# COMPARISON OF SWITCHGRASS (*Panicum virgatum* L.) GENOTYPES AS POTENTIAL ENERGY CROP

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ABSTRACT: Seven genotypes of *Panicum virgatum* L., a perennial grass crop, were compared over two growing seasons in order to investigate potential biomass yield, its stability in time, and to assess nitrogen and ash content as characteristics detrimental to utilization in the energy chain. Crops were planted in May 2002, harvested in February 2003 for the first year; in February 2004 and in July 2003 + February 2004 for the second one. The two early, upland octaploid genotypes (Shawnee and Trailblazer) performed a lower yield associated to a lower moisture and to a higher ash content. The remaining five lowland tetraploids featured variable traits: NL 94-1, SL 93-3 and SL 94-1 had the best performances in terms of biomass yield and ash content; Alamo and Kanlow had an intermediate behaviour between them and the two octaploids. In the second year, the double harvest (summer + winter) showed a 50% yield increase with respect to the single one, associated to an undesirable peak in nitrogen and ash impurities.

Keywords: Switchgrass, Biomass production, Ash.

## 1 INTRODUCTION

Perennial, herbaceous energy crops offer a great opportunity to improve agricultural sustainability in terms of crop diversification, improved control of soil erosion and recovery of soil organic matter content. Furthermore, reduced crop input reflects positively on soil and water environmental quality [1], as well as on the landscape. Its perennial habitus is an added value for cultivation in marginal lands, sloping and/or prone to soil erosion. Switchgrass is a warm season $C_4$ grass, native of Midwestern and South-Eastern US, with a good potential of yield in many European Countries such as Italy.

A suitable utilization as a biofuel requires low ash and nitrogen contents and, conversely, high lignin and cellulose [2]. Across the native regions, switchgrass has evolved into two types: lowland ecotypes (vigorous, tall, thick-stemmed, well adapted to wet condition) and upland ones (short, rhizomatous, thin-stemmed, well adapted to dry conditions). Switchgrass can be used for the production of energy through direct combustion, or combustion of fermentation products such as ethanol [3].

## 2 MATERIALS AND METHOD

Seven genotypes were included in the study; two upland octaploids (Shawnee, Trailblazer) and five lowland tetraploids (Alamo, Kanlow, NL 94-1, SL 93-3, SL 94-1). They were compared over two years in Ozzano (Bologna, Italy) in a hilly area. Since the second year, two harvest patterns were carried out: winter harvest and summer + winter one.

The crop trial was planted on May 7, 2002. Experimental plots were established in a randomized complete block design (four replications) with a split-plot arrangement: plot for genotype, sub-plot for harvest; the latter was 16,5 $m^2$ of surface.

Harvest dates were Feb. 13, 2003, Jul. 3, 2003 and Feb. 10, 2004. Machine cutting followed by manual harvesting and weighing was done on a surface of 6,6 $m^2$.

### 2.1 Ash and nitrogen determination

Samples from the harvested plots were submitted to ash determination on 3 g of ground sample by furnace combustion at 550 °C until constant weight, and to the analysis of total kjeldahl nitrogen (TKN) on 1 g of ground sample. Results are expressed on a dry basis.

### 2.2 Statistical analysis

ANOVA was performed on two separate data sets: the first one was composed of the winter harvests in the two years; the second one, of the two harvest patterns in the second year. Significant differences were expressed as Fisher's Lowest Significant Differences at p = 0,05 ($LSD_{0.05}$).

## 3 RESULTS AND DISCUSSION

### 3.1 Winter harvests

Biomass yield averaged 18 t $ha^{-1}$ over the two years. Wide variations were observed between genotypes: the two upland octaploids always yielded less than the five lowland tetraploids (table I). The year factor significantly affected yields, too: 2002 had a favourable, cool and wet summer, while 2003 a very hot and dry one. It is perceived as this occurrence may have curbed yield potential in the second year, after crop establishment had been accomplished in the first one.

The year effect did not reflect on dry weight, thanks to the higher dry matter content of the second year. The two early octaploids, Shawnee and Trailblazer, featured the lowest yields, below 9 t $ha^{-1}$, associated to a dry matter percent of about 80%. The rest of the genotypes yielded above 11 t $ha^{-1}$, with SL 93-3 and SL 94-1 as the top performers. Their relative lateness is shown by the lower percent of dry matter at maturity, in the range of 60 ÷ 70%. Achieving a good yield with a low moisture is a key goal in plant breeding for biofuels, since it allows the best possible yield with the lowest constraints in terms of transport and/or conditioning costs before actual utilization. In this respect, NL 94-1 showed the best compromise, thanks to a yield in the same range as the top performers (SL 93-3 and SL 94-1), and to an intermediate level of dry matter. A significant interaction was also observed concerning dry matter, between years and genotypes (fig. 1): in the dry year (2003), also late types such as Alamo, SL 93-3 and SL 94-1 attained a good maturity in terms of dry matter, while in the wet one (2002), they remained quite moister until harvest. Conversely, NL 94-1 was the least affected by weather variations between the two years.

Both TKN and ash impurities showed differences according to genotypes and to years: as for years, it cannot be stated whether the decreases observed in the second one are due to the higher thermal sum and to the subsequent better maturation of the plants, or to the completed establishment of the perennial crop, enabling a better translocation of nutrients to storage roots.

**Table I:** Biomass (FW), dry matter yield (DW), dry matter content (DM), total kjeldahl nitrogen (TKN) and ash content in Switchgrass genotypes in two years.

| Genotype | Harvest | FW ($t\ ha^{-1}$) | DW ($t\ ha^{-1}$) | DM (%) | TKN ($mg\ g^{-1}$) | Ash (%) |
|---|---|---|---|---|---|---|
| **Alamo** | | 20,3 | 11,7 | 59,7 | 8,9 | 5,3 |
| **Kanlow** | | 17,9 | 11,8 | 66,9 | 6,6 | 4,5 |
| **NL94-1** | | 19,3 | 13,2 | 69,7 | 6,6 | 4,4 |
| **Shawnee** | | 9,4 | 7,3 | 77,1 | 7,5 | 5,7 |
| **SL93-3** | | 23,6 | 13,9 | 61,1 | 8,0 | 4,7 |
| **SL94-1** | | 25,1 | 14,4 | 60,4 | 7,9 | 4,6 |
| **Trailblazer** | | 10,9 | 8,7 | 80,1 | 6,4 | 6,1 |
| | | *** | *** | *** | ** | ** |
| **LSD $_{0.05}$** | | 4.14 | 2.28 | 5.30 | 1.41 | 0.98 |
| | **Feb.-03** | 19,7 | 10,9 | 60,2 | 9,5 | 6,3 |
| | **Feb.-04** | 16,4 | 12,2 | 75,5 | 5,3 | 3,8 |
| | | * | n. s. | *** | *** | *** |
| **Genotype x Harvest** | | ** | n.s. | *** | n.s. | n.s. |

$*P<0,05$; $**P<0,01$; $***P<0,001$

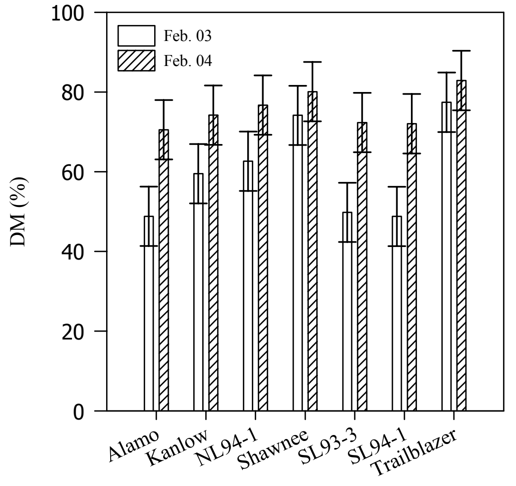

**Fig. 1:** Dry matter interaction Genotypes x Harvests. Vertical bars show LSD$_{0.05}$.

It is perceived as the differences in earliness expressed by dry matter content reflect the plant's ability to translocate nutrients to storage roots at the end of the growth season: the later the genotype, the slower was its maturation and the longer could be kept an active translocation of reserve substances to storing organs.

As for genotypes, both upland octaploids had a high ash content, while only Shawnee had a high TKN. The five lowland tetraploids had variable TKN levels, while the ash content was generally low.

By separating the two groups of genotypes, it is possible to highlight some significant correlations between dry matter content , TKN and ashes: within the upland group (n=16), dry matter is inversely correlated with TKN (r = -0,69**); the latter is, in turn, positively correlated with ashes (r = 0,64**). Within the lowland group (n=40), the two above-described correlations are stronger (r = -0,85*** and r = 0,84***, respectively), while a negative correlation is shown between dry matter and ashes (r = -0,76***).

**Table II:** Biomass (FW), dry matter yield (DW), dry matter content (DM), total kjeldahl nitrogen (TKN) and ash content in Switchgrass genotypes in two harvest patterns – Growth year 2003.

| Genotype | Harvest | FW ($t\ ha^{-1}$) | DW ($t\ ha^{-1}$) | DM (%) | TKN ($mg\ g^{-1}$) | Ash (%) |
|---|---|---|---|---|---|---|
| **Alamo** | | 30.8 | 15.9 | 57.1 | 8.6 | 5.0 |
| **Kanlow** | | 30.8 | 16.5 | 59.6 | 7.1 | 5.0 |
| **NL94-1** | | 30.0 | 15.9 | 60.7 | 6.9 | 4.7 |
| **Shawnee** | | 21.8 | 12.6 | 65.5 | 8.3 | 4.9 |
| **SL93-3** | | 31.4 | 17.0 | 59.2 | 7.3 | 4.8 |
| **SL94-1** | | 29.0 | 15.8 | 59.2 | 7.6 | 4.6 |
| **Trailblazer** | | 21.3 | 12.6 | 66.7 | 7.3 | 5.3 |
| | | * | * | *** | n.s. | n.s. |
| **LSD $_{0.05}$** | | 3.82 | 4.18 | 9.28 | | |
| | **Single** | 16.4 | 12.2 | 75.5 | 5.3 | 3.8 |
| | **Double** | 39.4 | 18.2 | 46.7 | 9.9 | 6.1 |
| | | *** | *** | *** | *** | *** |
| **Genotype x Harvest** | | n.s. | n.s. | n.s. | n.s. | n.s. |

*P<0,05; **P<0,01; ***P<0,001

**Table III:** Biomass (FW), dry matter yield (DW), dry matter content (DM), total kjeldahl nitrogen (TKN) and ash content in Switchgrass genotypes in the two cuts of the double harvest – Growth year 2003.

| Cutting time | FW ($t\ ha^{-1}$) | DW ($t\ ha^{-1}$) | DM (%) | TKN ($mg\ g^{-1}$) | Ash (%) |
|---|---|---|---|---|---|
| **Summer** | 37.8 | 16.9 | 45.4 | 10.0 | 6.1 |
| **Winter** | 1.6 | 1.3 | 82.3 | 8.1 | 7.2 |

### 3.2 Harvest patterns

Variations in fresh biomass and in dry weight between genotypes reflect those discussed above concerning the two growth seasons, apart for the differences among the five upland tetraploids, that in 2003 tended to level off (table II). The harvest pattern (summer + winter vs. winter only) highly influenced yield: biomass more than doubled, while dry weight underwent only a 50%-increase, because the plants, still immature at the time of the summer cut, retained a higher moisture. This cut prevailed by large in terms of yield, with 96% of the total biomass and 93% of the total dry weight (table III). The poor re-growth observed after the July cut may be due to the severe drought which in 2003 took shape during the summertime and lasted until mid-autumn. The potential constraint represented by high plant moisture in the summer harvest may be overcome in a few days of field-drying of the cut plants before actual harvest, operating in a way similar to hay-making. Conversely, the strong increases in TKN and ash impurities, associated to the double harvest with respect to the single one, are a more serious constraint, in the light of the current technology of bio-energy plants. They also support the hypothesis that high impurities are linked to immature plants, as it was outlined in the discussion of the winter harvests' results, although in other experiences in the same area on older plants, the opposite behaviour was observed [4].

## 4 CONCLUSION

Two years of field-trials on Switchgrass as a potential energy crop in Northern Italy have showed the good suitability of the crop to local growth conditions. In this respect, the good yield stability observed over the two years, the cool first at planting and the hot second at complete establishment, is a promising result that is hoped to be confirmed in the follow-up of the research, in the perspective of a steady flow of raw material feeding the transformation plants.

The two breeding types of the investigated species offer a combination of yield and quality features, enabling a well-considered choice of the most appropriate genotype. So far, lowland tetraploids outperform upland octaploids, since they can better exploit the thermal sum available in the area. Among them, preference should be given to selections of reasonable lateness, such as NL 94-1, in order to prevent an excessive moisture at harvest. Lowland tetraploids also feature a lower content of total nitrogen and ashes, which are impurities detrimental to energy output and represent residual wastes to be disposed of, at the end of the energy cycle.

A double harvest, in order to stimulate re-growth in immature plants, originating extra biomass to add to recoverable yield, did not prove effective in the adverse conditions of the second year: the contribution of the second cut was negligible; the first cut alone yielded more than the single harvest at final growth, but its high content in the above-mentioned impurities remains a major handicap within the energy chain.

The research carried out outlines as both genotypes and the timing of harvests are valuable tools in the effort of obtaining suitable biofuels at the cheapest cost.

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