COMBINING HARVEST DATE AND CUTTING HEIGHT TO OPTIMIZE THE SUSTAINABILITY OF *MISCANTHUS* PRODUCTION FOR ENERGY IN THE MEDITERRANEAN REGION

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ABSTRACT: *Miscanthus* is a perennial energy grass and achieves high productivity under high summer temperatures, in the Mediterranean. Considering its sustainable production, the aim of this work was to evaluate the influence of harvest date and cutting height on the yields and biomass quality of *Miscanthus* for energy purposes. In this context, *Miscanthus* biomass from field studies in Portugal were sampled at three different harvest dates: September, November and January. For each harvest date, stems were separated into fractions of 50 cm. The fresh and dry weight of each fraction was recorded and the moisture, ash and nitrogen content were measured. Results indicate that higher yields are obtained in September and the higher the stubble height the lower the yields. On average, yields obtained in November and January are 20% lower than the September harvest. And increasing the stubble height to 50 cm decreases the yields by 30%. Yet, extending the harvest date to November and January improves the biomass quality for combustion. From September to November, on average, the moisture content decreases by 40% (from 50g to 30g H_2O per 100g stems), the ash content of the stems decreases by 20% (from 3.5% to 2.7%, dry basis) and the nitrogen content of the stems decreases by 60% (from 0.19 % to 0.07%, dry basis). Increasing the stubble height from 0 to 50 cm does not influence the biomass quality. However, discarding the tops of the stems (fractions above 200cm), improves the biomass quality for combustion, once the ash content is reduced by 10% and the nitrogen content is reduced by 16%, while only 6% of yield loss is verified. The integrated analysis indicate that *Miscanthus* should be harvested in the period November-January, and that fractions above 200 cm should be left in the ground along with leaves, in order to improve the biomass quality and the soil nutrient status. In order to maximize the yield, the cutting height should be as low as possible given the constraints associated with the harvest machinery.
Keywords: miscanthus, biomass characterization, biomass quality, sustainability, energy balance

1 INTRODUCTION

Miscanthus is a woody rhizomatous C4 grass originated in South-East Asia and was initially imported to Europe as an ornamental plant. It is a perennial plant, related to sugarcane, with an estimated productive lifetime of at least 10-15 years, and both the stems and leaves of the crop can be harvested annually [1]. It is characterized by relatively high yields, low moisture content at harvest, high water and nitrogen efficiencies and an apparently low susceptibility to pests and diseases [2]. *Miscanthus* achieves high productivity under high summer temperatures, in the Mediterranean – and copes well with severe weather conditions such as flooding in autumn, winter or spring and dryness in summer [3]. Its robustness and physiological characteristics as a deep, dense and extensive root system, allows it to easily adapt to different types of soils and ecological conditions, being indicated for reducing soil erosion, minimize nutrient leaching and sequester more C in soils [4]. *Miscanthus* is a multi-use crop whose potential is not yet fully realized. The most current use is as a renewable energy crop. However, it is also an attractive material for many other uses, such as thatching, animal bedding, high quality paper pulp, fiberboards production and inclusion in composites [3].

Considering its sustainable production, the aim of this work was to evaluate the influence of harvest date and cutting height on the yields and biomass quality of *Miscanthus* for energy purposes.

2 MATERIALS AND METHODS

In 1990, several experimental plots, each one with an area of 10x10m^2 were established in Monte de Caparica, Portugal, at the experimental site of the Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa, by spacing rhizome pieces and plantlets of *Miscanthus* x *giganteus* at a distance of 50 cm. In 1998, the density of the plants was 88 plants.m^{-2} (average results from three different plots) [4]. No pesticides were applied in the fields. Fertilization was applied in all the fields when the plants had about 70 cm high. 60 kg N ha^{-1}, 140 kg K ha^{-1} and 100 kg P ha^{-1} were used (P was applied only in the year of the establishment of the plants and in 1998). Between the months of June and October, irrigation was applied, in order to compensate the water deficit of the soil and to prevent water stress (*ca* 350mm, year 3 and following of the crop). *Miscanthus* was harvested yearly in the end of January, beginning of February. Results presented correspond to the period 1998-2001, when the crop was already completely mature.

To evaluate the harvest date, *Miscanthus* biomass were sampled at three different harvest dates: September, November and January. To evaluate the cutting height, for each harvest date, stems were separated into fractions of 50 cm. The fresh and dry weight of each fraction was recorded and the moisture, ash and nitrogen content were measured. Moisture was determined by the weight loss obtained in a sample at 103 ± 2 ºC, until constant weight. Ash content was determined in each fraction by incineration at 550 ± 50 ºC for 2 hours in a muffler furnace. Nitrogen content was determined by the Kjeldahl method.

3 RESULTS AND DISCUSSION

3.1 Productivity

Figure 1 show the growth cycle of *Miscanthus* plantations in Caparica, Portugal. Figure 2 show the yields of *Miscanthus* plantations in Caparica, Portugal, per harvest date and per cutting height.

Highest yields were obtained in September, ca. 26 Mg per ha, dry matter. Harvesting in November or January represents a 20% loss in the productivity. Between November and January, differences in the productivity were not significant. In terms of the cutting height, Figure 2 shows that the fractions 0-150 cm represent the highest share in the productivity of *Miscanthus*. The fraction 150-250 cm, also represent a high share in the yields, in the September harvest, but not in the November or January harvest. Therefore, increasing the stubble height to 50 cm, will decrease the yields by 30%. Leaving the fractions higher than 200 cm in the field represent a yield loss of merely 6%.

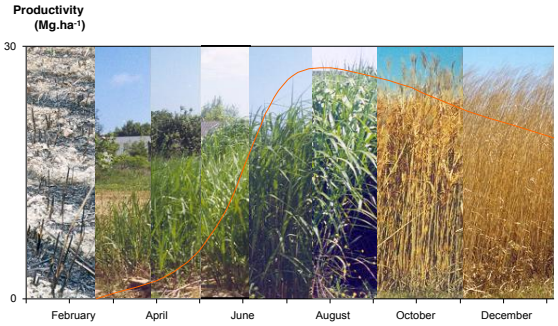

Figure 1: Yearly growth cycle of *Miscanthus* in Caparica, Portugal.

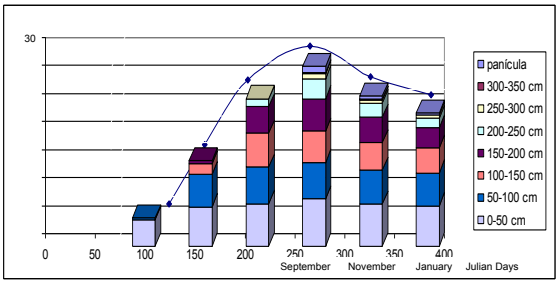

Figure 2: Yields (Mg per ha, drymatter) of *Miscanthus* in Caparica, Portugal, per harvest date and per cutting height.

3.2 Biomass Quality

The moisture content of the *Miscanthus* is 50% in September, but in the November and January harvests, the moisture decreases to 30%, a reduction of 40% when comparing with the September harvest (Figure 3). This means that if the crop will be harvested in September an additional treatment to the biomass will be needed in order to dry the biomass. This can add an energy cost to the life cycle of the production and use of *Miscanthus*. When harvested in November or January, this additional treatment will not be needed.

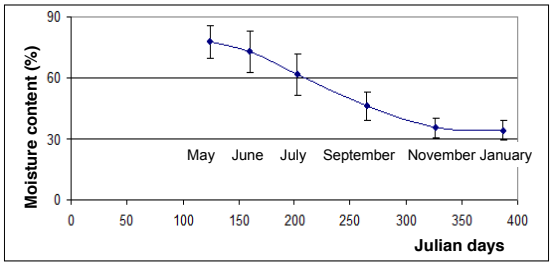

Figure 3: Moisture content (%) of *Miscanthus* in Caparica, Portugal, per harvest date.

Miscanthus presents an ash content of 5.7% in the September harvest. In this harvest, the crop still has leaves wich increases the ash content of the biomass. The stems present 3.5% ash content but the leaves present 12.2% ash content (all in dry matter). However, in the September harvest all the nutrients (N, P and other inorganic elements) have already translocated to the underground biomass (results not shown, [3, 4]). When harvesting in November or January, the biomass lost already almost all the leaves and the ash content is reduced by 20%. When biomass is harvested in November or January, ash content in the stems is 2.7% (dry matter) (Figure 4).

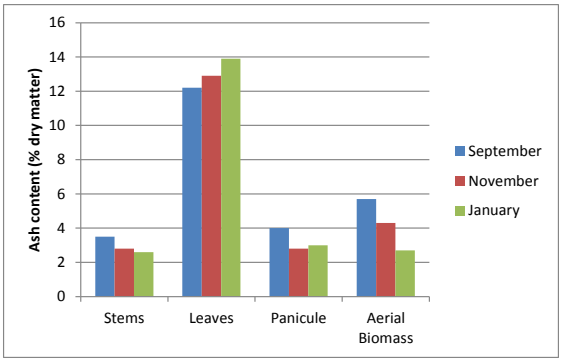

Figure 4: Ash content (%) of *Miscanthus* in Caparica, Portugal, per harvest date.

Concerning the cutting height, ash content increases with the height of the stem (Figure 5).

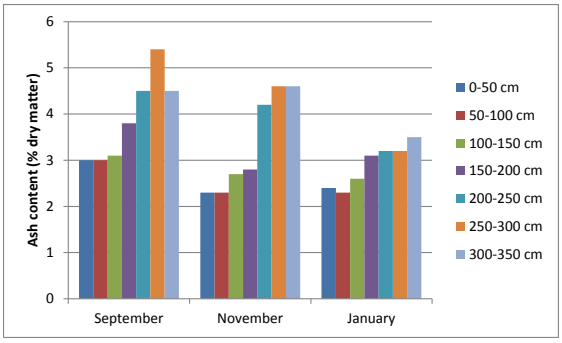

Figure 5: Ash content (%) of *Miscanthus* in Caparica, Portugal, per cutting height of the stems

From the bottom to the top, in the September harvest the ash content increases from 3.0% (dry matter) to 5.4% (dry matter). But in the November-January harvests the

increment from bottom to top increases in the range 2.3-2.4 to 3.5-4.6% (dry matter). By leaving the fraction above 200 cm in the ground the ash content of the crop is reduced by 10%, with benefits in terms of biomass quality.

Miscanthus presents a nitrogen content of 0.38% in the September harvest. In this harvest, the crop still has leaves wich increases the nitrogen content of the biomass. The stems present 0.19% nitrogen content but the leaves present 0.81% nitrogen content (all in dry matter). However, in the September harvest all the nutrients (N, P and other inorganic elements) have already translocated to the underground biomass (results not shown, [3, 4]). When harvesting in November or January, the biomass lost already almost all the leaves and the nitrogen content is reduced by 60%. When biomass is harvested in November or January, nitrogen content in the stems is 0.07% (dry matter) (Figure 6).

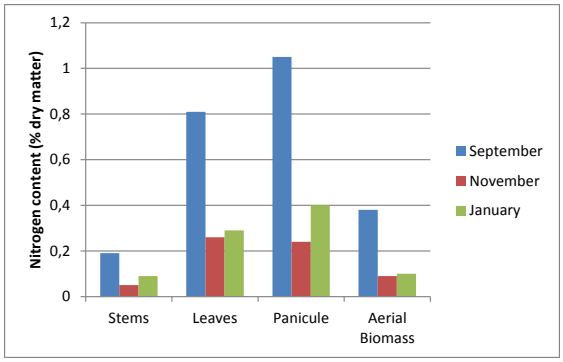

Figure 6: Nitrogen content (%) of *Miscanthus* in Caparica, Portugal, per harvest date.

Concerning the cutting height, nitrogen content increases with the height of the stem (Figure 7).

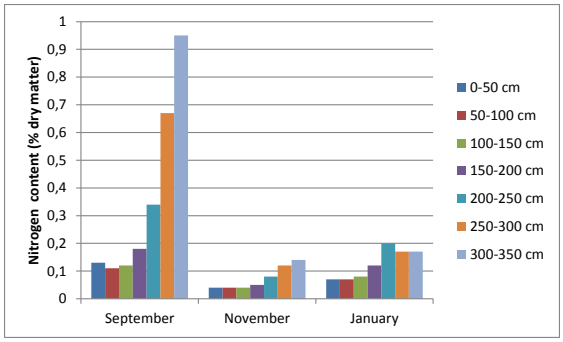

Figure 7: Nitrogen content (%) of *Miscanthus* in Caparica, Portugal, per cutting height of the stems.

From the bottom to the top, in the September harvest the nitrogen content increases from 0.13% (dry matter) to 0.95% (dry matter). But in the November-January harvests the increment from bottom to top increases in the range 0.04-0.07 to 0.14-0.17% (dry matter). By leaving the fraction above 200 cm in the ground the nitrogen content of the crop is reduced by 16%, with benefits in terms of biomass quality. Moreover, harvesting in November-January and leaving the top of the stems in the ground represents also an additional benefit in terms of nitrogen emissions if the biomass is being combusted. When biomass combusted presents less nitrogen content, NOx emissions that may be produced during the combustion process will be also reduced [5].

4 CONCLUSIONS

Results indicate that higher yields are obtained in September and the higher the stubble height the lower the yields. On average, yields obtained in November and January are 20% lower than the September harvest. Increasing the stubble height to 50 cm decreases the yields by 30%. Yet, extending the harvest date to November and January improves the biomass quality for combustion. From September to November, on average, the moisture content decreases by 40%, the ash content of the stems decreases by 20% and the nitrogen content of the stems decreases by 60%. Increasing the stubble height from 0 to 50 cm does not influence the biomass quality. However, discarding the tops of the stems (fractions above 200cm), improves the biomass quality for combustion, once the ash content is reduced by 10% and the nitrogen content is reduced by 16%, while only 6% of yield loss is verified. The integrated analysis indicate that *Miscanthus* should be harvested in the period November-January, and that fractions above 200 cm should be left in the ground along with leaves, in order to improve the biomass quality and the soil nutrient status.

5 ACKNOWLEDGEMENTS

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