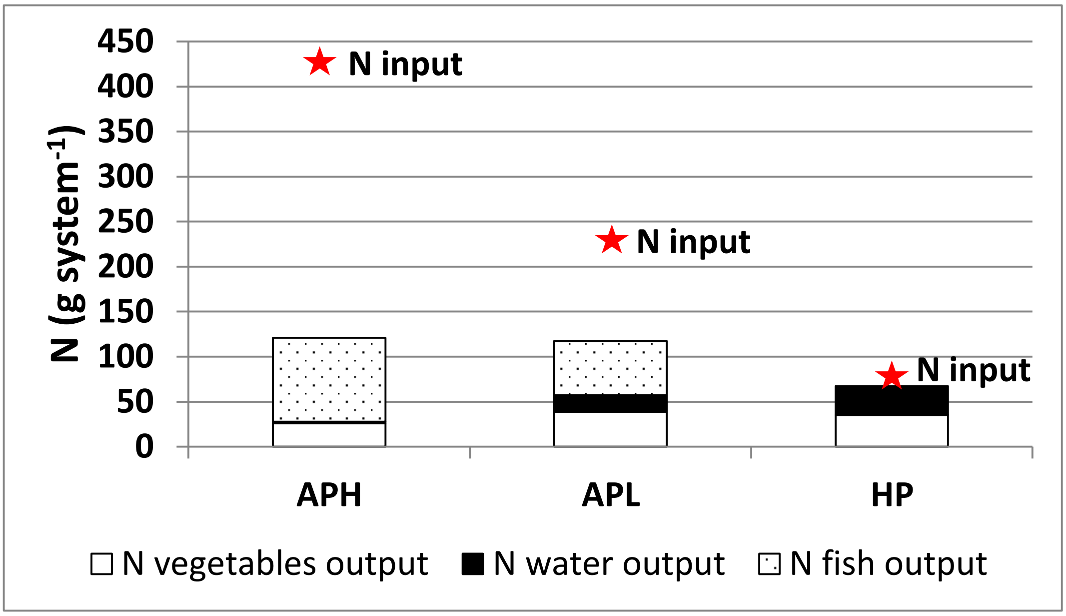
Results

The N supplied was 226.7±5.2 g $system^{-1}$, 420.5±12.3 g $system^{-1}$ and 72 g $system^{-1}$ in the APL, APH and HP respectively. N supplied with the fresh water added to refill evapotranspiration was not significantly different among treatments with an average value of 4.6±0.2 g $system^{-1}$. The N apparent balance, reported in figure 1, showed that AP treatments were characterized by lower N recovery capability than HP control. This is due to N that remained in the biofilter as fishes' feces, N that was released in the atmosphere as gas compounds (e.g. N_2, N_2O) during N nitrification and denitrification and N released in the atmosphere as NH_3.

Figure 1. Apparent nitrogen balance in the studied treatments.

Conclusions

The obtained results indicate that fish density significantly influence N balance in aquaponic systems with a NUE that, in our



experiment, was similar to those found in literature for aquaculture systems (25.0%) when APH treatment is considered, and about two times higher in the APL treatment. The lower N recovery capability in APH than APL was due to the high organic load that reduced oxygen availability in the vegetables substrate (data not shown) reducing nitrification. Considering vegetables NUE, the lower value in AP treatments than HP one is due to the continuous and not defined N supply with fish feed whereas in HP the N supplied with fertilizer was defined and supplied only at the beginning of the trial. HP control confirm the pilot system reliability showing a N balance in line with the data reported by FAO. Further research are desirable to improve the AP NUE.

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Biogas Production From Silage Flour Wheat Influenced By Chemical And Green Synthesized ZnO Nanoparticles

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Introduction

Biomethane production from energy crops and crop residues could be an interesting option for the sustainable use of agricultural biomass as renewable energy source. However, it is possible to create a useful product with bio-energetic properties only by correct processing and evaluating the use of crops, which require low energy inputs beside the ability to ensure appropriate biogas or methane yields. Nanotechnology is a technique of manipulating material at the nanoscale (1–100 nm) and it is considered as one of the most important advancements in science and technology of the last decades. Particles in nanometric size range are termed nanoparticles (NPs). The size greatly depends on the process used for their synthesis. They can be obtained by bottom-up assembly of atoms through chemical process or, on the contrary, from top-down fragmentation of bulk material. Many studies have reported on the effects of nanoparticles on biogas production. Results (e.g., Mu et al., 2011; Ganzoury and Allam, 2015) reported variable effect of nanoparticles on biogas production. The main problem is related the toxic effect of metals, in particular Zn, on biogas microbial community. Mu et al. (2011) refer that ZnONPs has inhibitory effects on methane generation at several concentration, but low concentration ZnONPs (6 mg/g-TSS) gave no impact on methane generation (Abdelsalam et al., 2017). Also, the possibility to obtain green ZnONPs can be a system able to reduce negative effect. The objectives of this study was to focus on the effects of ZnO nanoparticles with different concentrations on biogas production from flour wheat biomass using chemical and Green ZnONPs.

Materials and methods

The effect of ZnONPs was estimated on a biomass digestion that was carried out using biomass obtained from on farm experiments realized in Gravina in Puglia (BA). Flour wheat var. Agadir was used for this kind of experiment. Production data were measured at milk maturity and wax maturity. Composition of biomass was determined by using a CHN elemental analyzer. Chemical and green ZnONPs were extracted from wheat Agadir biomass at waxy maturity, as proposed by Saad et al. (2015), and were used to study the effect of NPs on biogas production and compared to the control samples. Biogas production was effected using 100 ml biodigesters syringes, in batch operation mode, in triplicated repetition. The effect of three ZnONPs concentrations was evaluated: 5, 10 and 20 mg L^{-1}. These concentrations were selected based on previous research conducted by Qiang et al. (2013). The operating temperature was maintained at mesophilic conditions (38 ^{0}C).

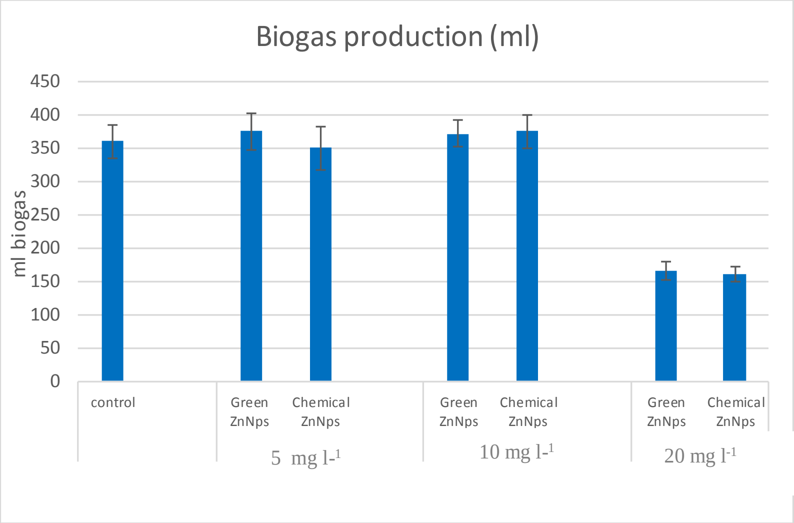
Results

Biomass production registered was 41.1 t ha^{-1} at milk maturity and 36.5 t ha^{-1} at waxi maturity (Table 1). Considering the dry biomass, the values were higher at waxy maturity with 13.2 t ha^{-1} compared to 12.1 t ha^{-1} at milky maturity (Table 1). Composition of biomass (Table 1) was quite stable between the two harvest dates, with an average content of about 52% of C, 6.6% of H and 1.8% of N. The hash content was different between the two harvest dates: 5.2% at milky maturity against 6.1% at waxy maturity stage. C/N ratio varied between 28 and 53, which can be considered not far from the range of 20-30 indicated as an optimum range in the literature (Bardiya and Gaur, 1997). Considering the biogas production, higher values were obtained during the 1st week, in agreement with other scholars (Abdelsalam et al, 2017). in comparison with the control, the startup of biogas production was improved when the substrates were treated with 10 mg L^{-1} of ZnONPs in both green and chemical ZnONPs and 5 mg L^{-1} for only green ZnONPs [Fig. 1].

Table 1. Biomass production and composition in relation to two harvest times of wheat var. Agadir.

	Biomass production	Dry biomass	Hash content	C	H	N	C/N
	(t ha^{-1})		%				
Milky maturity	41.1	12.1	5.2	51.621	6.721	1.858	28.12
Waxy maturity	36.5	13.2	6.1	52.506	6.672	1.8671	53.31

It is also clear that ZnONPs concentration of 20 mg L^{-1} of both chemical and green ZnONPs has inhibitory effects on the biogas production, which is in agreement with previous results by Abdelsalam et al (2017), who highlighted that the influence of ZnONPs is dosage dependent. Our results evidenced that both green ZnONPs with concentration of 5 mg L^{-1} and chemical ZnONPs with concentration of 10 mg L^{-1} lead to the highest biogas production.



Conclusions

The experiment carried out related to the effect of nanoparticles on biogas production give us some indications that ZnONPs improved the biogas production. The 5 mg L^{-1} concentration of green ZnONPs and 10 mg L^{-1} concentration of chemical ZnONPs provided the highest yield of biogas production.

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Comunicazioni orali

“Sistemi colturali e filiere di qualità”

Effects Of Environment x Genotype x Management In Durum Wheat Production In The Mediterranean Basin

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Introduction

Durum wheat (*Triticum turgidum L.subsp. durum*) is the most common crop in the Mediterranean basin, which is the largest durum producing area worldwide. A correct management practice is fundamental to ensure a healthy wheat development and high wheat production. Among the different factors which influence the durum wheat production, the sowing time and the choice of the cultivar are the most important (Bassu et al., 2009). In the Mediterranean basin, it is general practice to sow from November to December, the period of the onset of Autumn precipitations when the risk frost around anthesis is low. Shifting in the sowing window influences the grain yield in different ways, for instance the number of seed per unit area and the kernel weight are affected by the changing of sowing window (Tapley et al., 2013). The optimum sowing window is not a fix time, but rather than it seems to vary in relation with cultivar, location and other factors (Tapley et al.,2013). The complexity to reproduce Genotype x Environment x Management (GxExM) can be overcome using crop simulation models. The aim of this study included i) to evaluate the performance of SiriusQuality2 (SQ2) model, ii) to apply the model to investigate the effects of GxExM on four durum wheat cultivars yield in the selected locations.

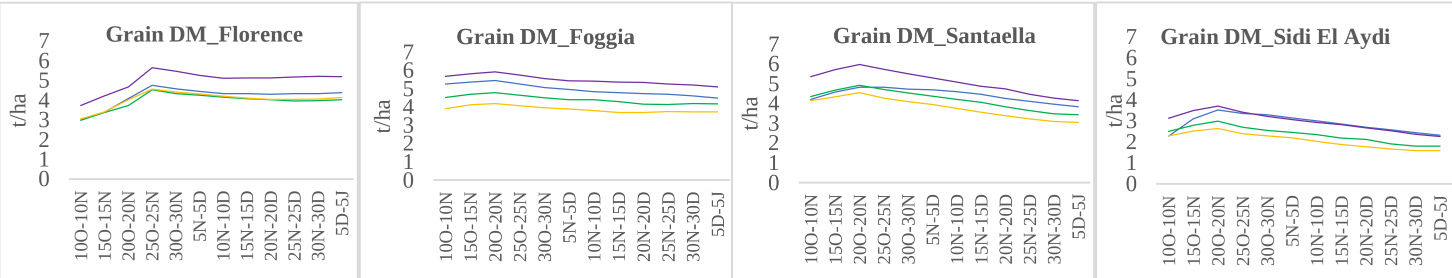
Materials and Methods

For this study, the data are collected from field experiments carried out in Florence and in Foggia, in the Centre and in the South of Italy respectively; in Carmona and in Santaella, both in the South of Spain; in Marchouch, Sidy El Aydi and Khemis Zemamra in Morocco. Different phenologycal stages and aboveground biomass are collected for all sites. SQ2 has been calibrated using an optimization process based on a specific algorithm which, considering the observed phenological and productive data, selected the best combination, with the minimum root mean square error, of parameters involved in the phenological and productive simulation processes. SQ2 has been applied in Florence, Foggia, Santaella and Sidi El Aydi using the typical management inputs. For this study, earlier and later sowing windows has been selected to investigate the better combination sowing window-yield. The sowing windows started on 10th October until the 5th January and they were shifted every 5 days with a duration of 30 days. For weather data, 100 years of daily weather data referred to the present period (1980-2010, CO_2=360 ppm) are generated by LARS Weather Generator (LARS-WG) for feeding the model (Semenov and Stratonovitch, 2015). Previously, LARS-WG has been calibrated for each site using long series of observed daily weather data. SQ2 calibration and validation have been evaluated considering the normalized Root Mean Square Error (nRMSE), the correlation coefficient (r) and the index of agreement (d). To evaluate the significance levels of the GxExM and the other interactions, the analysis of variance (3way-ANOVA) has been made. Instead, to evaluate the significance of difference between the yield distribution at the traditional sowing window and the sowing window which produce the highest yield, a t-test has been used.

Results

The SQ2 evaluation results showed a nRMSE less than 5% for days to heading, days to anthesis and days to maturity for all locations and the d value was very close to 1 (d=1 excellent model performance). For the yield, the biomass and the N grain content nRMSE values were between 10% to 20%. Only for two results of the biomass dynamic in Morocco the nRMSE was between 20% and 30%, while for the others was less than 20%. The ANOVA test results showed that there was not interaction between GxExM, but there were interactions between GxE and between ExM. The results suggested that the durum wheat yield is optimized at a specific sowing window for a growing location, and that the decrease of yield depending on earlier or later sowing respect to the optimum sowing period. In fact, in all locations for all varieties, an earlier sowing window increase the yield (Figure1), but only for Foggia, Santaella and Sidi El Aydi the p-value is significant. In Foggia an earlier sowing window of 30 days increased the yield of 13% for Creso, 15% for Simeto and Amilcar, and of 10% for Karim. In Santaella the yield is increased of was of 27% for Creso, 20% for Simeto and Amilcar, and of 8% for Amilcar with an earlier sowing window of 25 days. In Sidi El Aydi an earlier sowing window of 20 days effected a yield increase of 20% for Karim, Simeto and Creso, and of 10% for Amilcar. For these locations, at the optimum sowing window, an increase of the leaf area index at anthesis, a higher number of grain per m^{-2} and grain weight at maturity is observed. These parameters are all connected with the aboveground biomass accumulated by the plant and consequently by the grain. For all sites the maturity is delayed and also the grain filling is longer with an average of 5 days. These facts have had as consequence the increasing of the crop solar radiance intercepted, allowing a higher accumulation of the dry matter and a more quantity of biomass translocated in to the grain (Bassu et al., 2009). Among the genotypes, Karim and Amilcar are resulted having the highest number of grain per m^{-2} and the highest grain weight at maturity and they seem to ensure the highest yield in all locations.

Figure 1: Average yield (t ha^{-1}) for Creso, Simeto, Amilcar, Karim in Florence, Foggia, Santaella and Sidi El Aydi for the different considered sowing window.



Conclusions

The application of the model has suggested that the environmental conditions of each location influenced the yield cultivar response to the shifting in sowing window, and among the cultivars, Karim and Amilcar have had the best yield performance. The sowing windows traditionally used in Florence, Foggia, Santaella and Sidi El Aydi does not optimize the grain yield. In particular, the sowing window could be earlier in all locations with significative increase on the yield for Foggia, Santaella and Sidi El Aydi. An important aspect to considered is the soil workability, too. In fact, the soil workability implies a critical water content for tillage that could be insufficient at earlier sowing. In conclusion, an earlier sowing window is suggested for the yield maximization but it could in contrast with the agronomical practices. Furthermore, considering the importance of the cultivar choice for the durum wheat production, these results could be useful for a breeding program in the Mediterranean basin to select cultivars with high yield potential.

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Morphological Responses Of Maize Hybrids Under Extreme Flooding Stress

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Introduction

Anoxia is a severe abiotic stress that severely limits crop growth. Maize is very sensitive to an excess of soil moisture as a result of abundant rainfall, shallow water table or heavy soils (Zaidi et al. 2004; Lone et al., 2009). Oxygen (O_2) deficiency interrupts the mitochondrial electron transport chain and promotes anaerobic respiration patterns (Liu et al. 2014). Additionally, O_2 deficiency alters soil nitrogen pathways, reduces nutrient availability and soil pH (Bailey-Serres et al. 2012), and increases the solubility of toxic metals. Through these effects, flooding causes plant growth impairments, plant dying and yield losses. Plant responses to flooding vary according to duration of root submergence, soil and air temperature, plant growth stage and specific genotype tolerance. As climate change is expected to exacerbate frequency and intensity of flooding events, deeper insights on plant adaptation mechanisms to anoxic conditions are necessary. Within this framework, 19 commercial maize hybrids and the inbred line B73 were cultivated under extreme waterlogged conditions during early stage compared to untreated controls, with the aim to assess their tolerance extent to waterlogging and to identify useful morphological markers in screening tolerant genotypes.

Materials and Methods

The experiment was carried out in June 2016 at the experimental farm "L. Toniolo" of the University of Padua, Italy (45°21' N, 11°58' E, 6m a.s.l.). Seeds of 19 commercial maize (*Zea mays* L.) hybrids and the inbred line B73 (as reference) were sown in pots (4 seeds/pot) filled with 4 Kg of 1:1 (w/w) sand and soil mixture, and placed in a greenhouse (16-12 hours, 24-18 °C day/night conditions, and 70% RH) within a randomized experimental design. Sub-superficial flooding was imposed for 6 days, from 11 days after sowing (DAS) (BBCH 13) to 17 DAS (BBCH 15), transferring pots inside a tank, full of water. Three pots/replicates per genotype/treatment were implemented. To prevent water overheating, a balanced continuous water flow maintained water temperature between 20-22 °C. Some morphological parameters were recorded on 3 plants per pot at the end of the experiment (17 DAS) (Table 1).

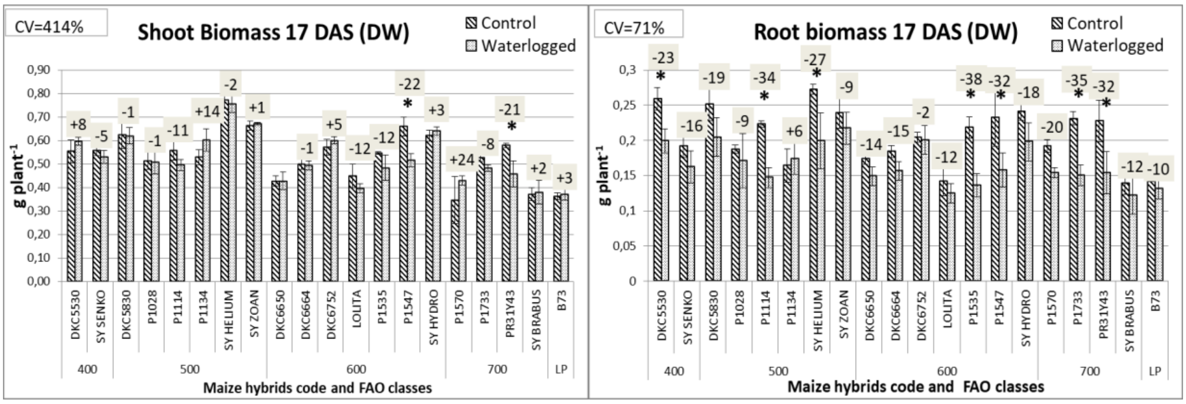
Table 1. Morphological parameters recorded at the end of the experiment (17 DAS) and materials and methods used.

Parameters	Recording materials	Methods
Leaf chlorophyll content	Chlorophyll meter SPAD-502 (Konica-Minolta, Hong Kong)	One SPAD value was recorded on the last developed leaf of each plant
Plant height	Image Gimp 2.8 software	Shoots separated from roots. Shoots of each plant were digitalized at 300 DPI and analyzed
Shoots and roots biomass		Shoots and roots (after digitalization) were dried at 105°C for 72 h and weighed
Root growth: - Length - Diameter - Area	EPSON Expression 11000KL PRO scanner (Epson, Suwa, Japan); KS 300 ver. 3.0 software (Carl Zeiss Vision GmbH, Munchen, Germany)	Roots were digitalized at 400 DPI according to the method of Vamerali et al. (2003). Root images were then analysed for morphological parameters.

Results

At 17 DAS, the SPAD values of plants subjected to waterlogging decreased compared to controls, significantly for 50% of hybrids. A considerable genetic variability was observed, as marked decreases for SPAD readings were recorded in some hybrids (-16% vs. controls), but even slight increases in others (e.g., P1028, P1134, DKC6664, DKC6752). The effect of waterlogging on the culm height was less clear and varied according to genotype choice: 2 genotypes increased significantly this parameter under waterlogging (up to +24%), 4 genotypes showed a slight increase, whereas decreased values were observed in the others. Shoot biomass was not highly affected by waterlogging, as it decreased in 11 hybrids, with only 2 of them showing a significant decrease compared to controls (Fig. 1).

Figure 1. Shoot (DW) (left) and root biomasses (right) (±E.S.; n=3) of waterlogged plants vs. untreated controls of 20 maize



genotypes, at 17 DAS, as grouped in FAO classes (400-700). Above histograms: % variation vs. controls for each hybrid; asterisks: significant variation at P≤0.05; CV: coefficient of variation of differences "waterlogged–control".

Root parameters showed a greater reduction compared to shoot parameters. Root length was severely reduced (by 30-60% vs. controls) in many hybrids, as well as root area and diameter. All the hybrids also showed a decrease in root biomass, significantly in 7 of them (average: -30% vs. controls, $P \leq 0.05$; Fig. 1). Only the P1134 hybrid had a slight increase in root biomass. Although aerial roots were visible in all waterlogged hybrids at end experiment, a different time appearance was observed among them.

Conclusions

When an extreme period of flooding is imposed at early growth stage of maize, a greater damage is detectable at root level compared to the shoot. As large genetic variability exists in the response of shoot and root traits in a large set of commercial hybrids, it is thought that there is large scope for screening towards waterlogging stress tolerance. Hybrids screening for root traits combined with analysis of gene expression may provide the better choice to cope against extreme flooding events.

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Influence Of Agricultural Practices On Bioactive Compounds Of Pigmented Wheat And Maize Grains

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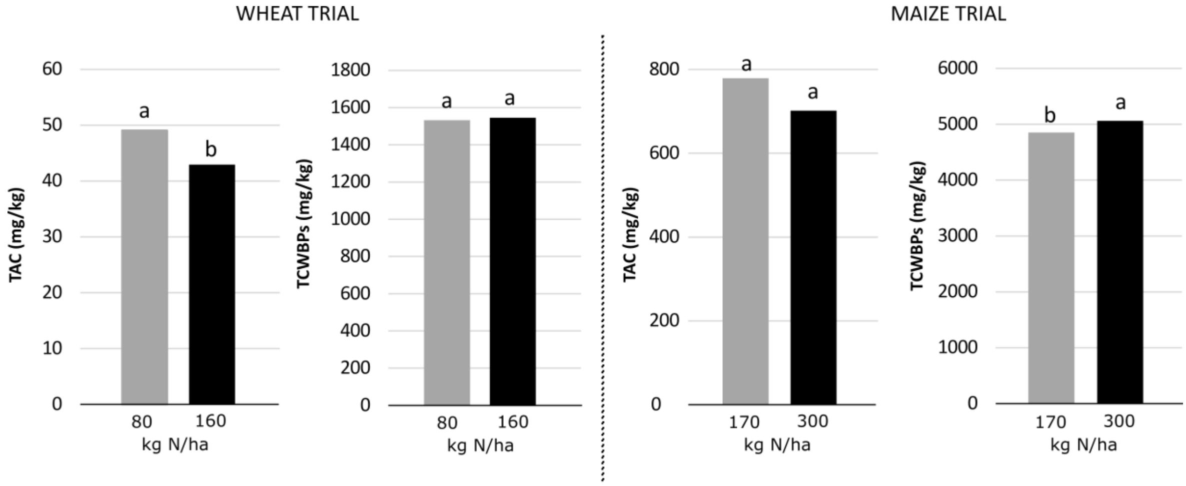
Introduction
Pigmented cereals are important source of biologically active phytochemicals and they could be valuable raw materials for the production of functional foods (Pasqualone et al., 2015). Different types of agricultural practices could influence cereal grain quality in terms of both physical and nutritional characteristics (Mason and D'croz-Mason, 2002), but at present little information is available on the influence of agronomic management on the bioactive compound content of cereals. The present study focused on the effect that nitrogen (N) fertilization rates have on the content of phytochemicals of wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) grains. Moreover, given the increasing use of early sowing in maize cultivation, as a strategy to improve grain yield and reduce mycotoxin contamination, the influence of different sowing times was also evaluated. Field experiments were carried out employing both conventional and unconventional pigmented grains.

Materials and Methods
Two N fertilization rates were compared in wheat and maize experimental trials: 80 - 160 kg N/ha and 170 - 300 kg N/ha, respectively. In the wheat experimental trials, 5 varieties, characterized by red, white, yellow, blue and purple grains, were compared. N fertilization was performed at the tillering (GS 22) and stem elongation (GS 32) stages with ammonium nitrate (granular 26%). In the maize experimental trials 10 genotypes were compared, both open-pollinated varieties and hybrids, characterized by a wide array of kernel traits (color, size and hardness). N fertilization was performed at the end of the leaf development stage (GS 19) with urea (granular 46%). All the other agricultural practices were carried out according to the conventional farm management system.
The effect of the sowing time on phytochemicals of maize grains was evaluated on the same genotypes previously described. Two sowing times were compared: early sowing, performed at the beginning of April and late sowing, performed at the beginning of May. The same amount of N (300 kg/ha) was used in all the plots.
All the experimental trials were carried out in northwest Italy in a completely randomized block design with three replications. The whole-meal flours of both wheat and maize were then analyzed for their content in total cell wall-bound phenolics (Folin-Ciocalteau method), cell wall-bound phenolic acids, total anthocyanins, β-glucans (only for wheat), and carotenoids (only for maize) as well as for their antioxidant capacity by means of the QUENCHER-DPPH method (direct measurement on solid samples).

Results
The present study highlights that N fertilization influenced the content of bioactive compounds of grains of different wheat and maize genotypes, although it usually played a minor role compared to the genotype and the growing season. As far as the wheat experimental trials are concerned, N fertilization did not significantly influence the yield (7 t/ha on average), but higher concentrations of cell wall-bound sinapic acid (+12%) were observed after applying higher N fertilization rates. Nevertheless, the concentration of total cell wall-bound phenolics and the antioxidant capacity were not significantly influenced. On the contrary, both the total anthocyanin and the β-glucan contents decreased (-12% and -13%, respectively) at higher N fertilization rates.
N fertilization also affected the content of the main carbon-containing secondary metabolites of whole-meal maize flour, especially in years characterized by high rainfall levels related to a higher N leaching from the soil. Higher N fertilization rates significantly increased not only the yield (+8%), but also the concentrations of total cell wall-bound phenolics (+4%), lutein (+13%) and zeaxanthin (+10%). Nevertheless, the concentration of the main cell wall-bound phenolic acids, and the antioxidant capacity were not significantly affected. It is worth

noting that even if fertilization did not significantly influence (p=0.061) the total anthocyanin content of maize grains, as observed for wheat, this class of phytochemicals was lower (-10%) the higher N fertilization rate was (Figure 1).

Figure 1. Influence of the N fertilization on total anthocyanin content (TAC) and total cell wall-bound phenolics (TCWBPs) of unconventional pigmented wheat and maize grains. The results are expressed on a dry weight basis. TCWBPs of maize and wheat



whole-meal flours were extracted by means of different extraction methods. Bars overlooked by different letters are significantly different, according to the REGW-Q test.

In temperate regions, the advance or the delay of sowing of maize can have a remarkable influence on the environmental conditions to which the grain is exposed during its ripening. As expected, early sowing significantly improved both grain yield (+26%), thousand kernel weight (+3%) and test weight (+2%). Sowing time significantly influenced also the chemical composition of maize grains, with an increase in the concentration of cell wall-bound phenolics (+5%), *p*-coumaric acid (+10%), sinapic acid (+10%) and β-cryptoxanthin (+23%) and a decrease in the concentration of lutein (-18%) and total anthocyanins (-21%) in early sown plots.

Conclusions

This study highlights that the agricultural management, optimized by farmers in order to increase the yield and the quality of cereal grains, can influence the concentration of healthy molecules such as phenolic compounds, β-glucans and carotenoids. Cell wall-bound phenolics were found higher in grains of well-fertilized wheat and maize plants and after early sowing of maize. On the contrary, anthocyanins, responsible for the blue-purple hue of unconventional pigmented grains, showed an opposite trend. Other compounds, such as lutein and zeaxanthin, increased in well-fertilized maize, while decreased in early sown plants. The combination of genotypes naturally rich in bioactive compounds with agricultural practices optimized according to the growing season is an effective strategy for the production of new food products and ingredients with added value for consumer health.

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Oregano: A Long-Established Plant For Modern Farming. Twenty Years Of Experimental Studies In The Mediterranean

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Introduction

Modern farming is expected to carry out a number of different functions, frequently not linked to mere production, and to provide a series of crucial services for the ecosystem, such as preserving the landscape and biodiversity, safeguarding soils, maintaining traditions of the rural population, etc. These functions can only be guaranteed if farming activities manage to produce sufficient revenue. In Sicily, one of the sectors of greatest financial interest for many rural areas, especially marginalized areas or at risk of marginalization, is that of traditional food crops. Today, it is still possible to find local ecotypes of wild species which are not only of interest to the food industry but also to the herbal and medicinal production sector. It is in these areas, where multifunctional farming plays a hugely important role in the financial sustainability of farming, that the cultivation of oregano is well placed as a strategic crop. Oregano is able to conjugate modern farming techniques, providing new agro-ecosystem management models with conservative techniques to safeguard environmental equilibriums. *Origanum vulgare* subsp. *hirtum* (Link) Ietswaart is a species which grows wild in many parts of Sicily, at an elevation ranging from 0 to 1,700 m a.s.l (Pignatti, 2003). The species does not require large inputs and flourishes even in marginal areas (Leto, 1994). It is a widely-used aromatic plant and enjoys great international trade. The harvesting of wild oregano is undoubtedly the oldest method of gathering the plant used by the local community. This method is able to satisfy limited requirements but is not suited to large-scale use (Licata et al., 2016). From its characteristic use as an aromatic spice for food, other less traditional and mainly industrial (Napoli et al., 2012) uses have been adopted, based on its antibacterial, antifungal, antioxidant and medicinal properties (Tuttolomondo et al., 2013). This paper looks at over twenty years of experimental studies on oregano (*Origanum vulgare*subsp. *hirtum* (Link)) which have contributed to the transition from species gathered in the wild to farm crop.

Material and Methods

Experimental activities began during the second half of the 1990s at the Dept. SAAF of the University of Palermo, and focused on the cultivation of oregano found in Sicily in the wild. More specifically, studies concerned:

a. Ethnobotanical survey on the species
b. Identification, gathering and conservation of O. vulgare germplasm
c. Biomorphological, yield and quality characterization of the ecotypes
d. The influence of environmental factors on quality and yield of essential oils
e. Phytochemical characterization and evaluation of antioxidant action of oregano extracts and essential oils
f. Cultivation techniques of the species

Results

Ethnobotanical studies confirmed the use of *O. vulgare* in folk tradition. It is used in many traditional Sicilian recipes as an aromatic spice in salads, fish and meat. Local populations also use oregano as a medicinal plant against common colds, flu and stomach upsets. From the study of the island, a number of different sites were identified with wild *O. vulgare* populations. All of the accessions sampled were identified as *O. vulgare* subsp. *hirtum* (Link) Ietswaart based on their morphological characteristics. Studies regarding quality and yield evaluation showed that essential oil (EO) yields were affected by environmental factors linked to harvesting sites, whilst chemical composition was more linked to genetic characteristics of the various biotypes. Of the components found in the oregano essential oils, thymol was found in greatest quantities, with a higher concentration in the inflorescences compared to the leaves. Oregano was found to be highly suited to vegetative propagation by herbaceous stem cuttings without hormone treatment. Layout density tests showed the effects of this factor on various parameters. Plant density determined significant variations in fresh biomass production and other parameters. Higher densities showed higher yields, thicker flower layer and larger plant size. Plant layout density did not show any statistical differences regarding both EO percentages and chemical composition. Although not demonstrating statistically significant differences, thymol showed increasing trends both in flowers and leaves when moving from a high density to a lower density, however. Plant layout density was not found to exert any influence over the number of glandular trichomes. The species showed good antioxidant and antimicrobial properties against many pathogen microorganisms. The chemotypes with greatest antioxidant/radical scavenger action were those containing thymol, gamma-terpinene and p-cymene in varying proportions. Regarding mechanical harvesting tests, studies showed that it is possible to reduce production costs by using a customized reaper-binder produced by BCS. Furthermore, it was shown that the double-row layouts, found to be more productive on average than single-row layouts, were more suited to mechanical harvesting. The two harvesting methods (manual and mechanical) did not influence the quality and quantity of the biomass produced.

Conclusions

The twenty years of experimental activities on wild oregano have led to the characterization of germplasm both on a production and quality level, the definition of cultivation systems and the mechanization of certain stages of cultivation, such as harvesting. This locally-gathered material with high quality levels and good yield production was and still is of interest for specialized farms. This is confirmed by high levels of trade in recent years and with exports to Europe and the USA. The surface area used for oregano farming has increased as has the number of farms producing oregano, above all in marginal and vulnerable areas in Sicily. Thanks to the high performance of the species, which requires low growth inputs, modern farming techniques can also be employed, providing new agro-environmental management models with conservative methods to safeguard the environmental equilibriums. These aspects, together with the financial implications from its many industrial uses, make this crop of great interest to rural development.

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Poster

“Sistemi colturali e filiere di qualità”

Beyond Beer With Hops: Fresh Spring Shoots And Their Proximate Composition From Ten Commercial Cultivars

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Introduction

Hop (*Humulus lupulus* L.) is grown commercially for its inflorescences called “hop cones", but it is also known for its young spring shoots which can be eaten like asparagus. The Mediterranean region is a new growing area for cultivated hop, but the use of wild plant as a vegetable is quite popular and its shoots are cooked according to traditional recipes. Even though numerous shoots sprout from the buds of the rootstock in early spring, just a few of them (from three to six) are trained up strings for cone production, while the others are removed by pruning and they are considered as a useless by-product of the supply chain. Conversely, taking into account the renewed attention towards the recovery of food traditions and the demand for a healthy diet, the use of surplus shoots as vegetables may be a valuable additional source of income for hop growers. From this point of view, very few data are available on the shoot yield potential and nutritional composition of young spring shoots from cultivated hop. Thus, the aim of this study was to verify if the genetic factor significantly affects shoot yield and proximate composition as previously demonstrated for cone production in Central Italy (Rossini et al., 2016).

Materials and Methods

The experiment was carried out in 2017 at the experimental farm of the University of Tuscia, Central Italy (42°26′ N, 12° 04′ E, altitude 310 m a.s.l.). The experimental design was a randomized complete block with three replicates; treatments were varieties. Ten female hop cultivars from USA, England, Germany and New Zealand were used. These genotypes were selected among the hop cultivars most used to flavor beers in the Italian brewing industry. Their maturity timelines and brewing use are reported in Table 1. For each cultivar, shoots were harvested after the completion of bine training. At harvest time, young shoots generally had 5 or 6 nodes completely differentiated and they were from 20 to 60 cm in length. Fresh shoots from each plot were counted, labeled, cut at the marketable length of 20 cm and weighed. Then, to determine dry matter (DM) yield, the samples were oven-dried at 55 °C until constant weight. Crude protein (CP), ether extract (EE), crude fibre (CF) and ash were determined using dry samples, according to AOAC Official Methods (AOAC, 2006). Data was subjected to the analysis of variance (ANOVA) and significantly different means were separated at the 0.05 probability level by the least significant difference test.

Table 1. List of hop cultivars used for the experiment, their harvest time, brewing use and origin.

Cultivar	Harvest time	Brewing use	Origin
Cascade	M	Dual purpose	USA
Centennial	M	Dual purpose	USA
Challenger	L	Dual purpose	UK
H. Aroma	E	Aroma	New Zealand
H. Bitter	E to M	Bittering	Germany
H. Magnum	L	Bittering	Germany
HNB	E to M	Dual purpose	UK
H. Spat	L	Aroma	Germany
Nugget	M	Dual purpose	USA
Omega	M	Bittering	UK

Harvest time: E =early; M= medium; L =late.

Results

As shown in Table 2, a significant genotypic variability was found for both shoot production and proximate composition. The number of shoots picked up per plant ranged from 29 of 'H. Northern Brewer' to 74 of 'H. Magnum', with an average of 49.5. This value has more than doubled if compared to the 20 shoots per plant found by Ruggeri et al. (2018), sampling two and three-year hop plants in the same pedoclimatic conditions. The top yielding varieties were 'H. Magnum' (205 g per plant), 'Centennial' (about 153 g per plant) and 'Omega' (about 119 g per plant), while 'H. Northern Brewer' and 'Challenger' had the lowest yields (54 and 57 g per plant, respectively). Shoot dry matter content at harvest markedly varied among varieties, ranging from 19% for 'H. Spat' to 29% for 'Challenger' (data not shown). As for the proximate composition, CP content varied from 21.6% DM for 'Challenger' to 31.2% DM for 'H. Aroma'. Six out of ten cultivars had CP content between 24 and 28% DM, with an average value of 26.2% DM. In this study, EE ranged from 3.5% DM to 6.3% DM and CF from 11.9% DM to 17.3% DM. The top yielding cultivar 'H. Magnum' showed also the highest fat content, while 'Omega' the lowest one. Conversely, 'H. Magnum' had the lowest fibre content, while 'H. Bitter' the highest one. The ash content varied from 10.5% DM to 11.6% DM, with 'Cascade', 'H. Northern Brewer' and 'Omega' having the highest values and 'H. Aroma' and 'Challenger' the lowest ones.

Table 2. Number of shoots before training, marketable shoot yield and proximate composition of the ten tested cultivars.

Cultivar	Shoots (no. plant^{-1})	Shoot yield* (g plant^{-1})	Ash (% DM)	CP (% DM)	EE (% DM)	CF (% DM)
Cascade	43.7 bd	90.1 cd	11.64 a	27.04 cd	3.88 cd	16.50 ab
Centennial	57.7 ad	153.1 ab	10.72 bd	24.02 df	4.23 c	15.60 bd
Challenger	37.3 cd	56.6 d	10.56 cd	21.56 f	4.03 c	14.10 de
H. Aroma	62.0 ac	90.4 cd	10.48 d	31.19 a	4.90 b	14.20 de
H. Bitter	34.7 cd	65.6 cd	10.61 bd	22.36 ef	4.73 b	17.30 a
H. Magnum	74.0 a	205.2 a	10.73 bd	26.75 cd	6.30 a	11.90 f
HNB	29.0 d	53.8 d	11.44 ab	28.06 bc	3.93 c	12.90 ef
H. Spat	44.0 bd	67.5 cd	10.62 bd	30.53 ab	4.15 c	16.05 ac
Nugget	42.3 bd	63.0 d	11.30 ad	24.73 de	4.95 b	12.90 ef
Omega	70.3 ab	118.8 bc	11.39 ac	25.85 cd	3.53 d	14.70 cd

CP: crude protein; EE: ether extract; CF: crude fibre;* fresh weight at the marketable length of 20 cm. Within each column, means followed by the same letter are not significantly different ($P<0.05$).

Conclusions

Hop cultivars differed significantly for all the traits investigated. The best performing cultivars for shoot production were 'H. Magnum', 'Centennial', 'Omega' and 'H. Aroma', while 'H. Northern Brewer', 'Challenger' and 'H. Bitter' showed the lowest yields. The data from proximate analysis revealed that the hop shoots were a rich source of proteins, dietary fibre but also of minerals. Further studies should deeply investigate the chemical composition of hop shoots, in order to better understand their potential benefits for human health.

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Effects Of Foliar Fertilisation As The Only Way Of Nitrogen Supply In Common Wheat

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Introduction

Grain protein content and gluten pattern play an essential role in the quality of wheat flours for bakery industry. In this regards, nitrogen fertilisation is a crucial affecting factor (Gooding and Davies, 1992). Foliar application is an alternative way of N supply and recognised as more efficient compared with soil-applied granular fertilisers, particularly under drought or leaching conditions (Visioli et al., 2017). Up to date, very few studies have reported the use of foliar N spraying to replace the main N dose conventionally applied to the soil, while the most considered late-season (between booting and anthesis) foliar supply of small doses (Readman et al., 2002).

This research compared yield and grain quality under conventional N management (i.e., granular fertilisers applied to the soil at tillering and stem elongation, together with a small dose at anthesis by foliar spraying) vs. foliar spraying of the entire dose split at different growth stages.

Materials and Methods

The trial was carried out in open field at the experimental farm of the University of Padova at Legnaro (Padova, NE Italy) during the 2016/17 growing season in 60 m^2 large plots arranged within a completely randomized block design (n=3). The var. Bologna (SIS, Bologna, Italy) was sown on 3 November 2016 (density 450 seeds m^{-2}; rows 12.5 cm apart), and harvested on 22 June 2017. Fertilisation doses and timing of N supply are detailed in Table 1.

Table 1. Dates and growth stages of N applications (kg ha^{-1}).

Treatment	N split					Total N dose
	Pre-sowing	End tillering (ZDS 23)	Stem elongation (ZDS 32)	Booting (ZDS 40)	Anthesis (ZDS 65)	
	31 Oct 2016	16 Feb 2017	15 Mar 2017	13 Apr 2017	11 May 2017	
S	32 (S)	60 (S)	60 (S)	-	8 (F)	160
F16	32 (S)	16 (F)	16 (F)	16 (F)	16 (F)	96
F12	32 (S)	12 (F)	12 (F)	12 (F)	12 (F)	80
F8	32 (S)	8 (F)	8 (F)	8 (F)	8 (F)	64

ZDS= Zadoks growth stage; S= soil application of N as ammonium nitrate (27% N); F= foliar spraying of N as UAN with 430 L water ha^{-1}.

Shoot parameters (SPAD, NDVI, biomass) were periodically revealed during the crop cycle, while yield the thousand seed weight (TSW), grain protein content, glutenins (GS) and gliadins (Gli) at harvest.

Results

The seasonal averages of shoot parameters (3 dates) were not significantly different among treatments. SPAD and NDVI showed only a minimal decrease under foliar N supply, while shoot biomass positively increased with foliar application, particularly in the F12 treatment (+12% vs. control S). Grain yield was very stable across treatments, while foliar N fertilisation led to appreciable, although not significant, improvements of the TSW (Table 2). Considering that the amount of N fertilisers under foliar supply was 40%, 50% and 60% lower than control S, in F8, F12 and F16, respectively, these results confirm the high efficiency of foliar fertilisation (Woolfolk et al., 2002).

Table 2. Vegetational indices (seasonal mean) and yield components. In brackets: % variation vs. conventional management S. Letters: statistical comparisons among treatments (Newman-Keuls test at $P \leq 0.05$).

Treatment	Shoot parameters			Grain parameters	
	SPAD	NDVI	D.W. (kg m^{-2})	Grain yield (t ha^{-1})	TSW (g)
S	46.8 a (ref.)	0.851 a (ref.)	1.36 a (ref.)	7.61 a (ref.)	32.7 a (ref.)
F 16	44.6 a (-5%)	0.847 a (-0.5%)	1.39 a (+2%)	7.64 a (+0.5%)	34.0 a (+4%)
F 12	44.3 a (-6%)	0.846 a (-1%)	1.52 a (+12%)	7.55 a (-1%)	34.6 a (+6%)
F 8	43.6 a (-7%)	0.846 a (-1%)	1.43 a (+5%)	7.56 a (-1%)	34.7 a (+6%)

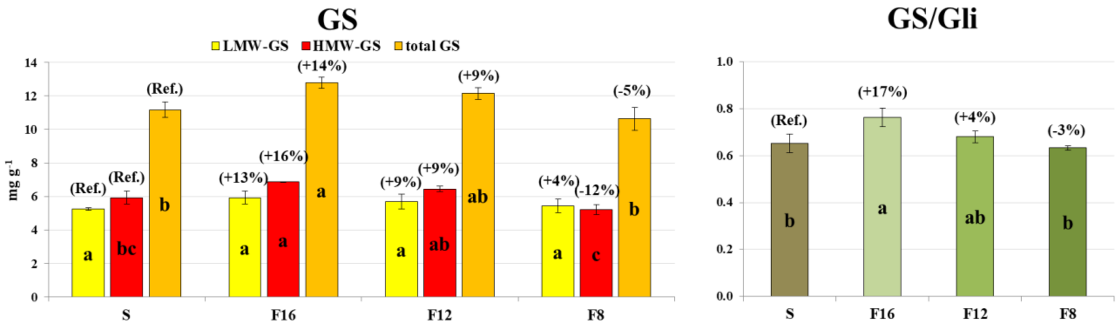

Figure 1. Low molecular weight (LMW), high molecular weight (HMW) and total glutenin subunits (GS) (left) and glutenins/gliadins (GS/Gli) ratio (± S.E.; n= 3) (right) in N treatments. In brackets: percentage variation vs. soil-fertilised treatment. Letters: comparisons among treatments within same parameter (Newman-Keuls test at $P \leq 0.05$).

A significant increase in total glutenin-subunit (GS) concentration was obtained with F16 (+14%; $P \leq 0.05$) compared to the soil-fertilised control (S), mainly due to the high molecular weight subunits (HMW-GS). A significant improvement of the GS/Gli ratio was also measured for the F16 treatment (+17%; $P \leq 0.05$).

Conclusions

In the fertile silty-loam soil of Legnaro, a marked reduction of N fertilisation in common wheat is feasible without compromising yield and flour quality when N is applied entirely by foliar spraying, with at least 3 split applications in order to avoid foliar phytotoxicity. Foliar application has even the advantage to improve the bread-making quality of flour through increases of the HMW-GS (Edwards et al., 2003) if N reduction is limited to 40%. Environmental benefits can be expected by this new N management practice, although some extra costs should be sustained for the purchase of liquid fertiliser and its field application.

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Nutraceutical Parameters Of Soybean Varieties Under Organic And Conventional Management

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Introduction

Soybean is a fundamental plant in the crop rotation of NE Italy. In recent years, the qualitative characteristics of soybean grains, like anti-nutritional content, polyphenolic and antioxidant activities, isoflavone concentration and the 11S/7S protein ratio, have assumed increasing importance due to the growing attention to the nutraceutical function of plant foodstuff. In this work, we studied the response of four soybean varieties under organic vs. conventional management in order to set-up a cultivation protocol for soybean with improved nutraceutical value.

Materials and Methods

Four varieties of soybean, i.e., M35, M22, Pedro and Demetra, belonging to maturity class 1 were cultivated in a pot trial according to both conventional and organic managements and soil provenance. The experimental design was completely randomized with 4 replicates. Large pots (35 cm upper diam., 28 cm lower diam., 30 cm height) were filled with soil coming from two different sites of the Experimental Farm of the University of Padova at Legnaro (conventional management) and Pozzoveggiani (organic management), respectively, very close each other. In both cases, the soil texture was silty-loam, which annually receives chemical fertilizers vs. cow manure, respectively, for many years. The variety M35, which has a more pronounced branching attitude, was also cultivated in open field of the two sites/managements in 3-replicated plots. The branch and main stem biomasses, together with pod weight and grain yield were evaluated under the two cultivation methods of both experiments. The auxin concentration in apexes of the main stem and the first-order branches was measured with a HPLC fluorimetric sensor (Kim et al., 2006) and expressed as concentration ratio. Grain samples were analysed for some nutraceutical parameters, such as anti-nutritional activity (A.A.) (Liu et al., 1989), polyphenolic activity (F) and antioxidant activity (DPPH) (Shaidi et al., 2015), and the isoflavone concentration (Hubert et al., 2005). Seed isoflavones were extracted using water or methanol, the first as low environmental impact extracting agent, and the second as the standard reference method. The grain yield of the variety M35 was also analysed by electrophoresis in order to identify the protein sub-units profile. An index Q of grain quality was calculated as follows:

$Q = DPPH \times F / A.A.$

Results

The higher soil organic matter content in organic management compared with the conventional one (2.5% vs. 1.8%) led to increased plant branching and grain yield on branches (range: from +10% to +59%, depending on variety) (Fig. 1). This was probably due to a modification of the plant auxin balance caused by the higher soil abundance of indole derivates (i.e., indole-3-lactic acid and3-Hydroxytriptamine) in organic management. We also found that the different branching attitude of varieties was related to isoflavone solubility in water: seeds of branches had 5% higher concentration of malonyl and glucosyl forms than seeds of the main stem, and these forms are more soluble in water than other forms (Fig. 1). The quality index Q of grains was 64% higher in variety M35 than in Demetra, but with greater variability (Fig. 2). The Q index was also 30% and 92% higher in organic farming compared with conventional management in pot and field trial, respectively. In var. M35, organic cultivation also favoured the lowering of the 11S/7S protein subunit ratio (-35.4%), while the opposite occurred under conventional cultivation.

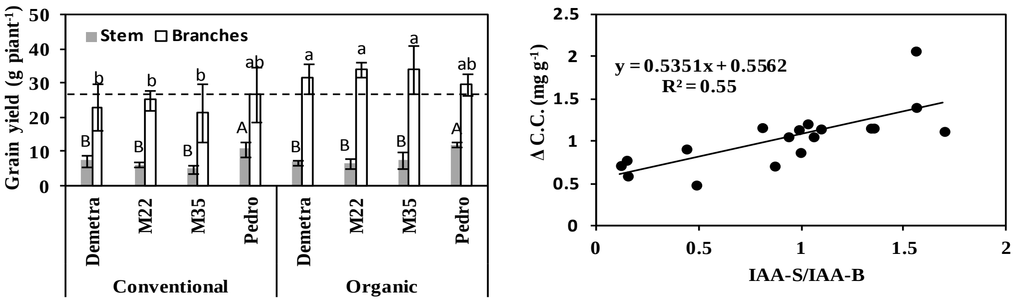

Figure 4. Grain yield on stem and branches in four soybean varieties and two managements (left), and regression between main stem-branches auxin ratio (IAA-S/IAA-B) and isoflavone lost with water vs. methanol extraction (right).

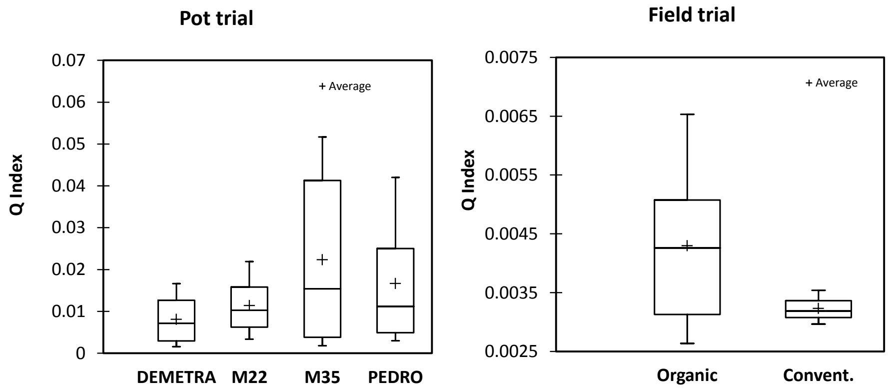

Figure 2. Quality index Q in four pot-cultivated soybean varieties (left) and two managements (right).

Conclusions

Varietal choice and agricultural management strongly affect plant morphology/branching and quality of soybean grains. These results suggest that the technological quality of soybean grains can be efficiently driven through the cultivation method. Grain stocks produced under organic farming seems more suitable for nutraceutical uses, they having high antioxidant and low antinutritional activities, and higher water solubility of isoflavones; the increased proportion of 7S proteins also suggests the use for high-density productions (e.g., Tofu, Tempeh, protein isolates), while grains produced under conventional management appear more suitable for livestock feeding and low-density food productions (e.g., soya-based beverages).

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Natural Colorants From Safflower Florets In Response To Sowing Time And Plant Density

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Introduction

Safflower (*Carthamus tinctorius* L.) is an oilseed crop grown in many semiarid areas of the world for use as vegetable and industrial oils (Weiss, 2000). Due to its drought tolerance, this plant is well adapted to dryland conditions, thus offering more chances to succeed than major crops in a global climate change context (Yeilaghi et al. 2012). Recently, natural pigments have been drawn general attention due to restrictions on using synthetic pigments for food colorants. Dried petals of safflower contain edible pigments largely applied in the past as textile dye but that are being currently used as a natural food colorant (Cho et al. 2000). In semiarid cultivation areas, early sowings in safflower may allow the crop to better exploit the water stored into the soil during the rainy season, and to escape part of the hot period during flowering. Besides, low plant spacing may counteract the deteriorative effect of high light intensity upon pigments. In this study, carried out in the framework of the EU H2020 project 'MAGIC', the effects of sowing time and plant density on florets and pigment production were examined in a cultivar of safflower under a typical Mediterranean environment.

Materials and Methods

Field experiment was carried out in 2017 in a flat site of Eastern Sicily (South Italy, 10 m a.s.l., 37°25'N Lat, 15°30' E Long), on a Vertic Xerochrepts soil. The cultivar 'Catima' of safflower was used for the experiment. In a split-plot experimental design with three replicates, the effects of three sowing times (I: 24/02, II: 28/03, III: 26/04) and two plant densities (25 and 50 plants/m^2) upon flower heads, florets and pigments production, were assessed. Before sowing, 100 kg/ha of P (as mineral perphosphate), K (as potassium sulfate) and N (as ammonium sulfate) were distributed. Irrigation was applied up to plant establishment, and then it was suspended. A total of 460, 490 and 700 m^3/ha was distributed in sowing time I, II and III, respectively. During flowering, flower heads from all plants in two rows were harvested twice for sowing I (June 22 and 28) and sowing II (June 28 and July 6) and once for sowing III (July 7), and measured for number and weight, then heads were sampled for fresh and dry weight (at 65°C) measurements, and florets were separated from heads and measured for fresh and dry weight. Total heads (number), fresh and dry weight of total heads and florets (per plant and m^2) and the incidence (%) of florets on total head weight, were calculated. Pigments were extracted from finely grounded air-dried florets (ca. 10 mg) in a Na_2CO_3 solution (1% w/v in water) and analysed by HPLC. Safflomins (yellow pigments) were visualized and quantified at 410 nm; carthamin (red pigment) was detected and quantified at 520 nm. All analyses were carried out in triplicate. Data for heads and florets yield (total of two harvests, for I and II sowing time) (per plant and m^2) and those for pigments were analyzed by a 2-way ANOVA. Means were separated by the Student-Newman-Keuls (SNK) test (at $p < 0.05$).

Results

In this study, sowing time had greater impact than plant density on heads and florets productivity. The shift of sowing from late February to late April induced a progressive decrease in plant and crop productivity, in terms of total flower heads (Fig. 1), as a consequence of the reduced number and size of flower heads following the delay in sowing time (data not shown). Minor spacing between rows decreased yield per plant. This result is predictable when water and light become limiting factors for biomass accumulation. However, increased plant population overcompensated yield losses per plant at higher density, leading to significantly greater total production of heads per unit area.

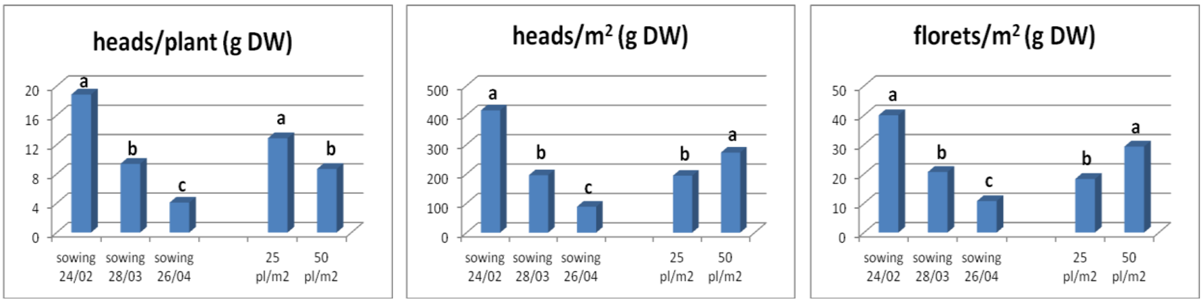

Fig. 1. Mean effects of sowing time and plant density on heads and florets yield in safflower (‘*sowing time* x *plant density’*, ns).

Tab. 1. Florets incidence (%) on total head weight.

Sowing time	Plant density (plants/m^2)	Florets on head weight (% DW)	
		I harvest	II harvest
I (24/02)	25	8.15	9.78
	50	7.90	11.66
II (28/03)	25	8.89	10.91
	50	9.58	12.46
III (26/04)	25	9.13	-
	50	9.56	-

Florets contribution on total head weight increased with the shift of sowing time (Tab. 1), mostly because single head weight decreased (data not shown) but that of florets was constant. However, according to heads yield, florets yield was the greatest with the earliest sowing (that of late winter). The study also revealed that the incidence of florets on total head dry weight may be increased through manipulation of plant density. Indeed, greater incidence overall was measured at higher plant density. This fact, together with higher heads yield, resulted in greater florets yield at 50 plants/m^2 density. Both yellow (safflomins) and red (carthamin) pigments (measured at the 1st harvest for each sowing time) were the lowest in florets from the last sowing (that of late April) (Fig. 2). High plant density had negative impact on the content of safflomins but positive impact on that of carthamin, irrespective of sowing time (no interaction).

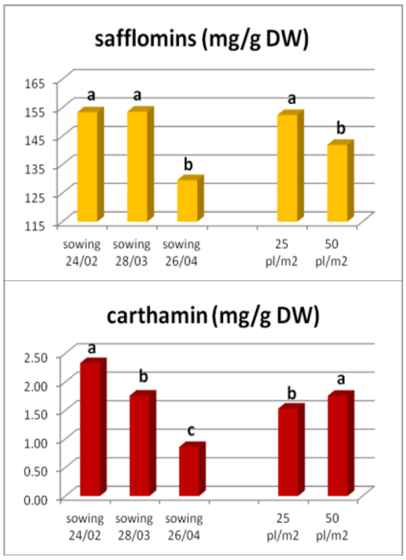

Fig. 2. Mean effects of sowing time and plant density on safflower pigments (‘*sowing time* x *plant density’*, ns).

Conclusions

Early sowing in late February in safflower had positive effects on florets production and pigments content. High plant density increased heads and florets yield, while having negative (safflomins) or positive (carthamin) effects on pigments.

The addition of pigment extracts from safflower may represent an added value to food products (e.g. icecream). However, despite its several uses, safflower remains a minor crop. Through additional research involving genetic resources, this plant has a high potential for further expansion and development.

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Influence Of Field Inoculation With Arbuscular Mycorrhizal Fungi On Wheat Gluten Quality

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Introduction

Arbuscular mycorrhizal fungi (AMF) are beneficial microbes, ubiquitous in natural and agricultural ecosystems. AMF establish a symbiosis with the majority of indigenous and cultivated plant species in terrestrial environments, supplying mineral nutrients to the plants in exchange for photosynthetically fixed carbon (Pellegrino et al., 2015; Ercoli et al., 2017). Although many field studies have assessed the benefits on wheat due to inoculation of AMF and have addressed the possibility of increasing wheat nutrient uptake, growth and yield (Pellegrino et al., 2015), little information is available about the effect of AMF inoculation on gluten protein quality. The aptitude of wheat to be processed for the production of different foods is mostly determined by gluten proteins composition and structure. Thus, both quantity and quality of gluten proteins are important traits for the quality of final products, as well as for their aggregation level. In this study, we analysed the effect of field inoculation with AMF on gluten protein composition and aggregation in four wheat genotypes.

Materials and Methods

The field experiment was carried out at the Centre of Agro-environmental Research (CIRAA) in San Piero a Grado (Pisa) during the growing season 2015-2016. A full factorial experiment with AMF and wheat variety as treatments was arranged in a completely randomized design (replicated plot: n=3; 500 m^2). Four Italian old varieties (Autonomia B, Frassineto, Risciola and Verna) were inoculated with AMF by coating the seeds with 0.55 g m^{-2} (5,556 spore m^{-2}) of *Rhizophagus irregularis* MUCL43194. Nitrogen fertilizer was applied as urea at tillering and at stem elongation at 40 and 40 kg N ha^{-1}, respectively. At physiological maturity plants were harvested by a plot combine. The wholemeal flour was sampled for the extraction of gliadins and glutenins that were separated by SDS-PAGE. Gels were analysed by software ImageQuant Tl (GE Healthcare Bio-Sciences AB). On the basis of their molecular weight, gliadins were subdivided into two classes (ω- and α-γ) and glutenins into HMW-GS and LMW-GS and the amounts of sub-fractions were calculated relative to the total extracted storage proteins according to De Santis et al. (2017). The size distribution of gluten proteins (gliadin monomers and glutenin polymers) of flour was determined by SE-HPLC (Tronsmo et al., 2002). Chromatogram peaks were integrated, and relative proportions of the different peaks (fractions) were calculated as {(peak area)/(total peak area)×100}, where the total peak area was the sum of peak areas of the two chromatograms (from the SDS- Statistical analyses soluble and the sonicated extract) from each sample (fig.1). The ratio between monomeric

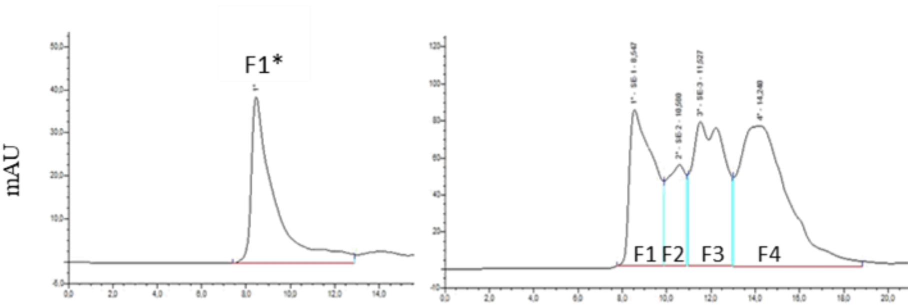


Fig.1. Size-exclusion chromatograms for sonicated proteins (a) and SDS-soluble proteins (b)

and polymeric proteins was defined as (F3+F4)/(F1*+F1+F2). The ANOVA procedure was adopted according to the randomized complete design with three replicates. The differences in the means were determined using Tukey's test. Statistical analyses were performed using the JMP software package, version 8.1 (SAS Institute Inc., Cary, NC, USA).

Results

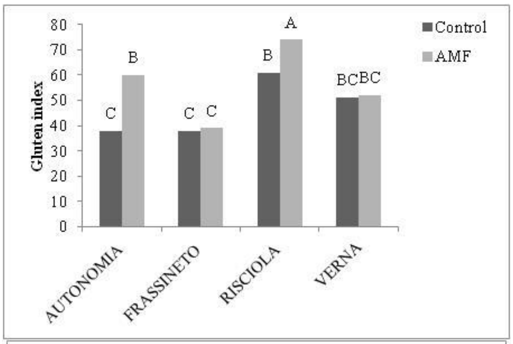
The effect of the interaction genotype x AMF inoculation on protein content and storage protein composition is showed in table 1. Genetic differences in protein content and in the expression level of gluten sub-units were observed. Generally, an increase in HMW/LMW, ω-gliadin and no difference in α, γ- gliadin were observed under AMF inoculation.

Table 1. Effect of the interaction genotype x AMF inoculation on storage protein composition.

	Autonomia		Frassineto		Risciola		Verna	
(%)	Control	AMF	Control	AMF	Control	AMF	Control	AMF
Protein content	14.2abc	12.3bcd	16.1a	14.6ab	9.8d	10.8cd	13.3abc	13.1abc
ω-gliadin	7bc	9abc	8bc	12a	5c	10ab	6c	8abc
α, γ-gliadin	35ab	39a	39a	37ab	37ab	38ab	39a	32b
HMW	17b	18b	13c	18b	19ab	19ab	15bc	22a
LMW	4a	35abc	4a	34bc	38ab	32c	39ab	37abc
HMW/LMW	0.43bcd	0.51bc	0.32d	0.54b	0.51bc	0.61a	0.4cd	0.6a

In each row, mean values followed by different letters are significantly different (P<0.05) according to Tukey's test.

a



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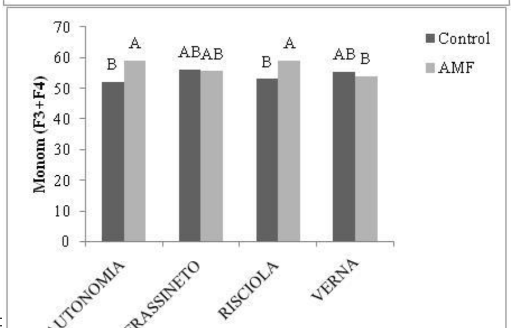

F
inoculation on gluten index (a) and monomeric protein (b). Mean values followed by different letters are significantly different (P<0.01) according to Tukey's test.

In fig. 2 the interaction genotype x AMF inoculation relative to gluten index and monomeric protein (F3+F4) is reported. The genotypes Autonomia B and Risciola showed a significantly higher gluten index under AMF inoculation, consistent with a significant increase in monomeric protein percentage. Moreover, the two parameters showed a significant correlation (r=0.47; P≤0.01).

Conclusions

The AMF inoculation differently influenced the four wheat genotypes. In particular, an improvement in gluten technological performance was observed in Autonomia B and Risciola probably due more to an increase in monomeric protein fraction than to a different protein composition.

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The Effects Of Different Postharvest Treatments On Shelf Life Of Pomegranate Fruits

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Introduction

Pomegranate (*Punica granatum* L.) is a perennial plant originating from Central Asia and now cultivated worldwide in many variable climatic conditions, indicating its flexibility, adaptability, and wide range of genetic diversity which is demonstrated by over 500 globally distributed varieties. Mediterranean countries are the main location of commercial cultivation of pomegranate, followed by Asian countries and areas of the former USSR. The pomegranate fruit has raised great attention in the last years thanks to its health benefits as it is an interesting source of potential active compounds including organic acids, vitamins, sugars, and phenolic components. It has been shown that the antioxidant activity of pomegranate juice is 20% higher compared to other beverages like cherry juice, orange juice, red wine, iced tea (Seeram *et al.*, 2008). Also, recent clinical research studies on the antioxidant activity have pointed out the antiproliferative and antiangiogenic effects of pomegranate juice in Multiple Myeloma (Tibullo *et al.*, 2016).

Postharvest management of pomegranate fruits is a critical challenge and it is necessary to find alternative treatments in order to minimize losses. In this regard, the edible coatings -alone or combined with acidifying natural substances, can play an important role in reducing postharvest losses. In this study, we have evaluated the effects of two pre-treatments on fruit storage performance and fruit quality of two Italian genotypes, 'Dente di Cavallo', an endemic Sicilian population, and 'Primosole', a Sicilian variety selected by Catania University (La Malfa *et al.*, 2009), throughout six months of storage.

Materials and Methods

'Dente di Cavallo' (DC) and 'Primosole' (PS) fruits have been harvested at ripening stage from plants grown in organic farming. Fruits of each genotype have been dipped in a solution of sodium hypochlorite at 0.5% (v/v) for 15 minutes and then subjected to two different treatments: one group immersed in a solution of citric acid (1% v/v) (CA) for 5 minutes; a second group immersed in a solution of citric acid (1% v/v) and Chitosan (2% v/v) (CA+CHI) for 5 minutes. Some untreated fruits (NT) have been used as control. After being dried at room temperature, fruits have been sealed in polypropylene food bags (three fruits for bag) and stored at 4±1°C. At harvest and every 45 days, on 9 fruits for treatment, the weight reduction of the fruit (%) was determined until 180 days of keeping (T0, T1, T2, T3 and T4). In fresh juice, °Brix, pH, total phenol content (TPC) and antioxidant activity (AA) have been detected.

Results

During the total storage period, we have observed an important weight reduction on untreated fruits only, starting right after 90 days of storage in 'Dente di cavallo' fruits and after 135 days in 'Primosole' fruits. On the other hand, treated fruits have not shown any significant variation in weight until the end of the keeping. PH and °Brix has shown a similar trend either in untreated and in treated fruits (figure 1).

The results of the antioxidant activity (AA) and the total phenol content (TPC) obtained from the analysis performed during the full period of storage (180 days) show that at the end of the storage period all fruits have turned overripe and no more suitable for human consumption. Table 1 reports the results obtained from the juice analysis carried out on the 135th day of keeping (T3), when fruits were still good-looking and edible. Fruits of both genotypes managed with the two different treatments (AC and CA+CHI) display higher levels of AA and TPC compared to untreated fruits.

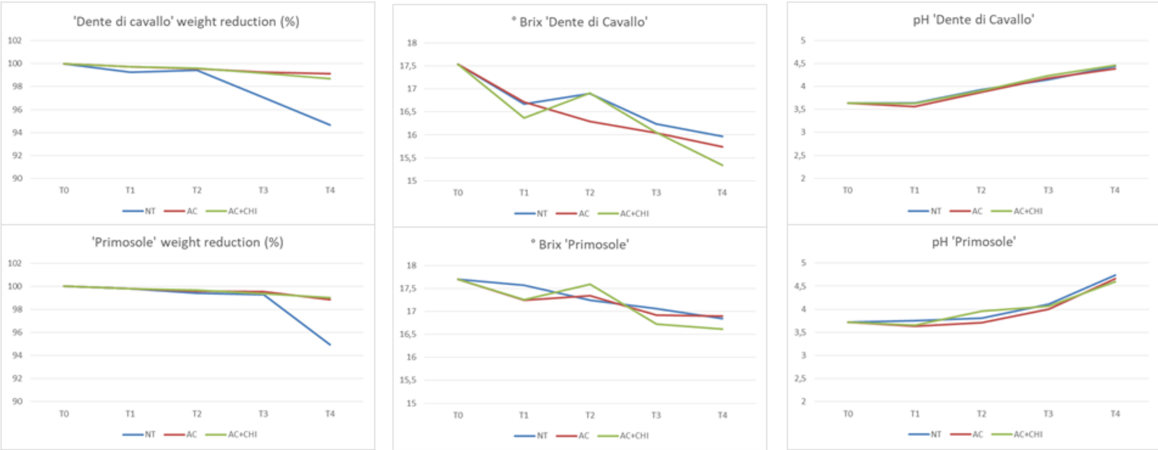

Fig. 1 Weight reduction, pH and °Brix in ‘Dente di cavallo’ and ‘Primosole’ fruits during 180 days of storage.

Tab. 1 Antioxidant activity (AA) and Total Phenol content (TPC) in ‘DC’ and ‘PS’ fruits at 135 days of storage.

Cultivar	Time	Treatment	AA (mmol/L)	TPC (µg/ml)
DC	T0	NT	6,24	668,33
DC	T3	NT	4,95	370,07
DC	T3	CA	6,23	462,77
DC	T3	CA+CHI	5,90	445,63
PS	T0	NT	7,15	833,66
PS	T3	NT	5,95	499,20
PS	T3	CA	6,75	598,17
PS	T3	CA+CHI	7,55	530,93

Conclusions

The fruits of both genotypes treated with CA and CA+CHI have shown no reduction in weight throughout the storage period, whereas a sensible weight reduction has been observed in untreated fruits. The healthy characteristics of the juice have remained quite constant up to 135 days of storage in treated fruits. On the contrary, a reduction of TPC and AA in untreated fruits has been recorded during the storage period. These results demonstrate that the two treatments tested in this work can improve the shelf-life of pomegranate fruits, allowing to extend the period of fresh consumption of this produce. Overall, ‘PS’ genotype displayed a longer shelf-life compared to ‘DC’ genotype in unprocessed fruits, both for weight reduction and for the qualitative characteristics of the juice.

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Toward A Production System Of Kentucky Tobacco Based On Agroecological Practices

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Introduction

The project on the "Improvement of sustainability and quality of tobacco Kentucky for cigar production" (MISOTAKY) has been promoted and funded by MIPAAF and Manifatture Sigaro Toscano. The research stems from the need to sustain the development of tobacco Kentucky toward a production model based on agroecological practices able to mitigate the criticalities generated by the current monoculture system as well as to comply the needs for a quality product for manufacturing industry. Challenge is represented by redesigning a crop system able to: 1- secure favourable conditions for plant growth, particularly by managing organic matter and enhancing soil biotic activity; 2- enhance recycling of biomass, optimizing nutrient availability and balancing nutrient flow; 3- minimize losses due to flows of water by way of soil management through increased soil cover; 4- ensure high productivity, resource use efficiency and biodiversity (TWN and SOCLA, 2015). In order to fulfill the characteristics of an agroecological approach, some practices were implemented in the experimental design: A) soil amendment by bio-waste compost by recycling the organic fraction source separated of the municipal solid wastes; compost is utilized to add adequate amounts of stabilized organic matter and mineral nutrients. B) cover crops during autumn-winter seasons used as green manure or mechanically flattened by roller crimper to create a mulch for weed control. C) increase water use efficiency maintaining yield levels with lower volumes applied.

Materials and Methods

Three experimental factors were laid out according to a strip split-split plot design with three replications in Terre Regionali Toscane farm at Marciano della Chiana (Arezzo). Cover Crop (CC) factor is modulated in four levels: bare soil, green manure of *Vicia villosa*, mixture of barley (*Hordeum disticum*) and hairy vetch (*Vicia villosa*) 50-50 % with termination by roller crimper, mixture of barley (*Hordeum disticum*) and hairy vetch (*Vicia villosa*) 20-80% with termination by roller crimper; each level is applied on a main plot of 360 m^2. Bio-waste Compost (BCom) factor is applied on two levels: 10 t ha^{-1} as dry matter, 0 ton; it is distributed in sub-plot of 180 m^2 once a year. Irrigation Volume (IrrV) factor is applied in sub-sub plots of 90 m^2 where tobacco will be irrigated by drip lines in two levels: full volume (100 % ETc) or deficit volume (70 % ETc). The experiment started in 2017 distributing BCom or not before the transplant of cv Foiano on May 30 with a density of 1 plant m^{-2}. Compost amendment has been integrated with 110 kg N ha^{-1} fractionated before transplant (38%) and in three topsoil dressings in the first two months of the crop cycle. According to the Regione Toscana Guide, mineral fertilization has provided 160-80-150 kg ha^{-1} di N-P_2O_5-K_2O, respectively, following the same fractionation as in BCom treatment. Harvests have been effectuated on September 6 and 30. After burying of tobacco crop residues, on October 30, 2017, cover crops were seeded. On May 8, 2018 fresh and dry above ground biomasses of green manure of vetch or barley-hairy vetch mixtures were measured. Due to rainy weather trend, only on May 21 it was possible to terminate the barley-vetch mixtures by roller crimper or shredding the green manure of pure vetch.

Results

As expected, the BCom treatment did not show a significant effect after the first addition to soil. Indeed, no significant difference has been recorded between the BCom or NPK treatments either in total yields or separating it in four commercial categories (wrapper, heavy filler, light filler and shredded) (Tab. 1).

Table 1.

Treatments	Total yield t ha^{-1}	Wrapper t ha^{-1}	Heavy filler t ha^{-1}	Light filler t ha^{-1}	Shredded t ha^{-1}
BCom	1.91	0.30	1.19	0.25	0.16
NPK	2.25	0.50	1.26	0.33	0.15
Anova probability	0.06	0.07	n.s.	n.s.	n.s.

Fresh and dry biomasses of cover crops are shown in Tab. 2. Hairy vetch biomass was again measured on May 20, 2018 just before its shredding and soil burying. About 50 t ha^{-1} as fresh matter corresponded to 8.7-10 t as dry matter, an amount like that added with compost. Fresh and dry biomass of barley-vetch mixtures were measured on May 8, pointing out that over 80 % of biomass was represented by barley plants due to the slow development of hairy vetch. Amounts of fresh biomass useful to act as mulch were recorded in barley-hairy vetch 20/80 plots. The tobacco transplant happened on June 11-12, 2018.

Table 2.

Cover crop	**Compost**	Vetch Biomass fr. weight	Vetch Biomass dr. w.	Barley biomass fr. weight	Barley biomass dr. weight	Total fresh biomass	Total dry biomass
		(t ha^{-1})	(t ha^{-1})	(t ha^{-1})	(t ha^{-1})	(t ha^{-1})	(t ha^{-1})
Hairy vetch	Yes					47 (5.67)	8.7 (0.58)
Hairy vetch	No					53.2 (6.82)	10 (0.37)
Barley-Hairy vetch 20/80	Yes	17.7 (7.4)	3.6 (2.07)	30.5 (13.9)	8.5 (2.6)	48.2 (7.8)	12.1 (0.65)
Barley-Hairy vetch 20/80	No	4.1 (3.71)	0.8 (0.64)	32.9 (13.8	8.6 (4.14)	37 (11.6)	9.4 (3.86)
Barley-Hairy vetch 50/50	Yes	3.8 (1.66)	0.8 (0.43)	25.4 (1.97)	7.1 (0.8)	29.3 (1.28)	7.8 (0.63)
Barley-Hairy vetch 50/50	No	5.4 (0.46)	1.36 (0.24)	26.8 (1.2)	8.2 (1.49)	32.2 (1.28)	9.6 (1.73)

Average of three replications; in brackets is standard deviation.

Conclusions

The innovative crop system for tobacco is providing encouraging but incomplete indications. Overcoming the criticalities to implement new practices, optimizing fertilization as well as irrigation, changing in soil organic matter will allow a better evaluation of agroecological practices impact in the next years.

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Increasing Oilseed Hemp (*Cannabis sativa* L.) Productivity In A Mediterranean Environment: Effect Of Crop Density And Foliar Fertilization

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Introduction

Industrial hemp (*Cannabis sativa L.*) cultivation is becoming an interesting opportunity for farmers due to the multifunctionality of this plant (Campiglia et al., 2017). It is well known that adopting an appropriate hemp variety it is possible to obtain high-quality cellulose (stems), valuable essential oils and resins (inflorescences) as well as high-quality oil and proteins (seeds) (Carus et al., 2013). Due to its characteristics, industrial hemp can increase crop diversification and improve the agronomic and economic sustainability of farmers (Vera et al., 2006). This is why in the last two years oilseed hemp has been introduced in cropping systems of Campania region (Southern Italy), covering more than 400 ha.

Agronomic management plays a pivotal role in industrial hemp cultivation affecting both quality and quantity of seeds and oil (Vera et al., 2006). Nutrient availability as well as crop density can modulate oilseed hemp behavior depending on the specific pedoclimatic conditions and the employed variety (Campiglia et al., 2017; Vera et al., 2006). The reported experiment is aimed at assessing the effect of different agro techniques on oilseed hemp cultivation in Campania region.

Materials and Methods

An open field experiment was carried out in 2017 at a private farm located in Caivano (Canapa Campana coop., Campania region, Southern Italy) to assess the crop performance of oilseed hemp USO31 variety as affected by different cropping techniques. The experimental field was located in a plain agricultural land where a winter-spring vegetable rotation was carried out prior to the trial establishment. Soil was characterized by a high native fertility (loam texture; C=2.5%; N=0.15%; pH=7.1) allowing to hypothesize a low input N management for hemp cultivation.

The following experimental factors were tested: i) pre-seeding soil fertilization: Fertilized (F) *vs* non-fertilized control (NoF); ii) foliar fertilization: fertilized (Fol) *vs*. non-fertilized control (NoFol); iii) crop density: 60 pt m^2 (D1) *vs*. 30 pt m^2 (D2). The abovementioned factors were fully combined obtaining a total of 8 treatments (F-Fol-D1, F-Fol-D2, F-NoFol-D1, F-NoFol-D2, NoF-Fol-D1, NoF-Fol-D2, NoF- NoFol-D1, NoF-NoFol-D2) each one arranged in a 1200 m^2 plot.

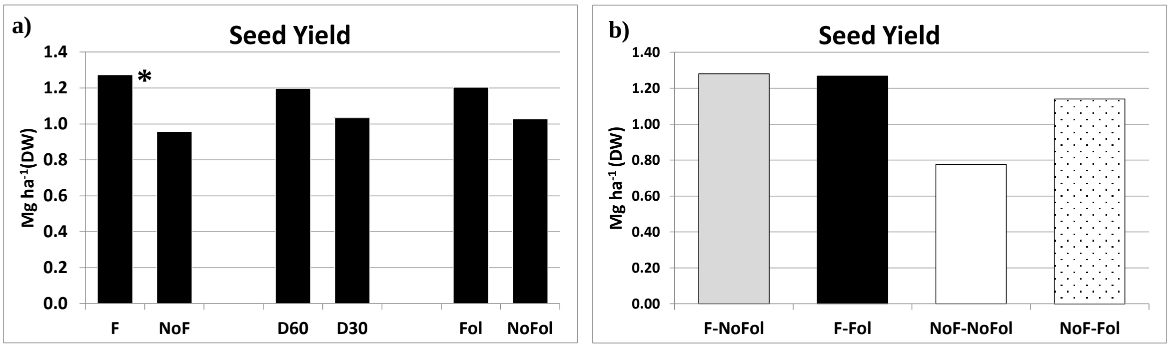
Pre-seeding fertilization was performed on April 20th (one week before crop seeding) supplying an organic fertilizer (a mix of poultry manure and feather meal) according to a reference dose of 40 kg N ha^{-1}. Foliar fertilization was made 2 weeks before flowering with 3 kg ha^{-1} of a ternary (N: 20%, P: 20%, K: 20%) fertilizer. Irrigation was carried out by a travelling gun system performing 3 waterings (one at seeding and two between 32 and 60 days after seeding) with a total water input of 100 mm.

Harvest was manually performed 77 days after seeding (12th July) at 70% seed maturity, sampling plants within 1 m^2 areas for a total of 3 replicates per treatment. Crop performance was monitored measuring: seed yield (fresh and dry weight), biomass production (fresh and dry) and plant height. Experimental data were statistically analyzed by analysis of variance using the SPSS 21 software package.

Results

An average seed production of 1.15 Mg (d.w.) ha^{-1} was recorded, being significantly affected by pre-seeding fertilization ($p<0.05$) that increased production by 32% (Figure 1a) compared to non-fertilized plots (1.3 vs 1 Mg (d.w.) ha^{-1}, for F and NoF respectively). The effects of crop density and foliar fertilization were close to the statistical significance (Figure 1a): a higher seed production was recorded with the 60 plant m^{-2} density ($p=0.10$; 1.2 vs 1.0 Mg seed (d.w.) ha^{-1} for D1 and D2, respectively) while foliar fertilization increased seed yield by 17% ($p=0.15$; 1.2 vs 1 Mg (d.w.) ha^{-1} for Fol and NoFol, respectively). In addition a tendency to higher seed yield ($p=0.10$) was recorded when foliar fertilization (Figure 1 b) was applied to not fertilized soil (1.25, 1.27, 0.78 and 1.17 Mg seed (d.w.) ha^{-1} for F-NoFol, F-Fol; NoF-NoFol and NoF-Fol, respectively). On average, both pre-seeding and foliar fertilization significantly increased plant height with a 16% increase in fertilized soils (164 *vs* 142 cm for F and NoF, respectively) and a 7% increase with foliar fertilization (158 vs 148 cm for Fol and NoFol, respectively).

Figure 1. Effect of pre-seeding fertilization, foliar fertilization and crop density on hemp seed yield



Pre-seeding soil fertilization: Fertilized (F) *vs* non-fertilized control (NoF); foliar fertilization: fertilized (Fol) vs non-fertilized control (NoFol); crop density: 60 pt m^2 (D1) vs 30 pt m^2 (D2). *=$p<0.05$.

Conclusions

Productive performance of USO31 oilseed hemp in the plain area of Campania region was in line with that reported by other authors (Campiglia et al., 2017) for the Mediterranean area.

According to the information collected in this first year of experimentation, oilseed hemp can take advantage from a higher crop density due to a reduced competition of weeds. Foliar fertilization increased plant height and seed yield when applied to not fertilized soil; this suggests an application of foliar fertilization to increase hemp seed yield under low N input management. It must be pointed out that this approach can be sustainable only if an appropriate management of fertility is planned considering the whole crop rotation (i.e. performing the fertilization only for the winter crop) and/or on soils with a high native fertility.

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Agronomic Performance And Qualitative Features Of Sicilian Durum Wheats

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Introduction

Until the first half of the last century, the cultivation of durum wheat in Sicily was based on more than forty landraces, selected by farmers mostly for their adaptability to the different pedoclimatic conditions of the island (De Cillis, 1942).
The recent guidelines of the EU agricultural policy, aiming to preserve agrobiodiversity and promote low-input, organic and small-scale agriculture, have stimulated a renewed interest for these local genotypes, often improperly called "ancient Sicilian grains", also in order to deepen the knowledge from the agronomic point of view, redirect the targets of breeding and valorize the products in healthy key (Guarnaccia et al., 2015; Venora and Blangiforti, 2017).

Materials and Methods

Twenty durum wheat genotypes, nineteen Sicilian landraces and an old improved variety 'Trinakria' (Tab. 1) were compared in a field experiment conducted in 2013/14 year in Sicily (Caltagirone, Catania province, 37° 05' 58" N., 14° 29' 56" E., 280 m a.s.l.) in a medium-sandy soil, in order to assess the main bio-productive traits and quality of the grain, wholegrain flours and doughs (Carrubba et al., 2015). The genotypes were laid out in the field in 10 m^2 plots according to a randomized blocks experimental design with three replicates, adopting an ordinary agronomic management consisting in a pre-sowing fertilization with 40 kg ha^{-1} N and 90 kg ha^{-1} P_2O_5 and 50 kg ha^{-1} N topdressing, and a post-emergence weeds control with dicotyledonicide. The experimental data were subjected to one-way ANOVA and SNK test was applied to compare the means ($p \leq 0.05$).

Results

Among the landraces evaluated, 'Manto di Maria', 'Ruscia' and 'Pavone' were found to be the earliest compared to the other genotypes, whereas Girgentana ' reached the highest plant height (Tab. 1).Grain yield, 2.3 t ha^{-1}, on average, was higher for 'Trinakria'. Eight Sicilian landraces ('Francesone', 'Chiattulidda', 'Farrolungo', 'Girgentana', 'Pavone', 'Russello SG8', 'Scavuzza', , 'Sicilia',) exceeded the average yield. 'Farrolungo' evidenced very high thousand kernels weight.
The hectoliter weight were appreciably higher for 'Chiattulidda' and 'Farrolungo'.. The highest protein and dry gluten content were observed in 'Sicilia' and 'Tunisina'. Among the studied landraces, gluten index varied, as expected, from a minimum value for 'Farrolungo' to a maximum for 'Vallelunga pubescente', which in any case was significantly lower than that observed for the improved variety 'Trinakria'.
The ash content of the wholegrain flour, depending on the mineral content of the grain, was above the legal limits (D.P.R. 187/2001), except for 'Chiattulidda', 'Lina', 'Manto di Maria', 'Bufala rossa lunga', 'Pavone' and 'Vallelunga pubescente'.

Table 1. Bio-productive and qualitative characteristics of the studied durum wheat genotypes. Mean values followed by different letters indicate significant differences.

Genotype	Hearing (d. from sowing)	Plant height (cm)	Grain yield (t ha^{-1})	Hectolitre weight (kg/hL)	1000 kernels weight (g)	Protein Content (% d.m.)	Dry gluten (%)	Gluten index (0-100)	Ash content (%)
Chiattulidda	127.7be	126.0g	2.6ac	86.5a	41.2o	12.5n	6.4k	34.9k	1.8e
Farrolungo	130.3bd	115.7i	2.4ac	82.6b	63.3a	11.5p	6.3k	23.9m	1.9de
Scavuzza	127ce	129.0fg	2.5ac	79.2f	44.4m	14.0j	8.9h	40.9i	1.9de
Russello SG8	130.7bc	125.8g	2.5ac	77.1j	56.0g	14.3h	9.8f	43.6h	2.0cd
Tumminia SG3	130.3bd	126.5g	1.9bc	76.5k	32.2p	13.6l	8.5i	25.4m	2.2ab
Girgentana	125ef	144.0b	2.5ac	80.1d	56.6ef	15.7cd	10.3e	55.7d	1.9de
Francesone	126.7de	135.0d	2.8ac	79.9e	56.7e	14.7f	11.3c	56.4d	2.0cd
Lina	125ef	115.0i	2.0bc	76.5k	57.8c	14.0j	8.8hi	31.3l	1.7f
Semenzella	130bd	127.7g	1.7bc	78.2i	57.2d	15.7c	12.2b	48.1g	2.0cd
Sicilia	124eg	133.8d	2.5ac	78.8g	48.9j	16.2a	14.1a	53.6e	2.1b
Manto di Maria	120hi	133.7d	2.0bc	80.4c	50.35i	13.7l	9.3g	48.8g	1.8e
Ruscia	121gh	132.3de	2.3ac	76.4k	48.8j	15.6d	12.1b	57.3cd	2.2ab
Bufala R.L.	131b	143.3b	1.7bc	71.2o	44.3m	12.0o	7.4j	40.8i	1.6f
Pavone	122fh	140.3c	2.5ac	78.5h	46.9l	14.5g	10.4e	51.1f	1.6f
Bufala N.L.	136a	155.4a	2.2ac	73.7n	50.6h	14.3h	10.6de	44.0h	2.0cd
Bufala N.C.	126e	140.0c	1.8bc	73.85n	43.2n	14.1i	10.0f	37.2j	2.0cd
Castiglione gl.	127ce	134.0d	2.0bc	74.3m	59.6b	13.8k	8.6hi	33.3k	2.0cd
Tunisina	124eg	130.5ef	1.9bc	78.3i	47.3k	16.1b	14.2a	58.6c	2.3a
Vallelunga pb.	127ce	122.3h	2.3ac	75.4l	47.4k	12.7m	11.9b	66.9b	1.7f
Trinakria	118i	132.7de	3.2a	80.3cd	56.45f	14.8e	10.7d	83.6a	2.0cd
MEAN	126.4	132.1	2.3	77.9	50.5	14.2	10.1	46.8	1.9

Conclusions

The results obtained highlighted an appreciable variability for the bio-productive features of the Sicilian durum wheat genotypes compared and a peculiar quality of wholegrain flours and doughs.

A re-evaluation of these germplasm could be contribute to the safeguarding of cereal agrobiodiversity and to diversification of farming systems, focusing in particular on low input and/or organic agriculture. In addition, some of these genotypes could be exploited for the production of bread and other typical bakery products and/or to make homemade pasta.

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Bioagronomic And Qualitative Characteristics Of Sicilian Bread Wheat Landraces

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Introduction

The cultivation of bread wheat is traditionally not widespread in Sicily. The oldest Sicilian bread wheat landraces is 'Maiorca', but 'Maiorca di Pollina' and 'Maiorcone' have also spread in the Palermo cereal areaa (Venora and Blangiforti, 2017). Other Sicilian bread wheat landraces are 'Cuccitta', once widespread in the mountain environments of Messina, and 'Romano', which has been cultivated in the hills of Catania province. Previous studies on these landraces have highlighted the peculiar quality characteristics suitable for making bread, and have aroused a renewed interest by farmers and bakers, because of consumer appreciation (Spina et al., 2004).

Materials and Methods

Five Sicilian bread wheat landraces (Table1) were compared in a field experiment conducted in 2013/14 year in Sicily (Caltagirone (CT), 37° 05' 58" N., 14° 29' 56" E., 280 m a.s.l.), in a medium-sandy soil. The main bio-agronomic and qualitative features of the grain, wholegrain flours and doughs have been assessed according to the official methods of analysis (Carrubba et al., 2015). A randomized blocks experimental design with three replicates was adopted with 10 m^2 plots. Agronomic management consisted of a pre-sowing fertilization with 40 kg ha^{-1} N and 90 kg ha^{-1} P_2O_5 and 50 kg ha^{-1} N top-dressed. A dicotyledonicide was applied in post-emergence to control weeds.
The experimental data were subjected to one-way variance analysis of variance and the means were separated with the SNK test ($p \leq 0.05$).

Results

Bio-productive data (Table 1) evidenced a certain variability among the studied genotypes, above all for the plant size and the length of the spike. 'Maiorcone' was significantly earlier than the other landraces. The average grain yield exceeded 2.0 t ha^{-1}.

Table 1. Bio-productive characteristics of the studied bread wheat landraces (means ± st.dev.). Different letters indicate significant differences between the means. (Starchy kernels % values are arcsin transformed before ANOVA)

Genotype	Hearing (days from sowing)	Plant height (cm)	Grain yield (t ha^{-1})	Spike length (cm)	Hectolitre weight (kg/hL)	1000 kernels weight (g)	Starchy kernels (%)
Cuccitta	130±0.05a	131.3±0.33b	1.8±0.21c	9±0.07b	73.6±0.14b	47.7±0.21b	11.5±2.12b
Maiorca	130±0.09a	117.0±0.54e	2.6±0.13a	10±0.09b	81.5±0.14a	43.7±0.28c	93±2.83a
Maiorca di P.	131±0.03a	121.0±0.81d	2.5±0.26ab	14±0.02a	74.4±0.14b	40.7±0.21d	2±1.41c
Maiorcone	123±0.55b	126.0±0.25c	2.4±0.56b	14±0.05a	72.9±0.21c	39.8±0.07d	0.5±0.71d
Romano	131±0.64a	134.0±0.38a	2.4±0.72b	7.5±0.08c	74±0.14b	53.5±0.21a	3.5±0.71c

The values of the hectolitre weight were low, while the thousand kernels weight was > 40 g, except for 'Maiorcone'. Concerning the grain defects, a very high percentage of starchy kernels was found only in 'Maiorca'. The ash content was high with the typical values of wholemeal flour (Table 2). The values of protein content was high, except for 'Maiorca'. With regard to the wet and dry gluten, different water binding capacity among the genotypes were found (data not shown). 'Maiorca' evidenced a low gluten content associated to a low protein content, because of the high percentage of starchy kernels. A strongest gluten was observed for 'Cuccitta'.

Table 2. Ash and protein contents, wet and dry gluten, gluten index of the studied bread wheat landraces (means ± st.dev.). Different letters indicate significant differences between the means.

Genotype	Ash (%)	Protein (% d.m.)	Wet gluten (%)	Dry gluten (%)	Gluten index (0-100)
Cuccitta	2.1±0.01a	15.4±0.07a	33.6±0.78ab	11.1±0.42a	66.3±0.78a
Maiorca	1.7±0.10b	8.7±0.14d	12.0±0.21c	4.3±0.21d	63.8±0.63b
Maiorca di P.	1.9±0.17a	13.2±0.00c	32.5±0.42b	9.5±0.07c	41.8±0.76d
Maiorcone	2.0±0.05a	14.6±0.07b	35.3±1.70a	10.4±0.14b	33.4±3.20e
Romano	1.8±0.07ab	14.5±0.00b	32.0±1.56b	10.1±0.42b	55.9±2.14c

Regarding the colorimetric indexes of the wholemeal flour, high values of brown index were found (11.9, on average).As expected, the yellow index values were very low (8.9, on average) (Table 3). The SDS sedimentation test showed better results for 'Maiorca di Pollina'. All the flours had a good amylase activity at the falling number, while the best technological performance at the mixograph was achieved by 'Maiorca' and to a lesser extent by 'Cuccitta'.

Table 3. Sedimentation and amylase analysis, mixographic and colorimetric analysis of the studied bread wheat genotypes (means ± st.dev.). Different letters indicate significant differences between the means.

Genotype	Brown index (100 - L)	Red index (a*)	Yellow Index (b*)	SDS Test (mL)	Falling Number (s)	Mixograph overall score (1-8)
Cuccitta	11.4±0.14c	0.22±0.02a	8.7±0.04b	51±0.00b	387±2.83a	6±0.00
Maiorca	10.9±0.04c	-0.24±0.01b	8.8±0.17ab	30.5±0.71e	250±2.83d	7±0.00
Maiorca di P.	13.3±3.54a	-0.52±0.01b	8.7±0.18b	56±1.41a	274.5±4.95cd	5±0.00
Maiorcone	11.5±0.03c	0.20±0.02a	8.8±0.20ab	40±0.00c	335.5±3.54b	5±0.00
Romano	12.2±0.01b	0.49±0.05a	9.4±0.01 a	37±1.41d	288.5±3.54c	5±0.00

Conclusions

A re-evaluation and the exploitation of the studied Sicilian bread wheats could contribute to the safeguarding of agricultural cereal agrobiodiversity as well as to the diversification of the cereal based-cropping systems, particularly under conservative agriculture regime (low input and organic). The peculiar quality characteristics of the whole meal flour of these landraces are particularly suitable for making bread and other typical bakery products.

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TOMRES: Screening Of Traditional Tomato Varieties For Water Use Efficiency And Nutrient Use Efficiency

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Introduction

Traditional varieties of tomato from the Mediterranean region represent a pool of biodiversity that can be mined for novel traits that can be used for the genetic improvement of commercial tomato varieties. As urban development and climate change exacerbate competition for water and critical resources, it is essential commercial production of vegetables increases the Water Use Efficiency (WUE) and Nutrient/Nitrate Use Efficiency (NUE) in order to reduce the environmental impacts in terms of water and fertilizer (Hirel et al., 2007; Erisman et al., 2008). In order to address the anticipated need for improvement of existing commercial varieties (Ruggiero et al., 2017), we are screening over 40 traditional tomato varieties for their WUE, NUE and combined stress indexes to identify genotypes that are particularly efficient in their use of water, nitrogen, or both these critical resources. The best performing genotypes will be further evaluated at the molecular and genetic level to determine which traits and genes are responsible for increased WUE and NUE.

Materials and Methods

Each genotype is first evaluated at early stages of development (seedling) *in vitro* for early responses to low nutrients (1/10 dose of Nitrogen and Phosphorous) and under osmotic stress (mannitol 200 mM). Growth in terms of FW, leaf area, root length, root area, and root branching were evaluated under control conditions, low nutrient conditions, 200 mM Mannitol, and a combined stress treatment (low nutrients and mannitol). Each genotype is then evaluated in a large-scale pot experiment. Ten replicates of ten genotypes are evaluated at each time using 15 L pots filled with sand in a randomized block setup. Each genotype is grown for six weeks under four separate treatments: Control (10.2 mM NO_3^-), Low Nitrate (2.88 mM NO_3^-), Drought (50% water) and Combined Stress (2.88 mM NO_3^- with 50% water). During the experiment, stomatal conductance, chlorophyll-SPAD, flowering time, and leaf surface temperature are monitored.

Results

Preliminary results from screening of seedlings show that primary root growth is affected by treatments in a genotype specific fashion (Figure 1). We observed that UNA 04 is reduced in osmotic and combined stresses (Fig. 1) and UNA 28 is only reduced in osmotic stress (Fig. 1). The behavior of the two varieties is evident also in large-scale pot experiment: plant height (Figure 2A) and leaf area (Figure 2B) are only affected in drought and combined stress.

Conclusions

Our preliminary results indicate that of the initial 10 genotypes tested, there exists significant variation between the responses to Low Nitrogen, Drought Combined Stresses. We are currently evaluating a second round of 10 genotypes in a second pot experiment. Once all 40 selected genotypes have been evaluated in pots over the first eight weeks of growth, a second experiment with the best and worst performing genotypes will be conducted for the fully life cycle of the plants.

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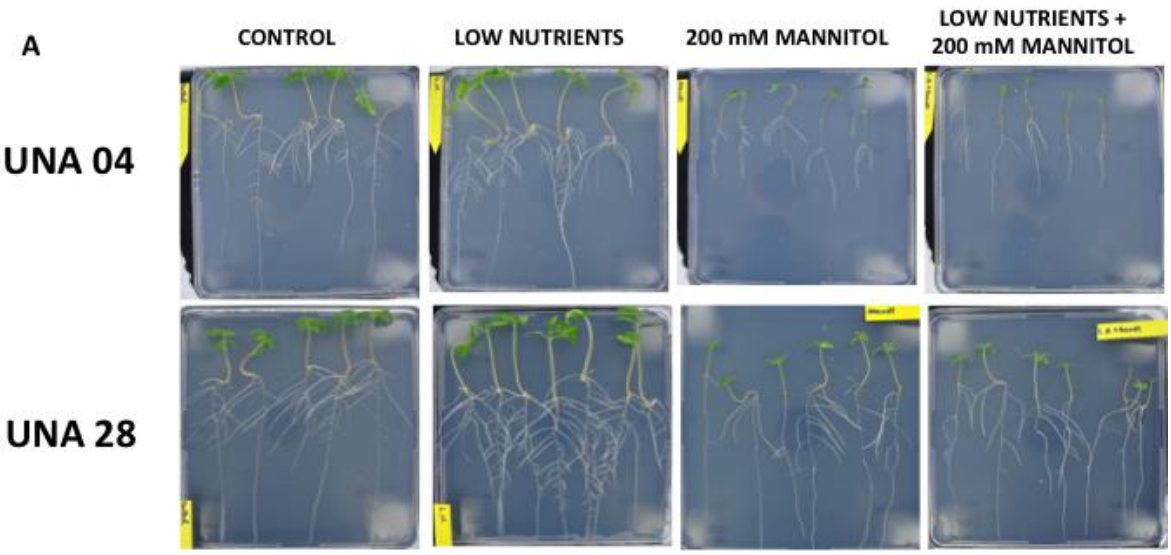

Figure 1
Representative plates of tomato varieties (UNA 04, UNA 28) seedlings grown on Control, Low Nutrients, 200 mM Mannitol and Low Nutrients+200 mM Mannitol

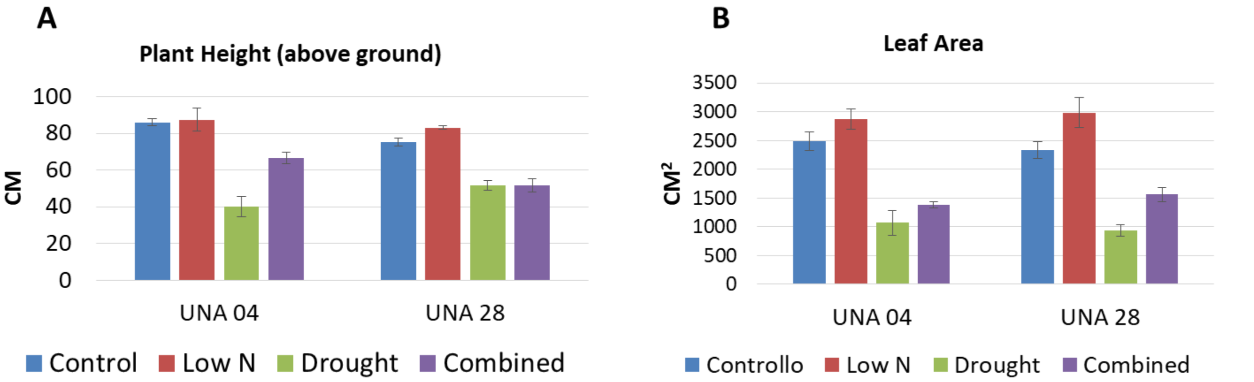

Figure 2
Plant height (A) and Leaf Area (B) of tomato plants grown in pots filled with sand under four separate treatments: Control (10.2 mM NO_3^-), Low N (2.88 mM NO_3^-), Drought (50% water) and Combined (2.88 mM NO_3^- with 50% water).

A New Role For Benzimidazoles As Regulators Of Nitrogen Use Efficiency

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Introduction

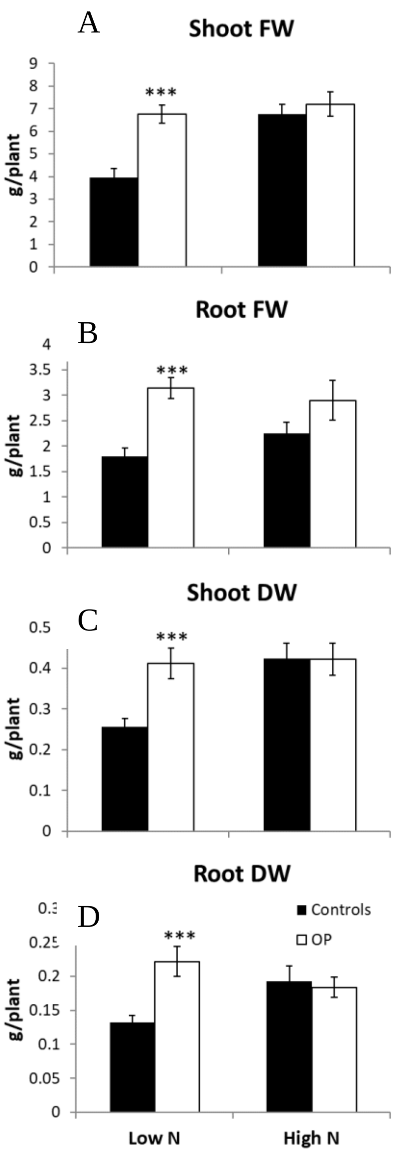
Omeprazole is a selective proton pump inhibitor in humans that inhibits the H^+/K^+-ATPase of gastric parietal cells. Omeprazole has been recently shown in plants to act as a plant growth regulator and enhancer of salt stress tolerance. Here we report that omeprazole treatment in hydroponically grown maize enhances nitrogen assimilation. The presence of micromolar concentrations of omeprazole alleviates the chlorosis and growth inhibition induced by low nitrogen availability. Assimilation is enhanced in omeprazole treated plants through changes nitrogen reductase activity, primary metabolism and gene expression. Omeprazole enhances nitrate assimilation through an interaction with nitrate reductase, altering its activation state and affinity for nitrate as a substrate. Omeprazole and its targets represent a novel method for enhancing nitrogen use efficiency in plants.

Materials and Methods

Maize plants of the p1619 line (Pioneer Hi-Bred International, Johnston Iowa USA) were grown for four weeks in a modified Hoagland's solution containing either 1mM (nitrogen stress) or 10mM (sufficient nitrogen) nitrate in the presence and absence of 1µM omeprazole. Biometrics were measured as per Van Oosten et al., 2017. NR protein was extracted according to Scheible et al. (1997) and NR activity was assayed according to Gibon et al. (2004).

Results

In non-stress conditions (High N), omeprazole treatment did not significantly increase growth in terms of fresh and dry shoot and root weight. In nitrogen stress conditions (Low N) plant growth was significantly inhibited. Fresh weight was decreased by 50% in shoots and 31% in roots (Figure 1A, 1B). Dry biomass accumulation was similarly affected with a 47% decrease in shoots and 36% roots (Figure 1C, 1D). The presence of omeprazole in the growth media had a significant effect in Low N conditions by reversing the effects



of N stress. Growth in terms of FW of shoots and roots was increased 58% and 71%, respectively. Biomass accumulation was similarly affected with shoot biomass increasing by 61% and root biomass by 68%. Overall, OP treatment did not significantly affect growth in High N conditions, however in Low N conditions it almost completely alleviated the symptoms of N stress induced by the 1 mM NO_3^-.

The activation state strongly increased under OP treatment independently of N nutrition and organ, even if not significantly in shoots (Figure 2B). OP induction of activation state was tested on pure Nitrate Reductase from Arabidopsis. OP 50 µM was able to increase the enzyme catalytic efficiency and the specificity for NO_3^- (as substrate) resulting in an increased Vmax and decreased Km (Figure 2C). This suggests that OP helps in maintaining adequate affinity of enzyme towards its substrate as well as its catalytic rate.

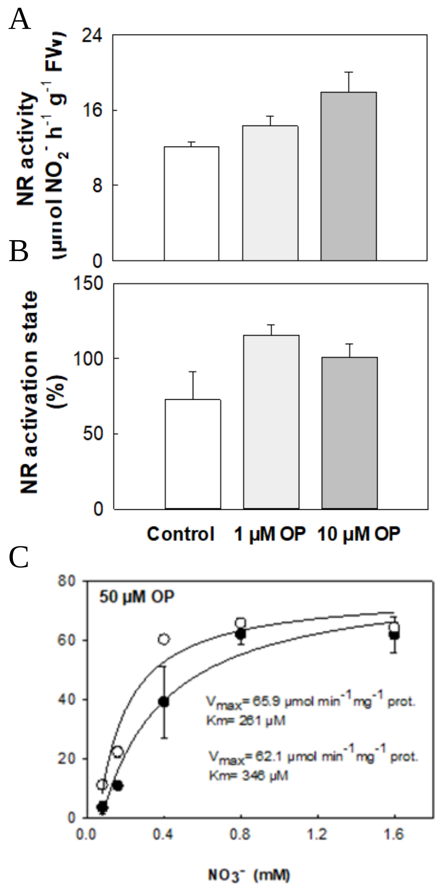


Figure 1. Biometrics of maize in nitrogen stress conditions with OP. (A) FW of shoots, (B) DW of shoots, (C) FW of roots, (D) DW of roots. Values indicate average ± SE (n=6). * denotes significant differences according to Student (P<0.05), ** (P<0.01) *** (P<0.001) between untreated controls and OP treated plants.

Figure 2. (A) Nitrate Reductase activity *in* vivo, (B) Activation State of Nitrate Reductase and (C) Nitrate reductase *in vitro* activity assay.

Conclusions

We have characterized a novel phenotype where the benzimidazole, omeprazole, alleviates nitrogen stress through alterations to primary and secondary metabolism. Furthermore, we have evidence that OP directly interacts with Nitrate Reductase, enhancing assimilation through an increased affinity for the substrate and constitutive activation of the enzyme. Omeprazole treatment in maize plants clearly alleviates the growth limitations imposed by low nitrogen in the environment. Our results show that it is possible to perturb the physiological process in the plant in such a way that uptake and assimilation can be enhanced through mechanisms present in the plant. Understanding how to regulate these processes is essential to enhancing NUE and subsequently developing sustainable crops with lower environmental impacts.

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Comunicazioni orali

“Analisi e confronti tra tipi di agri*culturae*”

Bioassays For Evaluation Of Sanitary Risks Due To Food Crops Cultivated In Potentially Contaminated Sites

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Introduction

Currently, in Italy the risk analysis of potentially contaminated areas is based only on the direct risks for people, while the indirect risk, associated to Potentially Toxic Elements (PTEs) uptake by food crops and to the foodstuff consumption, is not provided for. In Italy, the Environmental Law (D.Lgs 152/2006) does not apply in the case of agricultural areas, since the specific regulation in the Art.241 has not been enacted yet. In Europe, only Germany, Slovakia and Austria have guidelines for assessing the suitability of potentially contaminated soils for crop production, reporting trigger values based on PTEs bioavailable content in soils (Carlon, 2007); whenever the trigger values are exceeded, the analysis of PTEs in crops is required. Lead and cadmium contents in foodstuffs can be compared with the thresholds reported by EC Reg. 1881/2006 for some vegetables, while for arsenic and mercury the values could be compared with the thresholds reported in EC Dir 32/2002 relative to forages. For defining potential risks for consumers, the estimation of exposure to the PTEs can be made through the their content in food crops and the estimation of the related Hazard Quotient (HQ) based on ISS (2015) and USEPA (1989) methodologies Our aim was to define the suitability of an agricultural site classified as potentially contaminated by Cr and Zn, in which a more detailed environmental characterization highlighted some hot spots with high levels of As, Cd, Cu and Pb (Adamo et al., 2017).

Materials and methods

The study-site is an agricultural area of 60,000 m^2 that was confiscated for illegal dumping of tannery and that was characterized and remediated by using the ECOREMED protocol. For evaluating the potential uptake of PTEs in the vegetable edible parts, the soil hot spots (with higher PTEs concentrations) were collected, analyzed for their PTEs total and bioavailable content and used for filling 1.5 liter pots in which five vegetable species, known for their PTEs accumulation capacity in edible part, were grown: Chicory (*Cichorium intybus* L.), Lettuce (*Lactuca sativa* L.), Spinach (*Spinacia oleracea* L.), Radish (*Raphanus sativus* L.) and Rocket salad (*Eruca vesicaria* L.). Plants were harvested at commercial maturity, weighed and washed with tap water and then with deionized water for removing any residual soil particles from the samples. Determination of PTEs concentrations in fresh plant samples was made by using ICP-MS after acid digestion (HNO_3) in a microwave oven. For the evaluation of potential non-cancer risk of PTEs, the hazard quotient (HQ) equation was used for the single PTE. The hazard index (HI) equation (USEPA, 1989) was used for assessing the cumulative potential effects of the different PTEs on human health. If the ratios exceed the unit (HQ>1; HI>1) there could be a potential risk to human health.

Result and Discussion

Arsenic content in soil was high, but the bioavailable fraction was null. Therefore As content in all foodstuffs was very low (maximum values = 0.04 mg kg^{-1} f.w. in lettuce) and HQ was negligible (up to 0.2 in chicory). Copper content in soils was low and normal for this kind of volcanic soils (De Vivo et. al., 2012). Levels of bioavailable Cu as assessed by NH_4NO_3, were low (0.45 mg kg^{-1}) as confirmed by the moderate accumulation in vegetables (up to 1.2 mg kg^{-1} f.w. in the 1st harvest of rocket). No significant relation was found between soil content and vegetable accumulation. HQ values were very low both for adults (0.06 for chicory and spinach) and children (0.08 for spinach). Chromium values in the soil were very high (up to 2399 mg kg^{-1}) as expected for tannery sludge disposal. Nevertheless the bioavailable fractions were low (up to 0.54 mg kg^{-1}) and also accumulation in vegetables was low (up to 0.79 mg kg^{-1} f.w. in lettuce and rocket). Cr in vegetables resulted significantly correlated with Cr soil levels for radish and rocket. HQ values were close to zero in all vegetables due to the low toxicity of this PTE. Also Zinc values were very high in soils of the study case (up to 846 mg kg^{-1}) but the bioavailable amounts were high (1.78 mg kg^{-1}). In this case vegetables accumulated high concentrations of Zn with values up to 25 mg kg^{-1} in spinach. Zn concentrations in plants resulted positively correlated with total Zn content in soils, for all vegetables. In spite of these high concentrations, HQ values were always low with maximum value of 0.26 with spinach for children, also in this case for the low toxicity of this PTE. It must be pointed out that Zn is a microelement beneficial for human health, so that several researches have been carried out for producing Zn fortified foods just by increasing Zn content in agricultural soils. As regards Cadmium there is a hot spot with very high concentration (13 mg kg^{-1}), in which the bioavailable values were high (0.18 mg kg^{-1}). The accumulation in vegetables was very high and exceeded the thresholds of CE Reg. 1881/06, with the maximum value of 3.9 mg kg^{-1} f.w. in chicory. Cadmium concentrations in vegetables and in soil, resulted highly correlated for all crops. HQ values showed a potential risk for adult and children only for four crops, with values of 5.67-5.62 for lettuce baby leaf, 7.06-7.00 in lettuce; 11.27-14.99 for spinach and 19.07-22.27 for chicory, while radish and rocket salad did not represent a risk for human health. Lead is present in all the Campania plain both for geogenic and anthropogenic contamination (De Vivo et. al., 2012). In this study case, a hot spot (147 mg kg^{-1}) was selected in which the bioavailable value was 0.02 mg kg^{-1}. Nevertheless Pb content in rocket salad and radish exceeded the thresholds of CE Reg. 1881/06 not only in the hot spot but also in the other plots with lower soil total concentrations of lead. Indeed, only for lettuce and lettuce baby leaf there was a significant correlation between concentrations in vegetables and soils. However, HQ values were low for all crops, with maximum values of 0.063 in radish for adult and 0.078 in spinach for children, widely under the unit, thus confirming the results from another study carried out by Agrelli *et al.* (2017) in the same area. It is important to highlight the possible cumulative effect of single non-carcinogenic PTEs, because one element could contribute to an overall potential disease if cumulated to the effects of other PTEs. Many vegetables grown in the high cadmium plot showed a HI>1, but also chicory grown in other soil (high concentration of Zn and Cr) showed an overall HI>1. In both the cases the highest contribution to the overall hazard index was due to Cd followed by As. In all the other cases, the cumulative risk was widely under the unit.

Conclusion

The study site was characterized by very high concentration of chromium and zinc in soil. Nevertheless, not only the direct risk analysis calculated by law for workers and people who could frequent this site, but also the indirect risk analysis made in this work by considering the dietary risk for consumers, excluded any risk for these two elements, thanks to their low toxicity. Instead, our analysis on vegetables (made by using highly precautionary parameters) showed that the potential risk for consumers was due to cadmium, also in plots in which its total content in the soil was lower than the Italian screening values. It should be stressed that the legal methodology for carrying out the environmental characterization, based on few samples per hectare and on the comparison of total content of PTEs in soils with the screening values reported in the tables of the Italian law, do not help to evaluate the suitability of a potentially contaminated site for the agricultural use. In conclusion, the proposed methodology aims to fill a gap in Italian environmental legislation allowing to consider the agricultural use of soils and the consequent risk for consumers due to contaminant uptake by the food crops.

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Design Of A Multi-Criteria Model For The Sustainability Assessment Of Organic Durum Wheat-Based Farming Systems Through A Participative Process

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Introduction

The agriculture sustainability assessment is considered a difficult issue for the complexity and multidimensionality of sustainability performances and the presence of conflicting and opposing objectives. The environmental, economic and social pillars need to be simultaneously considered in an evaluation framework in order to properly take into account potential synergies and trade-offs of the agricultural processes and to identify more sustainable and suitable production systems.

Among several assessment methods, tools based on multi-criteria analysis (MCA) are becoming increasingly relevant in agriculture as they can evaluate simultaneously the three sustainability dimensions, assess contrasting and conflicting criteria, and analyze complex decisional problems decomposing them into easier to be solved and comprehensible elements (Carpani et al. 2012). Moreover, MCA tools able to manage qualitative information are considered more effective in dealing with the multi-dimensional constraints of sustainability due to the incomparability and incommensurability of data arising from different dimensions (Sadok et al. 2008). The aim of this work is to present the process designed and implemented within the BioDurum project (financed by the Italian Ministry of Agriculture - MiPAAF and coordinated by the Council for Agricultural Research and Economics - CREA) to develop a new qualitative MCA tool for the sustainability assessment of organic farms located in southern Italy and characterized by durum wheat-based crop rotations. The tool is being developed using the open-source DEXi software (Bohanec, 2013) that have demonstrated to be particularly suitable for creating qualitative multi-criterial hierarchic models. Moreover, it will provide suitable decision making frameworks for both farmers and policy-makers interested in the identification of agricultural practices that mostly affect or concur to sustainability. According to several authors (Colomb et al. 2013; Goma et al. 2001), to increase impact and relevance, it is important to involve potential users of an assessment model from the beginning, by their engagement in the process design. This allows to increase the confidence in the output results, to facilitate the acceptance and the utilization of the model, and to create a learning environment through which people can acquire and improve the ability to change their ways of thinking embracing an holistic approach needed for the sustainable development.

Materials and Methods

DEXi is a software that supports the creation of decisional tree models based on the aggregation of qualitative criteria that are organized hierarchically. The basic criteria (tree leaves) generally refer to elementary concerns of sustainability. Each criterion is quantified by proper indicators. The basic criteria are aggregated by “if-then” decision-rules or utility functions (Bohanec, 2013) according to their weights to allow the qualitative assessment of the different sustainability pillars (tree branches) and the overall system sustainability (tree root). The process of the design of the BioDurum sustainability assessment model through stakeholder involvement was structured on the following steps according to Craheix et al. (2015): 1. *Initial analysis and planning* - to clarify issues, procedures and to define actors to involve in the two representative areas of BioDurum project (one in Sicily and the other across the Basilicata and Puglia regions); 2. *Selection and hierarchy of the sustainability criteria* - with the aim to collect through participatory workshops the stakeholder point of views on aspects, issues, and concepts considered relevant for the sustainability assessment. These issues have to be clustered and translated into criteria to be included in the hierarchic model; 3. *Selection and building of the indicators*- for the identification of suitable indicators and threshold values to quantify each criterion; 4. *Model parameterization* – to reach agreed decision rules and weights based on stakeholder consensus; 5. *Validation* - to perform sensitivity analysis, evaluating the model outputs, and collect further feedbacks from end-users (participating or not in the design process) to improve the model prototype; 6. *Model transfer* – to release the final version of the model (scheduled for June 2019).

Results

Currently the step 1 and partially the step 2 have been implemented. The new model is being designed mobilizing the scientific community in interaction with different actors (farmers, advisors, farm-contractors, cooperatives, pasta makers, flour producers, associations) involved in organic durum wheat value chains. Two participatory workshops were organized in both the study areas (11 participants for Sicily and 15 for Basilicata and Puglia regions) to identify the relevant sustainability issues and aspects to include in the model. The 111 collected issues were classified according to their sustainability pillar (environmental, economic and social dimensions), clustered on the basis of their similarity and merged into potential thematic areas (Table 1).

Table 1. Potential thematic areas identified through stakeholder involvement in the three sustainability pillars.

Environmental pillar	**Economic pillar**	**Social pillar**
Rotation management	Economic results	Workload
Soil management	Farm Autonomy	Relational capital
Fertilization management	Product quality	Institutional context
Phytosanitary management	Product destination and short supply chain	Territorial development
Water management	Farm business diversification	Equity and Ethics
Energy management		
Biodiversity, Landscape		
Mitigation/adaptation to climate change		

Conclusions

The stakeholders involvement was seen as an opportunity for suitable discussions and co-learning adding value to the final outcomes and triggering the future model utilization by end-users. Furthermore, in the perspective of a new public good payment system under the Common Agricultural Policy (CAP) post-2020 aimed at remunerating farmers in relation to the achieved sustainability objectives assessed with performance indicators, the BioDurum model will represent a valid support for end-users for the identification of proper strategies to implement in an organic farm, thus strengthening sustainability goals in line with CAP likely developments.

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Promoting Sustainable Tomato Irrigation Strategies In Mediterranean Conditions Via Simulation Modelling

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Introduction

The tomato processing industry is a key agricultural sector in Italy, which is the 6th leading country worldwide, with an annual production of 6,437,572 t cultivated on 103,940 ha in 2016 according to official statistics (FAO, 2018). The Apulia region annually contributes to around 20% of the total national amount, with the Capitanata plain concentrating 88% of tomato cultivated area and 93% of the regional production (ISTAT, 2018). Tomato cultivation is highly intensive in this area, with large application of irrigation water (300 – 800 mm) and chemical inputs for fertilization and crop protection, and annual fresh fruits yield ranging between 80 and 160 t ha^{-1} (Rinaldi et al., 2011). The major constraint to tomato growth is water stress, as farmers face a large inter-annual variability of meteorological conditions in a semi-arid climate, with average maximum temperature ranging between 22.9-33.2 °C, and precipitation between 25-111.2 mm in 2005-2017 during summer months. In the last years, many efforts were made to support tomato growers to enhance tomato production levels while saving irrigation water, e.g., testing deficit irrigation regimes in open field trials (Giuliani et al., 2017) and projecting crop models in climate change scenarios to forecast yield trends and water use (Ventrella et al., 2017). The latter could help the identification of sustainable farmer adaptation strategies, which could be in turns promoted by regional policy makers to optimize tomato cultivation in the coming years. Here we present a modelling study dealing with the implementation of a new tomato simulation model, which has been calibrated and validated using long-term field experiments in which alternative irrigation strategies based on the crop evapotranspiration (ET_c) were tested.

Materials and Methods

The TomGro model (Jones et al., 1991), originally developed for greenhouse tomato, was adapted to address open-field growing conditions. It simulates the main processes associated with crop growth and development as driven by air temperature, solar radiation and CO_2 concentration. The tomato plant is represented by state variables (e.g., number and dry weights of leaves and fruits) which are daily updated with internal hourly simulation of photosynthetic and respiration rates. Main modifications to the original version involved i) the reproduction of phenological development (Boote et al., 2012), allowing the simulation of post-transplanting phase, the flowering of the first truss, the fruit breaking colours of the first truss and the harvest time; ii) the inclusion of the impact of water stress on photosynthesis and the effect of leaves senescence (CropSyst model) and iii) the massive reduction of the number of parameters. The field experimental trials used for model calibration and validation were carried out in the period 2005-2017 by University of Foggia in Capitanata plain. The processing tomato cv. Ulisse was grown under alternative irrigation strategies, ranging from minimal irrigation (only during transplanting and fertigation) to 100% of ET_c, with intermediate regimes providing restoration of 50% and 75% of ET_c, also varying deficit irrigation regime according to tomato phenological stages. Standard agricultural practices were implemented to assure non-limiting nitrogen conditions with fertigation and to keep the field pest and disease free. In 2017 growing season, multiple samplings of leaf area index (LAI, m^2 m^{-2}), total dry weight and fresh fruits biomass (g m^{-2}) and leaves and fruit number were carried out to allow a detailed model calibration. The tomato model was coupled with a soil model and with management rules to simulate the impact of irrigation on soil water availability and root water uptake. The model was then validated with the historical data collected in 2005-2016, using total fresh fruit biomass (q ha^{-1}) as reference variable.

Results

Figure 1 presents the simulation of leaf area index and fresh fruits biomass in 2017, and the comparison of observed and simulated tomato production in the period 2005-2016.

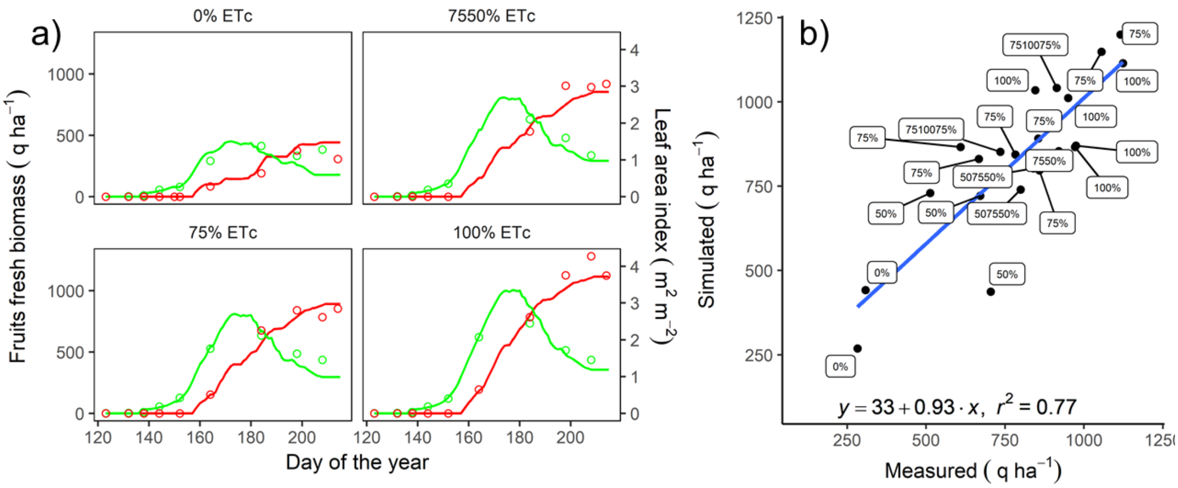

Figure 1. Simulated (solid lines) and observed (points) of leaf area index and fresh fruit biomass in 2017 experiments (a) and scatterplot between measured and simulated tomato production in 2005-2017 (b).

The new model accurately reproduced the LAI dynamics in 2017 growing season across irrigation treatments, leading to a simulated fresh fruit production coherent with dynamic samplings all along the growing season (Figure 1a). When applied to the historical dataset (Figure 1b), the model confirmed to be able to differentiate the simulated tomato production under contrasting pedo-meteorological conditions and irrigation treatments, with large correlation with field measurements (adjusted $R^2 = 0.77$, $p<0.001$). The average absolute model error (MAE) in reproducing tomato phenological stages in 2005-2017 was 5.8 days, while MAE for harvested production was equal to 125.9 q ha^{-1}, relative root mean square error of 15.04% and modelling efficiency of 0.752. Since a proper model calibration is an essential prerequisite of the subsequent model application in future climatic scenarios, we demonstrate here that the new version of the TomGro model is suitable for this purpose.

Conclusions

This work lays the basis for a spatially distributed assessment of the future tomato yield trends in Southern Italy, in which we will test alternative irrigation strategies to identify a trade-off between production and water use, also quantifying the associated sources of uncertainty.

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Outcomes From Five Decades Of Different Cropping Systems On Deep Soil Organic Carbon Stock And Its Distribution

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Introduction

Soil Organic Carbon (SOC) decline is one of the most relevant soil threats across Europe, particularly in hot environments with alternating humid and dry periods, such as the Mediterranean climate. Despite the considerable amount of information on C dynamic on superficial horizons (30 cm depth), long-term studies on the changes in agricultural soils below the topsoil have rarely been conducted (Gauder et al., 2016). The present work aims to give a contribution on this subject, analysing the effects of different cropping systems on SOC stocks in a long-term experiment, considering soil horizons up to 90-cm depth.

Materials and Methods

The soils analysed come from a long-term experiment started in 1962, comparing a set of crop rotations (from monocultures and permanent meadow to a six-year rotation) under different organic and inorganic nutrient supplies (Berti et al., 2016). Soil samples have been collected in autumn 2012, considering three layers (0-30, 30-60 and 60-90 cm). The air-dried remoulded soil samples have then been analysed for SOC content with the Walkley-Black method. Undisturbed samples allowed the determination of soil bulk density through core method. The equivalent soil mass (ESM) approach was applied in order to normalize the effects of different bulk density in SOC stock calculation (VandenBygaart and Angers, 2006). The minimum ESM was applied for incremental profiles and are indicated below as Layer 1, 2 and 3 from the superficial to the deeper horizon. Data have then been analysed through factorial ANOVA.

Results

The present abstract focuses on the comparison of the SOC accumulation a) in permanent meadow versus maize monoculture; b) depending on the effects of manure, slurries or mineral input on maize monoculture and c) on crop rotation.

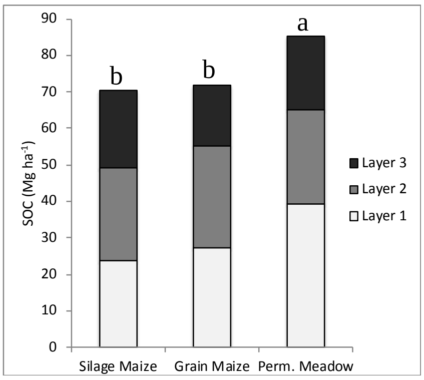

Fig. 1: SOC stocks in permanent meadow and maize monocultures.

a) *permanent meadow versus maize monoculture*: although the treatments here considered have the same nutrients input (20 t ha^{-1} y^{-1} of slurries + 0-0-0, 70-70-90, or 140-140-180 mineral NPK), differences of SOC between meadow and maize monoculture are significant, with a total stock 20% higher in the permanent meadow than in maize monocultures (85.2 Mg ha^{-1} *vs.* 71.8 Mg ha^{-1} of grain Maize and 70.4 Mg ha^{-1} of silage Maize) (Fig. 1). However, in the permanent meadow more than 45% of the total SOC stock is concentrated in the first layer. Layers 2 and 3 showed similar stocks in all the treatments that were compared. Considering that maize plots are tilled every year, this suggests that the root growth of meadow within Layer 2 compensates the increased C input in the intermediate horizon, due to tillage. In the maize plots, the same cultivar and sowing density have been used; thus these plots differ basically for the different behaviour of crop residues (removed with yield in silage Maize or incorporated in soil in the grain Maize). The effect of crop residues appears to be marginal, despite the relevant average annual C input (3.9 t ha^{-1} year^{-1} of C).

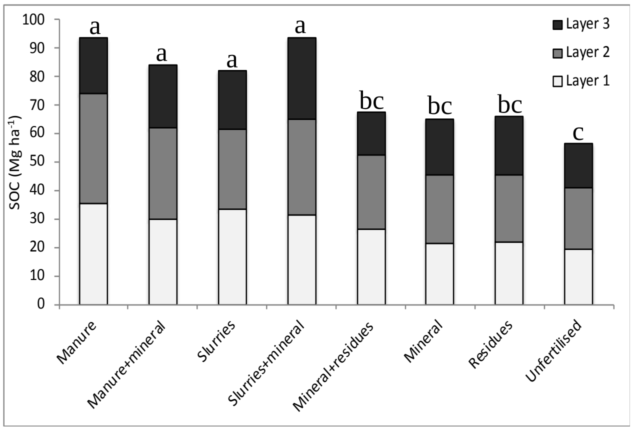

Fig. 2: SOC stocks in grain Maize monocultures with organic, mixed or mineral only inputs.

b) *effects of manure, slurries or mineral input on maize monoculture*: a consistent amount of nutrients (300-66-348 kg ha^{-1} NPK in organic and/or in mineral form) is added to this treatment, with the exception of the unfertilised plots (Residues and Unfertilised). The analysis of variance shows a marked difference between the treatments receiving organic amendments and those with only mineral inputs (on the average, 88.4 Mg ha^{-1} against 63.7 Mg ha^{-1}) (Fig. 2). The highest accumulation of SOC is obtained with a high dose of farmyard manure and with Slurries+mineral fertilisation. These treatments have higher SOC stock than the permanent meadow, despite the intensive tillage. The organic fertilisation increases the SOC content in the tilled layers, but also an accumulation in the deepest layer is observed. When the input is only mineral or Mineral+residues, the SOC distribution in the layers is far more constant, indicating a depletion of organic C, particularly in the first layer. Furthermore, the SOC stocks with only mineral inputs (Mineral+residues and Mineral) are almost equal to those of the unfertilised plots.

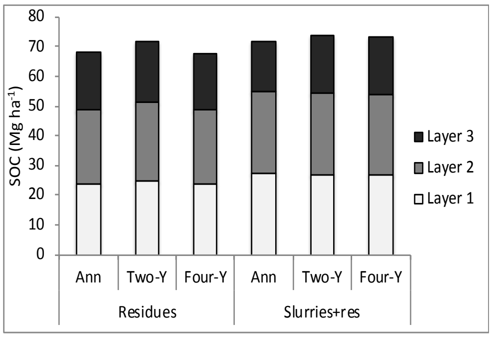

Fig. 3: SOC repartition with depth in 3 crop rotations.

c) *crop rotation*: The effect of rotation on SOC is very close to significance (p=0.053), with a tendency of a higher content on the whole profile with the two-year rotation maize-winter wheat (Two-Y, Fig. 3). It is worth noting that Two-Y rotation is characterised by the longest root growth period (≈60% of the year) in comparison with continuous maize (Ann) (≈42%) and the four-year rotation sugarbeet-maize-soybean-winter wheat (Four-Y) (≈46%). This difference might affect the amount of root-derived C, leading to a slight increase of SOC stock in the two-year rotation. Anyway, differences between crop rotations are almost negligible, and the absolute values of SOC are far lower than those of meadows and of the maize monoculture with farmyard manure input.

Conclusions

The data shows the effects of organic inputs, and particular manure, on SOC stock, also for the deeper soil layer. This stress the importance of considering also deep layers when evaluating C stocks and its sequestrations in agroecosystem. The higher SOC stocks have been obtained with solid manure, or reducing soil disturbance (permanent meadow), whereas the crop rotation seems to be far less relevant.

On the other hand, mineral fertilisation did not allow the conservation of C stocks, despite its strong effect on crop growth and, then, on C input from roots and residues.

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Estimating Soil Organic Carbon Of Arable Lands With Regional Legacy Soil Data And The LUCAS, In Contrasting Areas Of Italy

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Introduction

Land use is the main anthropic factors driving soil organic carbon (SOC) accumulation and cultivation can consist in a sturdy loss of soil C (Guo and Gifford, 2002). Aim of the work was to compare the topsoil SOC content (0-20 cm) of two Italian climate-contrasting cropland areas (i.e. one semi-arid Mediterranean, Sicily, and one warm humid continental, southern Lombardy) with the Land Use and Coverage Area frame Survey (LUCAS, taken from the European Soil Data Centre in 2009-2012), a continental benchmark for mapping topsoil properties (Ballabio et al., 2016). The comparison was made with data from detailed legacy regional databases. SOC data for land cover were aggregated in GIS to compare SOC estimates corrected by CORINE (2012) and observed land use. Lombardy and Sicily are highly intensively cropped regions with wide environmental differences. Each region has a soil database developed for studying soil diversity and building detailed pedological maps. The huge amount of information of the regional databases should be integrated in new soil assessments and managed.

Materials and Methods

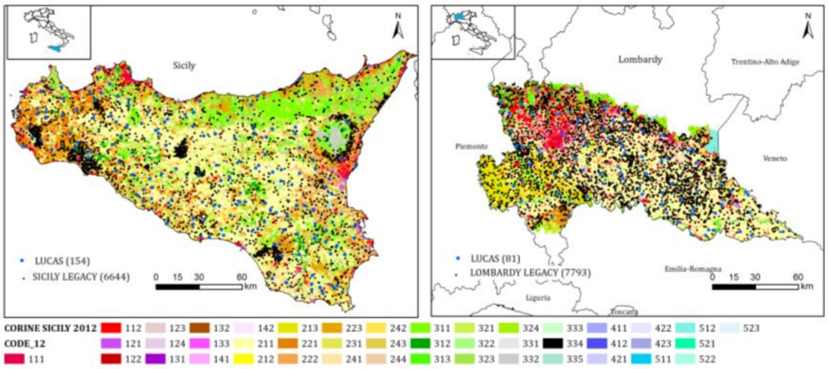

Figure 1. CORINE Land Cover (CLC) and number of total legacy samples of Sicily and Lombardy plain and LUCAS samples (numbers of land uses corresponds to CLC: 211 mainly rainfed cropland; 212 Irrigated croplands; 213 Rice; 221 Vineyards; 222 Fruit and berries plantations; 223 olive groves; 231 Grassland; 241 Grassland associated with perennial crops; 242 Complex agricultural systems; 243 Areas mainly occupied by agricultural crops with some natural; 244 Agroforestry).

LUCAS contains around 45000 samples, 43% of which from croplands (Orgiazzi et al., 2017), which represents around 34% of the EU-24 cropland. The regional databases used here were built for Sicily (Regional soil map 1:250.000, 2010) and the Lombardy plain (pedological map 1:50.000) (Fig. 1). The Lombardy soil database (LOSAN) has more than 6000 observations collected at various depths in different campaigns over 36 years. Although LOSAN has a big potential for spatial modelling of soil properties, it has not been harmonized yet for SOC accounting. Sicily has a soil database spanning 41 years (1967-2008) as georeferenced values derived by pedological profiles and soil pits from 44 sampling campaigns. Lombardy and Sicily legacy and LUCAS soil layers up to 20 cm depth were taken only to allow for harmonized comparison. Soil layers were from the CORINE “arable lands” (2.1.1 rain-fed field crops and 2.1.2 rice crops) and divided by the observed land use in the sampling point.

Results

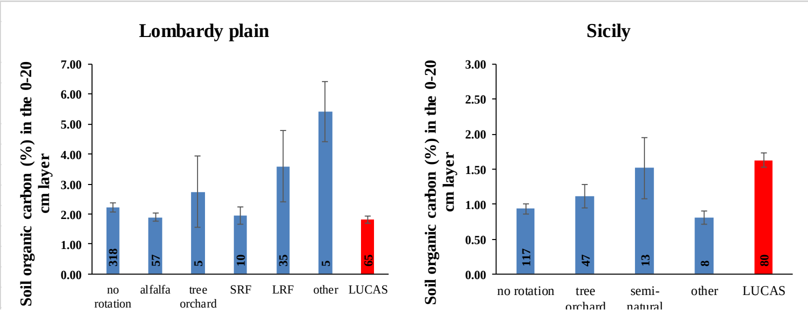

Figure 2. Means ± s.e. of SOC from CORINE Land Cover area 211 (Arable lands) from the legacy databases (blue bars) and LOSAN (red bars) from the 0-20 cm layers. Samples from legacy data were grouped by observed land use and rotation. SRF and LRF for short and long rotation forestry. Data at the bar base is sample number in each class.

All databases were homogeneously distributed (not shown). here There was no overlapping sampling sites in both areas with LUCAS.

Mean SOC in the 0-20 cm depth layer from Lombardy legacy and LUCAS was 2.30±0.15 (mean ± s.e., n=430) and 1.81±0.13 (n=65), respectively, whereas Sicily legacy and LUCAS mean SOC contents were 1.02±0.07 (n=185) and 1.63±0.11 (n=80). When data were grouped by the observed land use, Lombardy legacy data were close to those of LUCAS for observed arable lands for grain production, with alfalfa or short rotation forestry rotations (+0.42%, +0.09%, and +0.15%, respectively, compared to LUCAS, Fig. 2), whereas they strongly differed when in rotation with orchards or in long rotation forestry (+0.94%, and +1.78%, respectively, compared to LUCAS).

Conclusions

We showed that LUCAS offers a different picture of the SOC content in Sicilian cropland (higher than almost all observed rotations), while estimates were closer to observed legacy data in the Lombardy plain. When comparing SOC of the area under study by selecting only observed arable, difference between legacy and LUCAS slightly reduced in Sicily, but not in the Lombardy plain. These results suggest that the use of continental soil database for regional estimation should be thoroughly tested (i.e. on same locations/land cover) before comparing databases. This could minimize errors of estimation and comparison, which can depend on both the low density of the continental databases and correctness of attribution of the land use. This latter factor was seen to be important for SOC accumulation and estimation in the legacy databases (Schillaci et al., 2016, 2017b; a; Lombardo et al., 2018). Further studies will be conducted by splitting the legacy dataset by specific land cover and soil depth/horizon to improve sampling designs and allow their integration into an European frame.

Acknowledgement

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Use Of Mixed Effects Models Accounting For Residual Spatial Correlation To Analyze Soil Properties Variation In A Field Irrigated With Treated Municipal Wastewater

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Introduction

Knowledge about soil properties variation as effect of agronomic management is of great interest for assessing soil quality and should be investigated using appropriate methodological approaches.

Irrigation with treated municipal wastewater (TWW) can be considered an important strategy to save limited freshwater resource and protect the environment. TWW composition varies among sites and over time, thus its effect should be monitored to avoid soil fertility decline in the medium to long term.

In evaluating the effect of different agronomic managements on soil properties or plant response, data sampling and analysis play a crucial role to take into account variability that occurs at a scale smaller than the block size. Spatial dependence between observations and residuals may occur in the experimental fields and, if not properly considered, may result in erroneous conclusions about treatment significance (Hong et al., 2005; Littell et al., 2006). Linear mixed effects models (LMM) allow spatial components to be assessed and filtered from the total residual term of the model so improving the protection of the statistical tests (Rodrigues et al., 2013; Ventrella et al., 2016).

In this study, LMMs accounting for residual autocorrelation were used to investigate the effect of a three year irrigation with TWW on soil properties with particular regard to organic carbon. Auxiliary information deriving from proximal geophysical sensors was also used to assess and describe main sources of variability of the experimental field.

Materials and Methods

The field experiment was carried out in an olive grove located in Apulia (Southern Italy), irrigated over three years with treated municipal wastewater deriving from a treatment plant near the experimental field. Treatments compared were: irrigation with fresh water and full fertilization supply (FW); irrigation with TWW and full fertilization supply (R1); irrigation with TWW and fertilizer supply reduced by the amount provided by TWW (R2). Treatments were arranged in a randomized complete block design (RCBD) with four replicates.

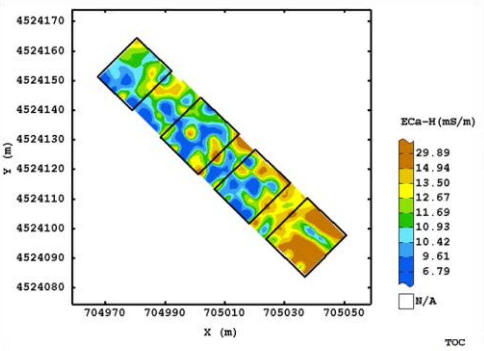
To investigate spatial variation of soil properties, soil samples with absolute coordinates were collected (April 2017) on a regular grid on six locations per plot at a 0-0.20 m depth for a total of 72 observations. On air-dried and sieved soil, total organic carbon (TOC) was measured through dry combustion; on field-moist samples, water extractable OC and N were quantified.

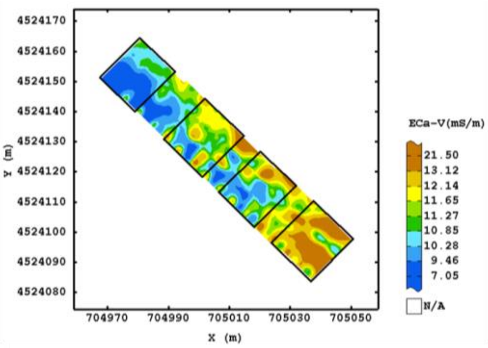
A geophysical survey was carried out using a EMI sensor (EM38DD) connected to a DGPS to investigate spatial variation of the experimental field. The EMI sensor measures apparent electrical conductivity (ECa) simultaneously in vertical (ECa-V) and horizontal mode (ECa-H).

After a preliminary statistical analysis, spatial analysis was performed computing Moran's I statistic and correlograms; afterwards a spherical model was fitted to the experimental variograms of TOC and ECa. ECa and TOC data were then interpolated with ordinary co-kriging and ordinary kriging on a 0.5-m x 0.5-m grid. LMMs were used to test the effect of treatments compared. Spatial (LMM_{sp}) and non-spatial models (OLS) with the same fixed effects were compared using likelihood ratio test (LR) and information criteria based on likelihood estimations (Ventrella et al., 2016). Data analysis was performed using PROC VARIOGRAM and PROC MIXED of SAS/STAT (release 9.3, SAS INST).

Results

The maps for ECa variables seemed to reveal a spatial continuity along the investigated soil profile in particular for the two blocks located in the southern part, with a similarity between ECa-H and ECa-V maps (Fig.1, a-b). As regards the lateral variation, ECa maps identified an area with higher values in the southern portion of the field while the northern corner was characterized by lower values. TOC distribution over the experimental site (Fig. 1 ,c) showed larger average values in the southern part of the field quite in accordance with the ECa maps. In addition, the map highlighted heterogeneity within blocks that is not taken into account in the blocking of the RCB experimental design. A significant spatial association was highlighted by the Moran statistic, both on the observations and on the residuals (P=0.0043 and 0.0073). In addition, likelihood ratio test was significant and LMM_{sp} showed a lower AIC value (15.4 *vs* 28.2 for OLS). The spatial covariance structure showed significant partial sill (P<0.0001) and range (P<0.0001). Finally, a lower F value was observed for the spatial model, indicating that ignoring spatial dependence might distort the results and increase the possibility of falsely declaring significant effects.





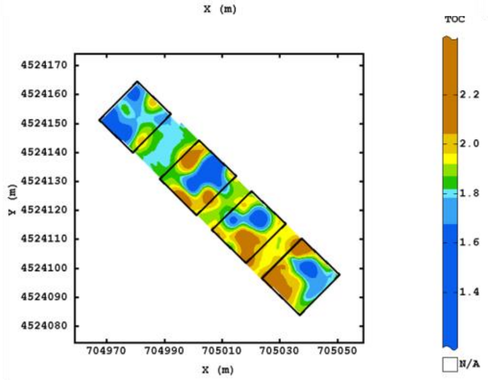


Fig. 1, a-c. Spatial estimates of ECa in horizontal (a) and vertical (b) polarization (in milli-Simiens per meter) and of TOC (g 100 g^{-1}, c). The black polygons indicate the four blocks in the RCB experimental design.

Conclusions

Correlation among observations and then residuals may occur in high spatially variable experimental fields. In these cases, the use of statistical approaches taking into account residual autocorrelation can be advantageous as can reduce the probability to make type 1 error, thus allowing a more correct interpretation of experimental results and improving the accuracy of predictions.

Acknowledgement

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Soil Organic Carbon Dynamics and Maize Yield under Climate Change: The Long-Term Impacts of Organic Fertilizations

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Introduction

The role of Soil Organic Carbon (SOC) in determining the sustainability of cropping systems is central because of its influence on soil fertility, nutrients and water cycles. Furthermore, to adopt agricultural practices that enhance the SOC sequestration is crucial in counteracting climate change (Follet, 2001). It is recognized that organic fertilization in agroecosystems is the most important practice that allow to enhance the SOC stocks (Maillard and Angers, 2014). Therefore, in order to assess the long-term sustainability of intensive cropping systems, it becomes crucial to investigate how the fertilization management could influence the SOC stocks variation under climate change.

In this contribution, a Multi-Model Ensemble (MME) approach was applied starting from data obtained from a Long-Term field Experiment (LTE). The aim of the study was to assess the long-term effects of different fertilization management practices on SOC changes and crop yield under irrigated continuous grain maize cropping system, under different sources of N fertilizer (mineral and organic), at current and future climate scenarios.

Materials and Methods

The study was conducted using the experimental dataset from the LTE of Tetto Frati, Turin (LTE-TO, Piedmont, IT; 44.88° N, 7.68°E), which belong to the Italian LTE network IC-FAR (www.icfar.it). The LTE-TO is based on continuous irrigated maize cropping system. Since 1991, the LTE experimental design have assessed the impact of both mineral and organic N fertilization on grain (MG) and silage maize (MS) yield and soil traits, by supplying N rates that varied over the years from 250 to 300 kg ha^{-1} (Zavattaro et al., 2016). A subset of the LTE-TO treatments was selected in order to extrapolate 19-year of experimental and meteorological data, which were used to calibrate and validate DSSAT, EPIC, CropSyst, DNDC, and SALUS models. The six selected treatments compared grain and silage maize under only mineral N fertilization; grain and silage maize with organic N fertilization by both slurry and manure supply. The climate scenarios were generated by applying a statistical downscaling model, based on Canonical Correlation Analysis, to the predictors of CMCC-CM global model. The model allow to obtain a 50-year meteorological dataset at local scale over the period 1971-2000 baseline scenario with atmospheric CO_2 concentration of 360 ppm (Control Run, PC-CR), and 2021-2050 (from both RCP4.5 and RCP.5 emission scenarios) with CO_2 concentrations of 460 ppm (FC-RCP4.5) and 490 ppm (FC-RCP8.5) future scenarios. Models performance were evaluated as proposed by Iocola et al. (2017). The models were ranked including the MME (mean values of model outputs) and considering index from both SOC and yield simulation performance. To perform the scenario analysis, models were run for each climatic scenario considering two management options: grain maize crop fertilized with urea (MG-MI); grain maize crop fertilized with manure (MG-MA).

Results

The models performances in simulating the SOC dynamics and the maize Yield are reported in Table 1. The MME overall showed the best performance considering both SOC and Yield simulation.

Table 1. Evaluation of the five models and of the Multi Model Ensemble (MME) in simulating Soil Organic Carbon (SOC, Mg ha^{-1}) and grain maize Yield (Mg ha^{-1}) for both mineral and organic fertilization (slurry and manure).

Model ID	Variable	MAE	RRMSE	EF	R^2	Mean of Ranks	Rank
1	SOC	4.10 (4)	0.11 (5)	0.25 (5)	0.58 (4)	3.38	3
	Yield	1.81 (2)	0.12 (2)	0.89 (2)	0.90 (3)		
2	SOC	2.19 (1)	0.06 (1)	0.77 (1)	0.87 (1)	3.00	2
	Yield	2.99 (5)	0.18 (5)	0.72 (5)	0.81 (5)		
3	SOC	3.15 (3)	0.08 (3)	0.59 (3)	0.70 (3)	4.50	6
	Yield	8.42 (6)	0.51 (6)	-1.15 (6)	0.34 (6)		
4	SOC	4.59 (6)	0.11 (4)	0.26 (4)	0.47 (5)	4.00	5
	Yield	2.06 (3)	0.13 (3)	0.85 (3)	0.88 (4)		
5	SOC	4.57 (5)	0.13 (6)	0.03 (6)	0.34 (6)	3.50	4
	Yield	1.55 (1)	0.10 (1)	0.91 (1)	0.92 (2)		
MME	SOC	2.72 (2)	0.07 (2)	0.72 (2)	0.73 (2)	2.63	1
	Yield	2.23 (4)	0.15 (4)	0.82 (4)	0.92 (1)		

MAE: Mean Absolute Error; RRMSE: Relative Root Mean Square Error; EF: Modelling Efficiency; R^2: Coefficient of Determination. The numbers in brackets represent the rank model in relation to the variable. The Mean of Ranks represents the average ranks values considering ranks of both SOC and Yield performance indexes.

The MME (Models 1, 3 and 4), under MI fertilization scenarios, showed an average SOC decrease of 10% with respect to the initial conditions, while under MA the SOC content increased, on average, by 22%. At the 50^{th} year, fertilization affected the SOC content ($P<0.001$), while not significant effects of climate were observed. The ensemble of Models 1 and 4 evidenced not significant trends of MG yield. A poor significance ($P<0.1$) was observed for the yield trends under FC-RCP8.5, for which were observed both a decrease (-1.71%) and increase (0.24%) in MI and MA, respectively.

Conclusions

The contribution reports the preliminary results of a multi-LTE study. The reported results partially confirm the hypothesis that in the long-term period, under climate change, the SOC content and the MG yield are affected by the organic fertilization. The significant increase of SOC content observed under MA fertilization confirm the importance of organic fertilizer in ensuring SOC sequestration. Nevertheless, the first evidence highlights, in the long term, a lack of significance of the future climate on determining SOC changes, while there is a signal of possible MG yield variations. These preliminary results evidences the need of further insights on SOC components changes (e.g. C pools) in relation to climate change, at different LTE maize-based cropping systems.

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Crop Management Of The Peach Orchard For Saving Water

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Introduction

Peach is among the most representative and valued fruit species in the Mediterranean Basin; Climate in Southern Italy (hot and dry till late summer) is particularly suitable for early and late ripening cultivar. However late peach varieties are more water demanding since the long-lasting persistence of fruits on the plant.

In this area, the limited availability of water implies the need to search for agronomical solutions that can mitigate the consequences of water deficits and increase the efficiency of the irrigation supply.

Solutions may be found through approaches which consider the soil-plant-atmosphere system as a whole and are therefore addressed to improve the entire orchard performance to cope with water scarcity (Jordan et al., 2014).

Innovative agro-techniques aiming at decreasing soil evaporation, using mulching (Wang et al., 2015), and creating favorable micrometeorological conditions (decrease in temperature and air pressure vapor deficit) by using shading nets (Losciale et al., 2011), can mitigate the consequences of water deficits on the peach orchard. The aim of this study was to evaluate the effects of 8 different orchard managements on productivity, water use efficiency and soil water stress coefficients in a late ripening peach cultivar.

Materials and Methods

The study was conducted during 2017 season in Southern Italy (Cerignola, lat: 41 20', long: 15 56', altitude 40 m a.s.l.), on 15 year old peach trees cv "California", spaced 5.0 x 3m.

Eight different orchard managements were tested, resulting from the combination of 2 different soil managements: soil completely tilled (T) and mulching with a biodegradable film to reduce soil evaporation (M); 2 different light regimes: reduction of the incident solar radiation of 10% by hail nets (H) and of 30% by shading nets both with high diffusivity (S); 2 irrigation regimes: full irrigation (W) to supply the amount of water lost by evapotranspiration (ETc) and deficit irrigation (L) to restore 50% of ETc from August until end of season.

During the irrigation season (June-September) and for each orchard managements the climatic parameters (temperature and relative humidity of the air, wind speed, PAR and rain) were monitored by agro-meteorological sensor installed at 1 m over the crop. Soil water content was measured in whole profile by capacitance probes (10HS, Decagon, USA) installed horizontally into the soil at three depths (−0.15, −0.3 and −0.5 m). All sensors were connect to data-loggers (Winet srl, Italy) and data were transferred every hour on a web-server via GPRS mode. To account the site-specific soil water balance, hydrologic constants (field capacity, FC, and wilting point, WP, of 30% and 20% in volume respectively) were determined. For each orchard management, the following crop water indicators were assessed: seasonal (ETc) in accordance to Allen et al (1998); Productiver Water Use Efficiency (P_WUE, as kg of fresh fruit per m^3 of ETc); soil water stress coefficient (Ks, dimensionless, as a reduction factor in transpiration ranging from 0 - maximum stress, to 1 - no stress). Ks values were calculated considering a readily available water threshold (p) of 0.5:

$$Ks = \frac{Wc-FC}{p(FC-WP)-WP}$$

At harvest, the production (t ha^{-1}) was evaluated on 6 trees for each treatment. The experiment was arranged according to a Split-Split plot Design.

Results

Seasonal irrigation volumes were 4790 m^3 and 3970 m^3 ha^{-1} in the W and L irrigation regimes, respectively. Shading net (S) determined a reduction of the air temperature (-1 ° C), wind speed (-42%), PAR (-24%) and an increase of relative air humidity (+5%). Below the shading nets VPD lowered to non-limiting values for the fruit transpiration (driving force for their growth), as a consequence, excluding SLM, production was generally higher in S treatments. In particular, the combined effect of shading net and mulching has also determined the lowest ETc (471 mm), for both irrigation treatments (full, SWM, and deficit, SLM). The direct consequence has been the increase of productive water use efficiency (12.6 kg m^{-3} for SWM). Moreover, the SWM orchard management did not show any water stress (Ks = 1) during the vegetative season, while the lowest value was calculated in the HLT management with seasonal average value of 0.89.

Table 1 – Production, crop evapotranspiration, water use efficiency and soil water stress coefficient in 8 peach orchard managements.

Treatments	Production ($t\ ha^{-1}$)		ETc (mm)	WUE ($Kg\ m^{-3}$)	Ks
HLM	51.8	bc	531	9.7	0.93
HLT	46.5	c	559	8.3	0.89
HWM	47.4	c	554	8.5	0.97
HWT	55.3	ab	589	9.3	0.95
SLM	49.3	bc	471	10.5	0.98
SLT	55.3	ab	506	10.9	0.92
SWM	59.4	a	471	12.6	1.00
SWT	54.6	ab	511	10.7	0.99

Conclusions

Crop management modified environmental parameters of peach orchard. The field survey quantified reductions of incident radiation load and VPD, through shading nets, and of soil evaporation, through mulching. The combination of both reductions affected the measured values of soil water stress coefficient (ks). Results indicated a straight relationship between ks and peach production, as well as that irrigation supply was not the only tool to control ks. The use of nets with a moderate shading effect, combined with mulching, could be promising to improve productivity, WUE, to avoid soil water stress conditions, and finally save water resources.

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Poster

“Analisi e confronti tra tipi di agri*culturae*”

Soil P Status In Piedmont: A Regional Assessment

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Introduction

Phosphorus (P) plays an essential role in soil fertility and world food security, but its actual major source, phosphate rock, is a non-renewable resource. Moreover, P frequently responsible of eutrophication in freshwater ecosystems. P fertilization management must therefore ensure long-term food security and in the meantime prevent environmental pollution (Scholz et al., 2013). The available fraction of soil P must be assessed at a field scale in order to increase the P use efficiency and to achieve a sustainable management of P fertilization. If a single soil analysis is important to pilot fertilization at a field scale, the collection of several samples from various farms allows a description of soil P status at a territorial scale. Regional labs contain lots of data in their databases that can be used for this purpose, also allowing to track temporal changes in the long term, as Lemercier et al. (2008) did for Brittany (NW France).

This objective of this work was to describe spatial and temporal trends of soil P status in the Piemonte Region (NW Italy), as emerged from the regional database of soil analyses commissioned by private farms.

Materials and methods

After a selection of data using internal consistency indicators in order to exclude outliers, the regional database of soils analyses in Piemonte contained 41 114 records, of which 32 683 reported an assessment of Olsen P since 1984. Metadata could include crop, year, sampling depth and geographic coordinates, but only 10 475 Olsen P values could be georeferred and attributed to a Macro Land Unit (MLU), sub-regional areas characterized by a particular cropping system (Bassanino et al., 2011). An ANOVA was performed, after log-transformation of data to account for non-normality of distribution, to test the effect of crop type on the soil Olsen P concentration.

Results

About 26% of soil samples in Piemonte had a low soil P status (<10 ppm expressed as P), and about 49% had an Olsen P value greater than 20 ppm. Differences were significantly related to the crop type (Tab. 1). Horticultural crops showed the highest values, followed by rice, arable crops and fruit trees. This order is in line with intensification of the cropping system.

Table 1. Olsen P concentration in selected crops classes and results of the REGWR post-hoc test.

Crop	Num. of samples	Olsen P (ppm)
Horticultural crops	1 028	29.8 a
Rice	3 915	28.8 a
Arable crops	8 553	24.2 b
Fruit trees	2 492	24.1 b
Grassland	1 224	15.2 c
Hazelnut	561	11.6 ef
Vineyard	5 474	9.9 f

The spatial distribution of Olsen P values across MLUs (Tab. 2) indicates that MLU3 and MLU5 were characterized by higher available P than the others. The high Olsen P content in MLU3 soils may be due to a high livestock concentration, as livestock farms were 31% in that area. Moreover, maize for grain was cultivated on 37% of the agricultural area, and this is the crop with the highest P surplus (Bassanino et al., 2011). In MLU5 the high available P content could be related to the particular soil conditions due to flooding, as 69.2% of the area were paddy fields (Bassanino et al., 2011). The low soil Olsen P contents in the other MLUs can be explained by the widespread cultivation of grapevine (18.7% in MLU4), winter cereals (33.6% in MLU2) or grassland (43.3% in MLU4), all having a low P surplus at the field scale.

Table 2. Olsen P concentration in the different Macro land units.

MLU	Description	Num. of samples	Olsen P (ppm)
1	Hilly area of Alessandria	1 527	16.0
2	Plain area of Alessandria	1 298	23.2
3	Plain areas of Cuneo and Torino	3 499	41.2
4	Hilly areas and valley floors	1 707	26.4
5	Paddy rice area	2 375	36.0

Figure 1 shows the temporal variation of the average content of Olsen P in the five MLU soils in the period 1984-2013. The availability of P has declined in the last 30 years in both plain and hilly areas of Alessandria (MLU1 and MLU2), as a consequence of the widespread adoption of integrated agriculture protocols, that impose a reduction or suspension of P fertilization in P rich soils. The reduction observed in MLU5 is probably as a consequence of a negative P balance management on 53% of the rice paddy area, as reported by Zavattaro et al. (2006). No clear trends were observed in the other MLUs, where livestock systems are widespread. A surplus of P in livestock farms occurs because of import of forages and concentrates from outside the farm, that creates big issues at a worldwide scale (Wang et al., 2018).

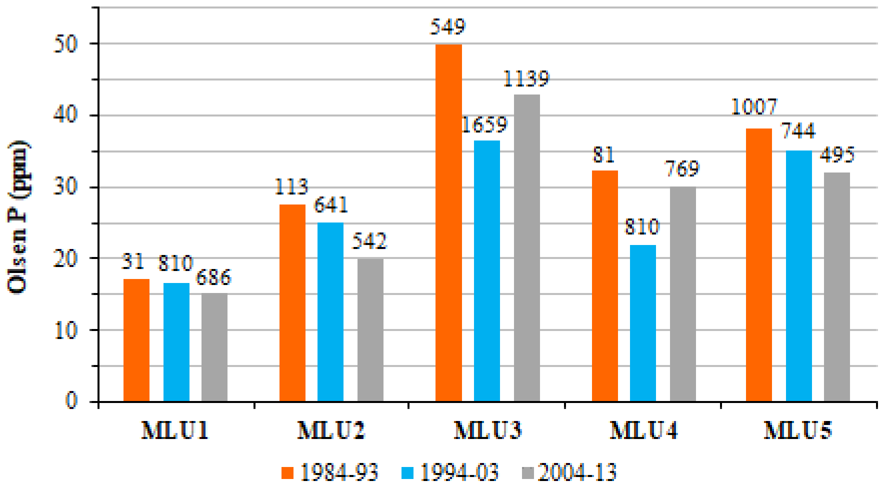

Figure 1. Olsen P concentration for the different MLUs in three decades. Numbers of samples are also reported.

Conclusions

Available soil P at a regional scale is influenced by the intensification level of dominant cropping systems and can be influenced by agri-environmental policies that impose a reduction of fertilization. Several years are needed to observe a change in soil P status after a modification in the fertilization strategy.

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Factors Controlling Total Organic Carbon And Permanganate Oxidable Carbon In Southern Italy Agricultural Soils

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Introduction

Soil organic carbon (SOC) stock and dynamics in agricultural soil have an important role in defining the agricultural results and climate change control. Indeed, increasing SOC has been proposed as the principal strategy to mitigate climate change with an additional benefit of improving soil structure and soil conditions (Lal, 2015; Minasny et al., 2017). Therefore, understanding the mechanisms controlling the accumulation of soil carbon is critical to predict patterns of long-term agriculture sustainability and global warming (Lal et al., 2015). The aim of this research was to investigate the distribution of total (TOC) and labile (POxC) soil carbon stocks in different agricultural areas of the Calabrian region, as well as, identify the critical parameters that influence it.

Materials and Methods

Soil samples were collected from several representative agricultural land uses practised across the Calabrian region, including one uncultivated soil: Olive modern; Olive traditional; Orange; Vineyard; Annual irrigated cropping systems; Annual rainfed cropping system; undisturbed soil covered by Mediterranean scrub and garrigue. At each site, composite samples were taken from the 0-5 cm (A) and 5-30 cm (B) soil layers by mixing three manually collected soil cores (manual auger). The total number of soil samples was 420. After sampling, soil samples were air-dried and divided in two aliquots: one sieved to pass through a 2 mm sieve was used to determine soil pH, electrical conductivity (EC), particles size distribution (PSD) and Permanganate Oxidizable Carbon (POxC) whereas, the other one, was crushed to pass through a 500 µm sieve and used for total calcium carbonate ($CaCO_3$), total organic C (TOC) and N (TON) determination. Climatic and bioclimatic data were provided from Worldclim (Hijmans et al., 2005) with a spatial resolution of 30 seconds (~1 km^2). Data used were monthly and yearly mean of the period 1950-2000. For TOC and POxC, globally for the two investigated soil layers, Pearson correlation coefficient (proc corr) and stepwise multiple linear regression (proc reg) were carried out in SAS v9.2 environment. In order to distinguish the contribution of pedological and bioclimatic factors to soil TOC and POxC distribution, variance partitioning (varpart) was performed using R v3.5.0 statistical software and vegan package v2.5-1.

Results

Mean soil TOC concentration in the investigated soil layer was 16.0 and 10.1 g kg^{-1}, in surface (A) and deep (B) soil layer, respectively. Average observed POxC values were 298.8 and 122.9 mg kg^{-1} (Table 1). Agricultural land use areas showed significant differences in soil TOC and POxC content, especially in the surface layer. In this soil layer, the higher values were observed in olive groves, both modern and traditional (24.5 and 26.2 g kg^{-1}) with similar values to undisturbed land use areas (26.6 g kg^{-1}). Small differences were observed between annual cropping system, irrigated and rainfed (10.1 *vs* 12.2 g kg^{-1}). Vineyard and orange orchard showed intermediate values compared to other cropping systems, precisely 12.9 and 15.7 g kg^{-1}. Soil POxC showing a similar trend to TOC representing, on average, between 2.0 and 1.3% of TOC. In the different land uses, in A soil layer was retrieved 2.5-3 fold higher POxC concentration than in B soil layer with the only exception of the annual cropping system under rainfed condition where both soil layers showed similar amounts (Table 1).

Table 2. Soil TOC and POxC values and related statistics.

Land Use	Soil layer	TOC [g kg^{-1}]				POxC [mg kg^{-1}]			
		min	max	mean	dev.st	min	max	mean	dev.st
	A	17.2	32.2	24.5	4.0	261.8	569.6	405.1	90.7

Olive modern	B	9.8	18.8	13.2	2.3	56.1	271.4	131.4	63.3
Olive traditional	A	19.2	33.6	26.2	4.1	284.6	665.7	479.1	102.7
	B	12.6	26.2	16.7	3.3	50.0	271.4	145.2	57.7
Annual irrigated	A	7.9	13.1	10.1	1.6	111.6	370.1	218.0	75.5
	B	5.7	10.2	8.0	1.1	33.2	180.9	98.4	48.9
Annual rainfed	A	8.5	18.7	12.2	2.4	102.9	252.9	141.2	35.4
	B	7.4	13.3	10.7	1.6	63.6	239.0	131.3	51.5
Vineyard	A	9.0	16.8	12.9	1.8	218.9	438.6	284.4	67.7
	B	7.1	13.0	10.3	1.3	115.9	242.5	182.4	36.5
Orange orchard	A	12.1	20.7	15.7	2.3	284.2	593.0	405.4	80.3
	B	7.7	17.6	12.0	2.2	37.3	186.0	117.3	45.9
Natural vegetation	A	12.6	41.5	26.6	7.4	332.7	542.6	456.9	78.0
	B	6.3	14.5	10.2	2.0	102.5	273.9	177.0	40.4
A		7.9	41.5	16.0	7.7	102.9	665.7	298.8	140.1
B		5.7	26.2	10.1	3.3	33.2	273.9	122.9	56.41

Pearson correlation coefficient, calculated between TOC, soil properties, climatic and bioclimatic data allowed to find correlation among them. In particular, in A soil layer, soil TOC concentration was correlated with soil pH (r = -0.71), POxC (r = 0.80), Silt (r = -0.55) and monthly precipitation (r = 0.69, on average), BIO08 (r = 0.68), BIO14 (r = 0.57) as climatic and bioclimatic indicators. In the deeper soil layer (B), factors correlated with soil TOC were: soil pH (r= 0.56), BD (r = -0.52), Silt (r = -0.49), BIO08 (r = 0.60), BIO13 (r = 0.51). Soil POxC in A soil layer show a significant correlation ($P< 0.05$) with: TOC (r = 0.80), pH (r = -0.58), Sand (r = 0.54), monthly precipitation (r = 0.68, on average), BIO04 (r = -0.53), BIO 08 (r = -0.64) and BIO14 (r = 0.55). In the deeper soil layer Pearson correlation between POxC and soil-climatic-bioclimatic indicators retrieved poor results. Stepwise multiple linear regression applied to soil TOC concentration in A soil layer allowed to calculate a relation with soil (EC, BD, PSD), climatic (temperature, precipitation) and bioclimatic (BIO03, BIO13) parameters reaching good estimation ($R^2 = 0.85$) ($P< 0.05$). In the deeper soil layer (B), estimation by regression show a $R^2 = 0.70$ with a model including soil (pH, BD), climatic (temperature, precipitation) and bioclimatic (BIO14, BIO17, BIO19) parameters ($P< 0.05$). For POxC estimation regression reached a $R^2 = 0.91$ and $R^2 = 0.70$ for A and B soil layer, respectively. Variance partitioning analysis showed that up to 22% and 24% of TOC variation, in both soil layer, depends on soil properties and climatic-bioclimatic parameters, while their interaction accounts for 41% and 26%. Soil properties affect POxC concentration by 14% in A soil layer and 23% in B soil layer while from climatic and bioclimatic parameters depend up to 16% and 29%. The interaction between soil and bioclimate contributes for 48% and 26% to POxC concentration, respectively, in A and B layers.

Conclusions

The results highlighted that land use, chemical properties and climatic conditions can significantly and selectively influence total and labile soil C stock. Therefore it is important to investigate how climate change can represent a critical factor affecting soil C dynamics and how agronomic practices in different cropping system can counteract these changes in order to maintain soil productivity and increase the portion of sequestered carbon.

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The Adapt2Clima Project: Assessment Of Future Climate Impacts On Agricultural Areas Of Three Mediterranean Islands

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Introduction

The Adapt2Clima (A2C) project is triggered by the need to understand the impacts of future climate on agricultural areas of three Mediterranean islands: Crete (Greece), Sicily (Italy) and Cyprus. These areas, considered very sensitive to climate change (Giorgi, 2006), have experienced a generalized decrease of precipitation (Sousa et al., 2011), a significant annual warming trend (+0.75°C) and an increase in climate extremes (Ulbrich et al., 2013). These changes have negatively affected the whole agricultural sector of the regions around and within the basin, negatively affecting the physiological status of the plants (Barnabás et al., 2008), thus reducing crop growth and gross primary production of terrestrial ecosystems (Ciais et al., 2005). In the Mediterranean basin, the main losses are due to a strong decrease in quantity and quality of harvests, with sensible damages for cereals and tree crops. For assessing the impacts of future climate on agricultural sector in these regions, crop models can be used. These tools can provide indication about the expected yield losses as well as evaluating benefits provided by the adoption of adaptation strategies compared to the current management. In this study, phenological and yield changes of wheat, barley, potato, tomato, olive trees and grapevine were assessed over the three Mediterranean islands using three different models (i.e. CropSyst, OLIVEmodel.CNR and UNIFI.GrapeML) under two climate scenarios (RCP4.5 and 8.5).

Materials and Methods

The simulation models used in this study were:

i) CropSyst (Stockle et al., 2003) can simulate productivity of crops and crop rotations in response to weather, soil and management as well as to assess both the climate impact on crop performances determined by different management. The model was used for wheat, barley, tomato and potato:

ii) The OLIVEmodel.CNR (Moriondo et al., under revision) simulates the growth and development of olive agroecosystem at daily time step, considering the competition for water between the two layers. A phenological sub model reproduces changes in biomass allocation and the final yield;

iii) UNIFI.GrapeML (Leolini et al., under revision) is a BioMA software library jointly developed by UNIFI and CREA-AA. The model takes into account phenological development, leaf area growth, biomass accumulation and partitioning, extreme event impacts and grape quality.

The models, previously calibrated for confirming their robustness at reproducing the growth dynamics of the investigated crops, were then run for current (Baseline 1971-2000, CO_2 concentration at 360 ppm) and future (RCP4.5 and 8.5, 2031-2060, CO_2 concentration at 485 and 540 ppm respectively) for assessing crop phenology (flowering and maturity) and yield changes.

Results

Concerning phenology, an advancement of the two phases (i.e. flowering and maturity) was observed for all crops and scenarios in the three areas. Specifically, the advancement was higher under RCP8.5 than RCP4.5 compared to the baseline. For flowering (Fig 1), the maximum advancement was found for potato (-26 days), whilst the lowest for grapevine (-7 days). The remaining crops ranged between 10-20 days of advancement. For maturity (Fig 1), the maximum advance was found for olive tree (-45 days), whilst the lowest for grapevine (-10 days). The remaining crops ranged between 15-25 days of advancement. Concerning yield, contrasting patterns were observed among the crops (Fig 2). Cereals, potatoes and olive showed an increase under both scenarios, showing the highest production under RCP8.5. The highest increase was found for potato (+20%), whilst the other crops showed a general increase by 7% compared to the baseline. By contrast, tomatoes and grapevine showed yield decreases compared to the baseline under both scenarios, showing the highest losses under RCP4.5. The highest decrease was found for grapevine (-9%), whilst the lowest for tomato (-2.7%) compared to the baseline.

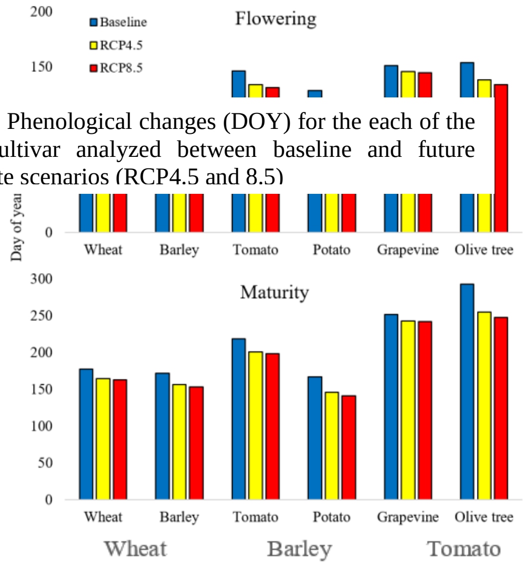

Fig 1. Phenological changes (DOY) for the each of the six cultivar analyzed between baseline and future climate scenarios (RCP4.5 and 8.5)

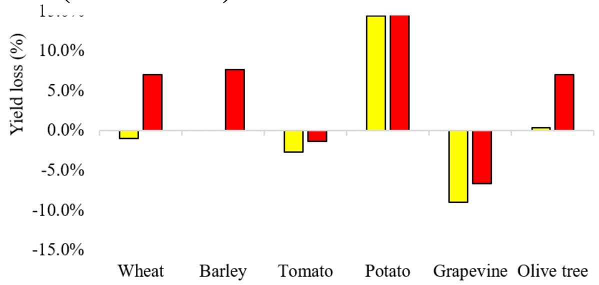

Fig 2. Yield changes (%) for each of the six cultivar analyzed between baseline and future climate scenarios (RCP4.5 and 8.5)

Conclusions

The use of crop models for assessing the impacts of future climate on agricultural sector over the three Mediterranean islands of Crete, Cyprus and Sicily, has provided relevant information on the expected phenological and yield changes in the near future. Our results showed as, on average, an increase in warm conditions can lead to contrasting results depending on the cultivation adopted. These results, showing the productivity pattern of the analysed cropping systems, should be considered as fundamental indicators for the future production over Mediterranean areas, resulting highly useful especially if considered as a starting point to develop agricultural strategies to cope with the projected impacts of climate on crop yields.

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Yield Performance Of a Maize Early Hybrid Grown In Tunnel And Open Air Under Different Water Regimes

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Introduction
Global mean surface temperature (T) increased by 0.85 °C from 1880 to 2012 and is projected to increase further by 1.0–3.7 °C by the end of 2100. This T increase is expected to bring about increase in the frequency of heat waves and variable precipitation patterns over most land areas. High T during plant growth exerts severe influence on productivity. Temperature is one of the most important factors that influence seed viability and seedling growth, the capacity and rate of germination, as well as processes that influence the production of biomass, fruits and grains (Hay and Walker, 1989). High average "seasonal" T can increase the risk of drought, limit photosynthesis rates and reduce light interception by accelerating phenological development. In Italy, Tubiello et al. (2000) described that warmer temperatures accelerated plant phenology and reduced dry matter accumulation, with an impact on yields on the order of 20%. They also found that maize growing cycle was shortened by 16 days respect to ordinary cycle – 114 days and actual evapotranspiration was diminished by 70 mm.
Another important factor for the production is the water availability. Some studies report that corn appears to be relatively tolerant to water deficit during the vegetative and ripening periods, and that the greatest decrease in grain yield is caused by moisture deficit in the soil profile during the flowering period. Short-term effects of water deficit are described as delaying leaf tip emergence and leaf area reduction. Long-term consequences are reported as reduced final size of the leaves and internodes and yield losses of 15–25%. Some authors reported that highest grain yield, dry matter, kernel numbers and water use efficiency were obtained from both the fully irrigated treatment and that receiving 80% of the required irrigation water amount applied. The aim of the experiment was to evaluate the adaptability of an early maize hybrid grown in two environments (open air and tunnel) and subjected to different water regimes.

Materials and Methods
The experiment was set up in 2017 at experimental site of Department of Agriculture, in Portici (Naples-Italy; lat. 40° 49' N; long.14° 20' E) in two environments: open field and a polyethylene tunnel characterized by ordinary and high temperature condition, respectively. Maize seeds (early hybrid – class FAO 200) were sown on 3 April in plastic pots of 0.33 cm^2 (3 plants per pot). Physical and chemical soil properties were as follows: 79.1% sand, 14.3% silt, 6.6% clay (loamy sand – USDA), 7.4 pH, 2.5% organic matter, 0.15% total nitrogen and EC 0.3 dS m^{-1}.
In both environments five water treatments (100%, 75%, 50%, 25% and 0%) were established with five replications. The amount of irrigation water was calculated by Hargreaves method, every 5–7 days after deduction of rainfall, and crop coefficient (Kc) changed in function of pheno-phase. The open 0% treatment had only the rainfall water (12 mm during the crop cycle) and the same quantity was given also to the corresponding tunnel treatment. Ordinary fertilization (N 160 kg ha^{-1}) was given.
The harvest was made in two times in the first week of July; the biomass was cut and its components (stalks, leaves and ears) were weighed and put in a oven at 60 °C until constant weight; on the ears, the basal diameter, length and the percentage of fertile ear (ear length with filled grains) were measured.

Results

In the experiment period the minimum air external temperature was similar to the tunnel one, ranging between 4 °C in April and 18 °C June. The maximum temperature trend was different, in fact under tunnel it was averagely 3.3 °C higher than the external temperature (Fig.1). In particular, starting from the end of May and until the harvests, the temperature was always higher than 33 °C, limit for an optimal growth and flowering.

The interaction between environment and water level was found for all parameters (Tab. 1 and 2). In both conditions the 0% plants didn't produce and reached an height of about 36 cm. For the all other treatments the height of tunnel plants was always higher than the open plants. The 100% treatment under the tunnel (tab. 1) had a yield statistically higher than corresponding treatment in open air (9.9 *vs* 8.5 t ha^{-1}, respectively), due to the higher number of ears per square meter (13 *vs* 11 m^2, respectively); instead the 75% treatments showed opposite trend; the other treatments (50% and 25%) were not different between them.

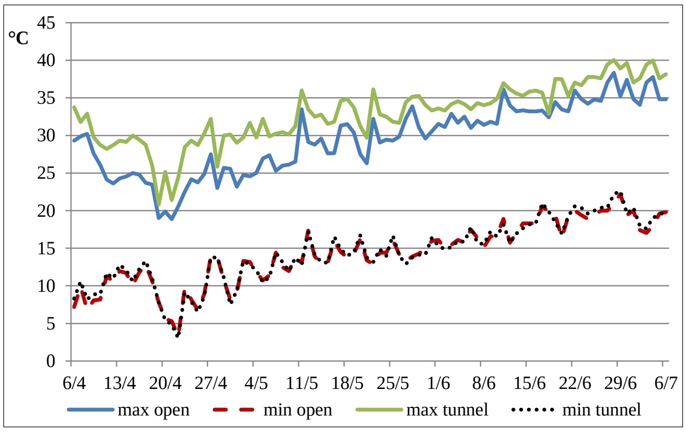

Figure 1. Trend of minimum and maximum temperature during the test period

Table 1 Interaction between environment and water treartment on plants height, number of ears and yield

Irrigation	Plants Height		Ears		Yield	
	cm		*n° m^{-2}*		*t ha^{-1}*	
	Tunnel	**Open**	**Tunnel**	**Open**	**Tunnel**	**Open**
100%	146,6	133,8	13,0	11,0	9,9	8,5
75%	123,2	114,4	10,0	9,0	5,8	6,7
50%	90,8	78,8	8,0	7,0	1,7	1,7
25%	58,4	49,2	1,0	1,0	0,8	0,4
0%	35,7	36,7	0,0	0,2	0,0	0,0
DMS	*11,2*		*1,5*		*0,9*	

About ears parameters (tab. 2), the basal diameter of ears of open plants was higher than tunnel plants, but with significant differences only for 100% treatments, while for the length, the trend was opposite.

Finally, the percentage of ear length with filled grains (Fertile Part – F.P.) was slightly higher in open conditions, probably because the high temperatures, reached under the tunnel, caused disorders especially in the flowering and grains ripening phases. In both conditions, the percentage of fertile ear decreased to increasing water stress; in fact the less stressed treatments (100% and 75%) exceeded the 73% F.P. with an average value of 75.7%. The 25% plants of both environments had less than 30% of ear fertile part.

Table 2 Interaction between environment and water treatment on basal diameter, length and Fertile part (F.P.- % on total length) of ears

Irrigation	Basal diameter		Lenght		F.P.	
	cm		*cm*		*% on total lenght*	
	Tunnel	**Open**	**Tunnel**	**Open**	**Tunnel**	**Open**
100%	3,2	3,7	17,0	16,5	76,0	77,4
75%	3,1	3,5	15,3	15,3	73,9	75,7
50%	1,9	2,2	10,7	10,4	54,2	67,5
25%	1,3	1,2	5,0	4,2	27,8	26,7
0%	0,0	0,6	0,0	2,4	0,0	0,0
DMS	*0,4*		*0,9*			

Conclusions

This early maize hybrid could seem to have the best yield performance in high temperature conditions (about 3°C upper the current condition) but only in no stress water conditions (restitution 100% ET). Therefore it is possible that this hybrid can also adapt to the future climate-change scenarios.

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Analysing Crop Model Response To Extreme Events; Implications For Climate Change Impact Assessment Studies

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Introduction

Future climate projections are characterized by large uncertainty in weather variability, which is likely to unpredictably affect model-based yield estimation in climate change impact assessment on crop production.
A study was undertaken to quantify the extent to which crop models outcomes might be biased by this uncertainty. The problem was approached by artificially expanding air temperature and rainfall variability of input climate projections, but keeping the same monthly means, and using the obtained weather series to drive maize growth simulations. The resulting yield estimates were then compared with the ones obtained with the unaltered weather series.
The crop growth models used were the existing and a modified version of the CropSyst model (Stöckle et al., 2003). The latter one was obtained by coupling the original models with a software library specifically developed to simulate the impact of extreme weather events. The analysis was performed for three locations in Italy and three time horizons (2000, 2030, 2050).

Materials and Methods

Climate dataset. The input weather data were a realization of the SRES A1B scenario obtained by the GCM model HadCM3 (Semenov et al., 2014) coupled with the HadRM3 RCM. Three time horizons were considered: 1993-2007 (2000, baseline), 2023-2037 (2030) and 2043-2057 (2050), for three sites in Central and Northern Italy selected from the MARS database (Duveiller et al., 2015), i.e. Roma (S1), Torino (S2) and Padova (S3). From these data the Climak3 weather generator (WG) (Rocca et al., 2012) was used to generate 300-years of daily weather series for each scenario. By appropriate tuning of WG parameters, three types of synthetic weather series were generated:

1. *Unaltered* (U), with the same statistical properties of the starting GCM-RCM series;
2. *Low-Altered* (LA), with +15% variability increase in air temperature and precipitation;
3. *High-Altered* (HA), with +30% variability increase in air temperature and precipitation.

Modelling solutions and simulation plan. Two modelling solutions were tested: the JRC-MARS version of CropSyst 3.0 implemented in the BioMA (*Biophysical Model Applications*) platform (http://bioma.jrc.ec.europa.eu), and a modified version obtained by its coupling to the MODEXTREME.WeatherExtremesImpact component (hereafter "EXTREME"; Movedi et al., 2015). The EXTREME component extends the capabilities of crop models to simulate plant response to weather extremes (drought, heat, cold) by simulating their impact on crops.
Rainfed maize was simulated by adopting a unique sowing date (10 April) and a unique soil (silty loam, 2 m deep). For each scenario 300 annual yield estimates were obtained.
Output processing. From the set of yield estimates, 1000 samples (n = 30) were randomly extracted (sampling with replacement), calculating each time the sample mean ($\overline{x}$) and Coefficient of Variation (CV). Pairs of samples from the altered- (LA or HA) and unaltered- (U) based set were then resampled, and the means and CVs differences were calculated. This procedure was repeated 1000 times again, thus obtaining distributions of means and CV differences, which were graphically represented as box and whiskers plots.

Results

In all scenarios broadening variability turned out in a yield reduction and an increase in interannual variability, confirming the initial hypothesis that underestimating weather variability is likely to strongly bias yield

predictions. In modified CropSyst the shift in yield was much more relevant than in the conventional model version (Fig. 1).
Weather alteration induced also an increase in CV, which was more important with the modified version of the model (Fig. 2). With the conventional version, the difference between the alteration levels in yield means and CVs was hardly visible, whereas in the modified version HA showed higher variation than LA. The effect of time horizon was particularly evident only in HA in the modified model version.

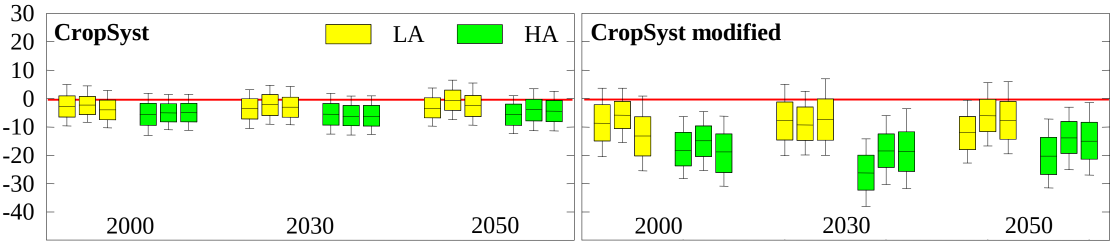

Figure 1. Distributions of yield relative differences (($\bar{x}_{altered}$ - $\bar{x}_{unaltered}$)/ $\bar{x}_{unaltered}$, %) between the altered- and unaltered-based estimates. In each group of bars, from left to right, locations S1 to S3 are shown. LA = low weather alteration, HA = high weather alteration.

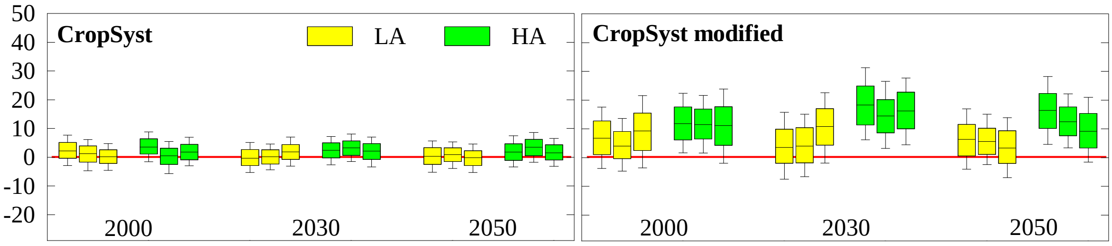

Figure 2. Distributions of CV differences ($CV_{altered}$ - $CV_{unaltered}$, %) between the altered- and unaltered-based estimates. In each group of bars, from left to right, locations S1 to S3 are shown. LA = low weather alteration, HA = high weather alteration.

Conclusions

Artificial alteration of weather time series had a relevant impact on the predicted yield and CV in three Italian case-studies, confirming the initial hypothesis that underestimation of weather variability may cause serious bias in crop model estimates.
The results also demonstrated that current model versions could not behave differently in presence of higher weather variability; using updated versions with improved sensitivity to extreme weather events, is therefore recommended to better capture their impact on crop production.

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An Easy-to-Apply Tool To Check The Sustainability Of Prunings Removal From The Field And Their Energy Use

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Introduction

According to the EU Renewable Energy Directive (2009/28/EC), no direct impacts (i.e. no GHG emissions or energy consumptions) should be assigned to the agricultural phase of a bioenergy value chain if crop residues (such as those deriving from pruning) are removed from the agricultural land with the purpose of energy conversion. This assumption, indeed, is a rough simplification and does not consider indirect effects and drawbacks that might be related to a systematic removal of crop residues. Crop residues could actually play a relevant role in sustaining agricultural activities and supplying agro-ecological services. Several authors (Gliessman, 2000; Kumar et al., 2000; Lal, 2004; Lal, 2008) report the positive effects of crop residues on the physical, chemical and biological characteristics of agricultural soils: sustaining soil organic matter (SOM), favouring nutrients recycling, allowing carbon sequestration, improving soil aggregation and structure, enhancing erosion control, increasing water infiltration, retention and drainage. Therefore, the present study, performed in the frame of the H2020 project "*uP_running*", is offering to farmers an easy and straightforward evaluation tool to assess if biomass from fruit tree pruning could be removed from the field and utilized as feedstock for energy conversion. Alternatively, pruning residues can be shredded and left on the soil surface making a mulching cover or incorporated into the top soil layer.

Materials and Methods

A minimum set of good soil and climate conditions was defined in order to prevent soil degradation and assure a stable and long-term soil fertility with respect to the management of pruning. If these conditions are met, the removal of pruning residues for energy use can be considered a sustainable practice. Conversely, farmers should apply an improved soil management and pruning removal should be avoided. Four indicators were selected: *SOM content*; *soil texture*; *terrain slope*; *climatic condition*. For each indicator, threshold values and ranges were given to properly judge current soil conditions (*Table 1*). SOM content is the guiding driver, while soil texture is associated to soil water retention, permeability and water conductivity, aeration, compaction and mechanical workability; it significantly affect SOM dynamics and its turnover. Soil slope affects soil erodibility due to heavy rains and consequent water run-off. The De Martonne Annual Aridity Index summarizes climatic conditions; aridity is correlated with SOM content, since higher temperatures and lower water availability promote SOM mineralization. A simple evaluation approach was set up, based on the following three-step procedure (*Figure 1*). *Step 1:* assessing the indicator scores; *Step 2:* setting the SOM management strategies, according to the average score; *Step 3:* implementing the technical options to preserve SOM while eventually utilizing pruning residues for energy purposes. Three possible scores are assigned to each soil indicator: 1, 2 or 3, respectively, according to their values. The average of each single score assigned to the four indicators identifies soil conditions and provides useful information to farmers about the set of pruning management options to be applied and the final decision on removing or retaining pruning residues on the field.

Results

The first outcome of the tool is the total score assigned to soil conditions. Based on this, a three-coloured light signal can be activated (*Table 1*). An average score higher than 2.5 corresponds to optimal soil conditions; a "green light" allows pruning removing to energy conversion; a "SOM maintenance strategy" is prescribed, in this case (*Table 2*). An average score in the range 1.5-2.5 identifies good soil conditions; a "yellow light" indicates that pruning can be utilized for energy purposes if a "SOM combined strategy" to preserve soil fertility is also applied (*Table 2*). Finally, an average score lower than 1.5 highlights bad soil conditions; a "red light" suggests that pruning residues utilization for energy purposes should be avoided and the farmers are recommended to adopt a "SOM increasing strategy" (*Table 2*). To each of these soil management strategies corresponds a set of technical options able to preserve and maintain soil fertility (*Table 2*). Organic fertilization, cover crops or soil grass covering, soil mechanical operations are the main influential management options.

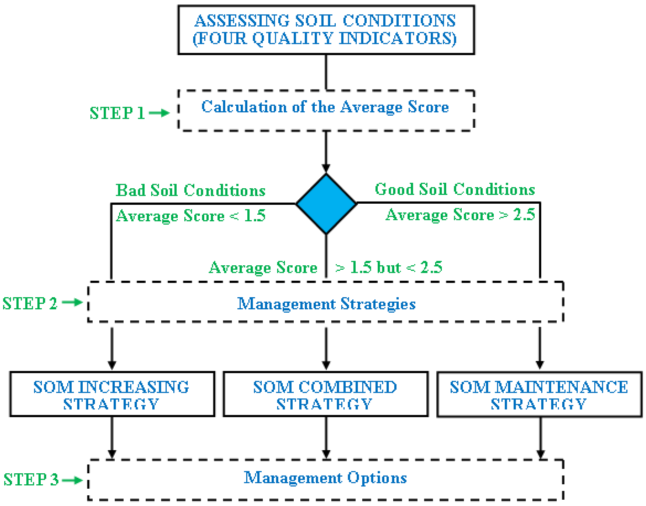

Figure 1. Proposed methodology for the assessment of soil conditions allowing the removal of pruning residues.

Conclusions

The energy conversion of pruning residues is not necessarily in contrast with a sustainable soil management and a long-term soil fertility. Pruning residues can be removed and addressed to energy purposes providing that a set of counteracting operations are arranged and routinely implemented in the farming management. Having ensured adequate and safe soil conditions, the energy use of pruning residues can be recommended without any kind of burden on both the farm resources and the environment. To this respect, an evaluation tool to be used by farmers has been developed and presented here. This tool is based on the assessment of just a few soil characteristics, some basic information on the cultivated field and local climate which are easily accessible to farmers, without any need to perform analyses and/or difficult calculations.

Table 1. Selected indicators on soil and climate conditions.

Score	SOC (%)	Texture (%)	Slope (%)	Climatic conditions*
3	> 3.0	clay 10-30 and silt < 50 and sand < 50	< 5	> 30
2	1.5-3.0	clay 10-30 and silt > 50 or sand > 50	5-20	20-30
1	< 1.5	clay < 10 or clay > 30	> 20	< 20

**De Martonne Annual Aridity Index*

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Table 2. Soil management strategies recommended to farmers according to soil conditions.

Strategy	Fertilization	Degree of soil cover	Period of soil cover	Soil mechanical operations	Soil mechanical trafficability
SOM increasing	organic manuring	total	annual	no-tillage	low
SOM combined	organic manuring or green manuring	total or partial	annual or winter	no-tillage or minimum tillage	low or moderate
SOM maintenance	green manuring	partial	winter	minimum tillage	moderate

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