EVALUATION OF HARVESTING AND POST-HARVESTING TECHNIQUES FOR ENERGY DESTINATION OF SWITCHGRASS

P. Venturi[1], A. Monti[2], I. Piani[2], G. Venturi[2]

[1]Department of Agricultural Engineering and Economics, Viale Fanin 50, 40127, Bologna, Italy.
Tel: +39 051 2096189, e-mail: piero.venturi@unibo.it
[2]Department of Agroenvironmental Science and Technologies, Viale Fanin 44, 40127 Bologna, Italy.

ABSTRACT: Recently, a growing interest for alternative destinations of Switchgrass have been investigated. Harvesting chains and their timing, that represent bottleneck of the system, have been tested with the aim to evaluate the most profitable in Northern Italian environments. Chains performed were: summer harvesting chain that includes mowing, conditioning, raking and round baling and winter harvesting chain that was carried out with mowing, raking and square baling. Results show that dry matter yield in the summer harvest (5.7 t ha^{-1}) was lower than that of winter harvest (8.0 t ha^{-1}) with dry matter content of 62% and 47% in winter and summer harvest, respectively. In summer time different conditioning systems were tested and baling (round bales) were carried out without any problem using a constant chamber round baler. In winter time the round baler couldn't work due to the characteristics of the stems, while a big square baler was successful. Generally, it can be maintained that production chain is ready and machines used for other crops can be employed on switchgrass, choices concerning the most appropriate system will be dependent by the indications of converters.
Keywords: switchgrass, harvesting, bales

1 INTRODUCTION

Switchgrass (*Panicum virgatum*, L.) is a perennial C_4 crop native of North America. The most common use of switchgrass is for feedstock but, recently, a growing interest for alternative destinations have been investigated. Energy use (combustion, gasification and ethanol production) seems to be of relevant interest in the short term.

Mainly, the chances to transform switchgrass for energy use depends on economical convenience that is strictly connected to agricultural techniques, product yields and qualitative characteristics. While cultivation technique has been drastically improved, many efforts have to be carried out concerning harvesting, handling and storing with the aim to obtain a suitable material for thermo-chemical conversions.

Main qualitative characteristics for a energy crop are: high biomass production, high calorific value, low moisture content at harvesting time, material characteristics (hash content, silica, etc.), regular shape and size. They are strictly dependant by production and harvesting or post-harvesting techniques.

In this research, different harvesting chains and timing have been tested with the aim to evaluate the most profitable system in Northern Italian environments. These considerations could contribute as guidelines for economical and logistics modeling. In fact it is fairly known as harvesting time affects quantitative and qualitative characteristics of biomass. For example, dry matter losses of switchgrass over winter period can range from 30-40% [1]. Otherwise, summer harvesting can make product drying operations in the field easier and faster but, at the same time, it can limit biomass yields. Nonetheless an early harvest may lower the biomass quality since it could hamper the natural translocation of assimilates to the rhizomes thus to increase ash content of harvested material. According to this, some researches have stressed that the translocation of mineral components from the above ground dry matter to the roots occurs late in the season [2; 3]. In spite of this, summer harvesting represents a logistic optimization because the moisture content of the material decreases very fast, bales storage and transport is made extremely cheap and efficient, and no soil compaction can occur.

However, same disadvantages are clearly present as unfavorable climatic conditions that don't allow to keep the material in the field thus to reach a suitable moisture level. Nonetheless, muddy soils and crop lodging could cause biomass contaminations with a decrease of the quality.

This article deals with **preliminary** results on switchgrass harvesting methods and timing. Same experiments will be repeated next years focusing on energy balances of different chains and machineries and on the opportunities to increase the energy effectiveness deriving from pelletization.

2 METHODOLOGY

Different harvesting chains have been performed:

- summer harvesting chain (August) includes mowing, conditioning, raking and round baling;
- winter harvesting chain (February) carried out with mowing, raking and square baling.

Machines used in two tests are shown in Table I;

Table I: Machine characteristics. M-C means mowing-conditioning. In winter time bales were square, while in summertime bales were round. Fella and BCS models are TS 671 and 650 respectively.

Period	Work	Model	Tractor
Winter	M-C	Bovolenta F 310 FC	Same Explorer 90
Winter	Raking	Fella	Same Organ 70
Winter	Baling	New Holland D1210	Same Titan 145
Summer	M-C	Bovolenta F 310 FC	Same Explorer 90
Summer	M-C	BCS	New Holland L 65
Summer	Raking	Fella	Fiat 45 66
Summer	Baling	Gallignani 9250 s	Fiat 100 90

Harvests were carried out in a second year stand of about 9 ha, in a hill-field located near Bologna (44° 33' lat.; 11° 02' long.). Machines functional parameters are mentioned in Table II.

During the summer harvest two different mowing-conditioning systems have been tested and their effect on the drying period and moisture content has been compared with an hand-mowed and non-conditioned material. Machines were a mower conditioner Bovolenta (A), which has a drums mowing system and two plastic conditioning rolls, and BCS (B), which is a disc mower with rolls for conditioning (one metal and one plastic). Winter harvesting have been performed with a mower-conditioner A.

Differences between the cut devices were due mainly to the mowing system and conditioning (0,7 cm and 1,0 cm of distance between rolls, respectively for A and B). Product was windrowed after mowing and round-baled.

Baling was carried out with a pulled big baler.

Table II: Machine characteristics. M-C means mowing-conditioning. In winter time bales were square, while in summer time bales were round

Period	Work	Width	Work capacity	Consumption	
		(m)	(h ha^{-1})	Oil (l h^{-1})	Fuel (l h^{-1})
Winter	M-C	3.1	1.30	0.39	8.0
Winter	Raking	7.5	0.25	0.04	3.5
Winter	Baling	2.2	0.35	0.13	12.0
Summer	M-C	3.1	1.30	0.39	8.0
Summer	M-C	2.0	1.50	0.42	7.0
Summer	Raking	3.5	0.55	0.11	4.0
Summer	Baling	1.7	0.85	0.28	10.0

3 RESULTS

The canopy heights were 130 cm and 175 cm in summer and winter harvests respectively. Diameter of stem was similar during both harvests ranging from 3.1 to 4.2 mm.

Dry matter (DM) yields were substantially different between two harvest periods: as expected, dry matter yield in the summer harvest (5.7 t ha^{-1}) was lower than that of winter harvest (8.0 t ha^{-1}) since the crop growth continued significantly until early October.

At the harvest time, natural dried standing plants had lower moisture content than summer harvested stems (62% vs. 47% dry matter content in winter and summer harvest, respectively). However in the summer harvest the drying in windrow of mowed biomass was extremely fast becoming 78% of dry matter only 5 days after the cutting. Anyway it must be remembered that the yield of summer harvest was 2.3 t ha^{-1} lower than the winter harvest.

Mowing conditioning Bovolenta built windrows with better characteristics. They were more voluminous and permitted a better penetration of the sun in the windrow and, at the same time, a reduced contact area with the soil to decrease the material contamination. Results on figure 1 show that, in spite of the different windrows shapes, the course of moisture contents were not significantly different among treatments. This lack of differences is probably due to the high temperature during drying in windrows that enhanced the drying of not conditioned material too.

Summer harvest and baling (round bales) were carried out without any problem using a constant chamber round baler. However, it must be remembered that notwithstanding the second year of plantation the summer harvest was performed early when the crop did not still reached a representative height and stem diameter. For this reason the round baling tried in the following winter harvest appeared fairly unsuccessfully. Specifically this was due to the high moisture content of the material and the stems size which determined difficulties to bend in the core of the bale which was almost totally empty. For this reason a big square baler was used successfully on the same material. This make think that with a high size crop, in winter harvesting it will be necessary to bale with a square baler.

The kind of bale influenced the bulk density. Specifically, bulk densities were 141.7 and 112.0 kg m^{-3} for round and square bales, respectively. Therefore, considering a 11.5% of empty room for round bales and a calorific value of 17 MJ kg^{-1}, it can be calculate that the storage place of square bale is 1904 GJ m^{-3} compared to 2131 GJ m^{-3} of round bales. Hence, with a likely truck+trailer transport available volume of 30 m^{3}, 57.1 and 63.9 EJ of square and round bales can be transported in one way.

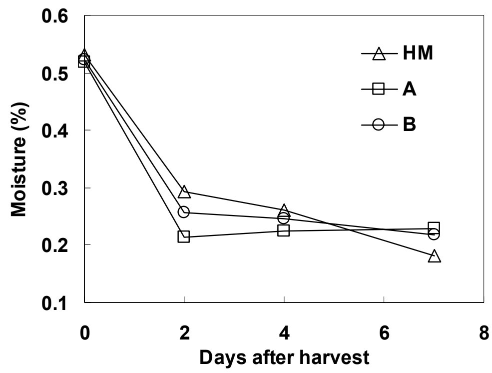

Fig. 1: Course of biomass moisture content after the summer harvest. HM = hand-mowing; A = Mowing-conditioning with Bovolenta F310 FC; B = Mowing-conditioning with BCS.

4 CONCLUSION

It appears that both summer and winter harvesting can be performed in Mediterranean climatic conditions. Summer harvest is easier to carry out with machines commonly used for forage chain. The possibility to dry the material in windrows is a relevant advantage even if the total yield is lower.

Winter harvesting can be carried out without mowing difficulties. Big square balers must be used when canopy is higher than 150 cm and stem size is large. This may likely occur from the second year onward.

The production chain is ready and machines used for other crops can be employed on switchgrass, choices concerning the most appropriate system will be dependent by the indications of converters. Winter harvested biomass will be suitable if peculiar attention will be paid to not contaminate the material with soil. This increase drastically the hash content creating combustion difficulties.

Next step of the research will be to repeat these experiences with the aim to evaluate further problems during harvesting; particular care must be paid to energy balances of different chains and machineries and on the opportunities to increase the energy effectiveness deriving from pelletization.

5 ACKNOWLEDGEMENT

Present research has been supported by the EU Project "*Bioenergy Chains from Perennial Crops in South Europe*".

6 REFERENCES

[1] R. Jannasch, P. Duxbury, R. Samson, (2001). Canada, final report, REAP (2001), contract 23384-005068/001/SQ
[2] D.J. Parrish, D.D. Wolf, W. L. Daniels. Rep. No. 19X-SK098C (1997), Virginia Polytechnic Institute and State University.
[3] T. Radiotis, J. Li, K. Goel, R. Eisner. Proc. TAPPI Pulping Conference (1996), 371-376.