SWITCHGRASS VARIETY CHOICE IN EUROPE[A]

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ABSTRACT: Switchgrass is a perennial C_4 grass native to North America, where it occurs naturally from 55º N latitude to deep into Mexico. It is used for soil conservation, forage production, as an ornamental grass and more recently as a biomass crop for ethanol, fibre, electricity and heat production. In Europe research into the crop has just started and the choice of varieties for different geographical areas is an important issue. Currently some 20 different varieties are being evaluated for adaptation to different regions of Europe. The main factor determining area of adaptation of a variety is latitude of origin. Yields of varieties are correlated to the latitude of origin of the variety, with southern varieties having higher yield potential. If varieties are grown too far north they fail to winter-harden which decreases biomass quality and winter survival. From the limited data on switchgrass grown in Europe it appears that in Europe switchgrass may be grown further north than in North America. The best variety for a given latitude or geographical area will be a compromise between yield, quality and long term winter survival.

INTRODUCTION

Switchgrass (*Panicum virgatum* L.) is a perennial C_4 grass native to North America where it occurs naturally from 55º N latitude to deep into Mexico, mostly as a prairie grass The grass is also found in South America and Africa where it is used as a forage crop.

In North America it has been used for more than 50 years for soil conservation, as a fodder crop and as an ornamental grass. Over the last two decades it has become an important warm-season pasture grass for fodder production when cool season C_3 grasses are less productive in summer (Moser and Vogel, 1995).

Research since the 1930´s has generated much valuable information and many different varieties for soil conservation and for fodder purposes (Moser and Vogel, 1995). Since the early 1990s the crop has been developed by the United States Dept. of Energy (DOE) as a model herbaceous energy crop for ethanol and electricity production. In Canada, Resource Efficient Agricultural Production (REAP) has worked on switchgrass since 1991 for thermal conversion (electricity and heat) and ethanol production and is involved in projects to use switchgrass for paper pulp production.

Many reasons are given for using switchgrass as a biomass crop for energy and fibre production, including the high net energy production per ha, low production costs, low nutrient requirement, low ash content, high water use efficiency, large range of geographic adaptation, ease of establishment by seed, adaptation to marginal soils, and potential for carbon storage in soil, (Christian and Elbersen, 1998; Samson and Omielan, 1992, Sanderson et al., 1996).

In Europe switchgrass was, until recently, only know as an ornamental grass. Research into the use as a biomass crop for energy and fibre has only just started. The crop has the potential to play a role in supporting policies to increase the use of durable products, reduce CO_2 emissions, utilise marginal and set aside lands and provide new economic activities for rural communities. Over the last years many larger and smaller individual field evaluations of switchgrass have been conducted (Christian and Elbersen, 1998; Lewandowski et al., 1998). We estimate that in Europe some 4 ha of experimental switchgrass fields exist of which 2.5 ha is within the current European Union sponsored switchgrass productivity network. In this network 6 organisations co-operate in evaluating the agronomic, fibre and energy potential of more than 20 switchgrass varieties under European conditions. In this paper we will discuss the important issue of allocation of varieties in relation to latitude of origin of the variety and the effect on establishment, yield and quality for energy production.

AVAILABLE SWITCHGRASS MATERIAL

Ecotypes

Two switchgrass ecotypes are generally defined based on morphological characteristics and habitat preferences. Lowland types are generally found in floodplains. They are taller, coarse, have a more bunch type growth habit, and may be more rapid growing than upland types. Upland types are found in drier upland sites. They are finer stemmed, and often semi-decumbent (Moser and Vogel, 1995; Porter, 1966). Artificial hybridization between lowlands and uplands have largely been unsuccessful (Taliaferro and Hopkins, 1997).

Switchgrass is highly polymorphic and largely self incompatible (Talbert et al., 1983; Taliaferro and Hopkins, 1997). The basic chromosome number of switchgrass is x = 9. The ploidy levels of switchgrass range from diploid (2n=18) to duodecaploid (2n=108) (Hulquist et al., 1996; McMillan, 1959; Nielsen, 1944; Riley and Vogel, 1982).

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Most varieties are tetraploid or octoploid. In Table 1 the ploidy levels of available switchgrass varieties are given. Switchgrass varieties have been developed since the 1930s.

Varieties
Early varieties like Blackwell and Nebraska-28 are wild accessions that showed good performance and were released without additional breeding work (Moser and Vogel, 1995). The earlier varieties were mostly selected for soil conservation purposes, for example Dacotah and Alamo. More recent varieties have been developed by breeding for establishment, yield, quality, and disease resistance (Moser and Vogel, 1995; Sanderson et al., 1996). Currently breeding takes place at several locations in North America. New lowland and upland varieties are being developed specifically for biomass production for biofuel (Taliaferro and Hopkins, 1997). The high genetic variation for important traits should make development of improved varieties for several purposes possible.

Table 1. Ecotype, ploidy level, origin, and seed weight of available switchgrass varieties.

Variety	Ecotype	Ploidy level	Origin	Seed weight†
Alamo	lowland	Tetraploid	south Texas 28°	94
Blackwell	upland	Octoploid	Northern Oklahoma 37°	142
Caddo	upland	Octoploid	South Great plains 35°	159
Carthage = NJ-50	?	?	North Carolina 35°	148
Cave-in-Rock	Intermediate?	Octoploid	Southern Illinois 38°	166
Dacotah	upland	Tetraploid?	North Dakota 46°	148
Forestburg	upland	Tetraploid?	South Dakota 44°	146
Kanlow	lowland	Tetraploid	Central Oklahoma 35°	85
Nebraska 28	upland	?	Northern Nebraska 42°	162
Pathfinder	upland	Octoploid	Nebraska / Kansas 40°	187
REAP 921	upland	tetraploid	Southern Nebraska 41°	90
Shawnee	upland	Octoploid	South Illinois 38°	
Shelter = NY4006	mixed?	Octoploid?	West Virginia 40°	179
Summer	upland	Tetraploid	South Nebraska 41°	114
Sunburst	upland	?	South Dakota 44°	198
Trailblazer	upland	Octoploid	Nebraska 40°	185

(Alderson and Sharp, 1993; Anonymous. 1979; Barker et al., 1988; Barker et al., 1990; Boe and Ross, 1998: George and Reigh, 1987; Gunter et al., 1996; Hopkins et al., 1995; Hopkins et al., 1996; Jung et al., 1990; Newell, 1968; Stout et al., 1988; Vogel et al., 1991; Vogel et al., 1996). A question mark indicates that there are contradictions in the literature.

† Seed weight is expressed as seed weight per 100 seeds in mg. Reported seed weights are those found by the authors in one or two seed samples but should be typical for the variety.

VARIETY CHOICE

Yield
The main factor determining area of adaptation of switchgrass varieties is latitude of origin. The plant has a photoperiod response which is modified by growing degree days (Moser and Vogel, 1995). Decreasing day-length will induce flowering in early summer. Other factors determining adaptation are precipitation and humidity. Varieties developed in dry areas will be more susceptible to fungal diseases when grown in humid conditions.

When different varieties are grown at the same site northern ecotypes will remain shorter, flower earlier and mature earlier than southern ecotypes. Also, production of biomass will be considerably less compared to southern types (Jacobson et al., 1984). A clear strong correlation has been found (in N. America) between time to maturity, latitude of origin of the variety and yield (Sanderson et al., 1999, Samson et al., 1997). This effect can also be found in Europe as demonstrated in Figure 1A. Southern varieties matured later and had higher yields than northern varieties.

Winter survival
At Northern sites (Figure 1B) intermediate varieties appeared to have highest yields in the second year. The lower yields for the southern varieties at Rothamsted and

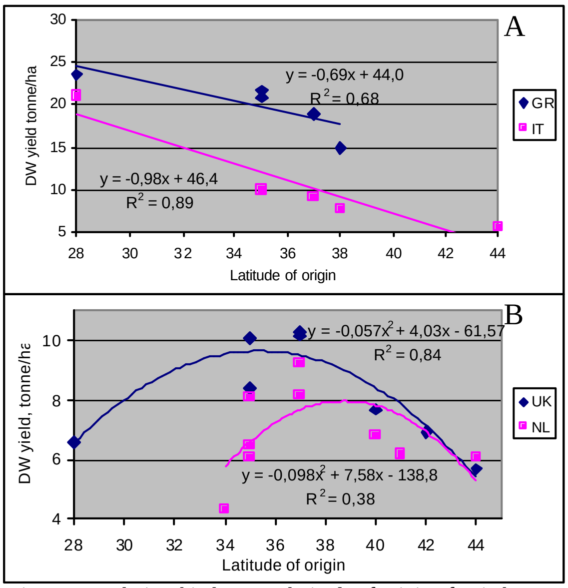

Figure 1. Relationship between latitude of origin of switchgrass varieties and second year biomass yields in Aliartos (GR, Trisaia (IT), Rothamsted (UK) and Noordoostpolder (NL).

Noordoostpolder can be explained by lower winter survival of southern varieties in the first (establishment) year. Southern varieties matured too late to winter harden before a killing frost. This is illustrated in Figure 2. Southern varieties grown in the Netherlands failed to properly mature in fall which reduced re-growth in spring. Southern varieties did not flower in the first season and were still partially green when frost killed the above ground parts in November. This reduced second year re-growth and thus yield (Figure 1B).

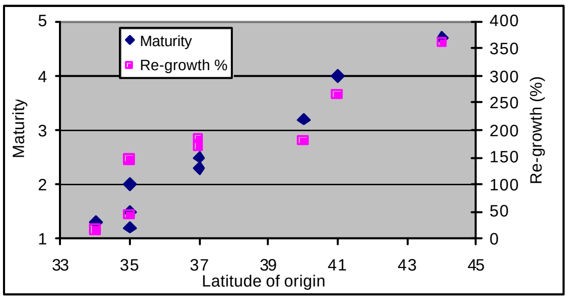

Figure 2. Relationship between latitude of origin of switchgrass varieties and maturity rating in fall and re-growth in early spring. First year at Noordoostpolder (NL) .

Quality

Southern varieties that mature very late in fall will also fail to trans-locate nutrients to the below ground parts before winter sets in leading to winter injury and reduced spring re-growth.

Table 2. Cumulative yield between 1993 and 1998 and nutrient content of switchgrass varieties differing in latitude of origin. The plots were established in 1993 in Rothamsted, England (»53 °N). Plots were harvested after a killing frost in winter. Results of N treatments (0 and 60 kg N ha^{-1}) are combined .

Variety	Latitude of origin	DM yield 93-98	Nutrient content, 1995			
			N	P	K	Mg
		Tonne ha^{-1}	---------- Kg tonne^{-1} ------- ----			
Dacotah	46°	34	6.0	0.5	1.0	0.4
Forestburg	44°	50	4.9	0.4	1.1	0.5
Cave-in-Rock	38°	51	6.0	0.5	1.4	0.8
Kanlow	35°	52	6.9	0.6	1.8	1.7

This is illustrated by the results of the experiment at Rothamsted (Table 2.).

Kanlow, the most southern variety clearly had higher N, P, K, and Mg contents while Dacotah, the most northern variety had the lowest contents. Thus it is possible that southern varieties require more fertiliser.

The higher mineral content of the biomass reduces combustion quality. The increased alkali content, like potassium, reduces combustion efficiency by reducing the ash melting point. Nitrogen in biomass increases N0x emissions.

Southern varieties generally have higher water contents at harvest because they mature later and have thicker stems. This reduces the harvest window and biomass quality (Christian and Elbersen, 1998). This is illustrated in Figure 3 where southern varieties had lower moisture content at harvest both at southern and west European sites.

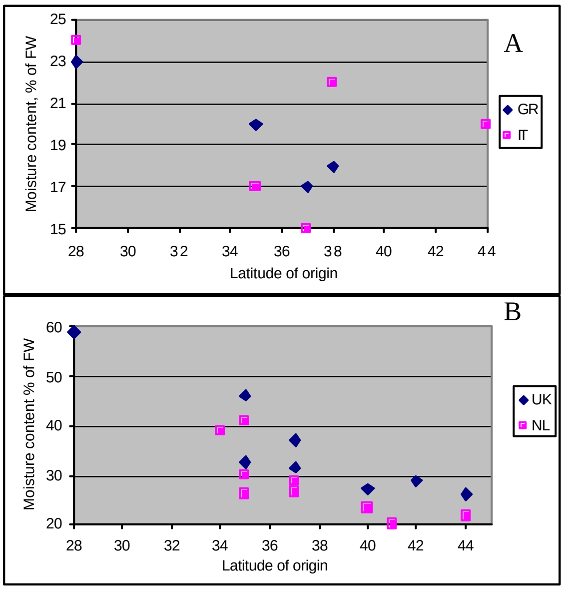

Figure 3. Relationship between latitude of origin of switchgrass varieties and second year biomass moisture content in Aliartos (GR, Trisaia (IT), Rothamsted (UK) and Noordoostpolder (NL).

CONCLUSIONS

It should be possible to find switchgrass varieties that are adapted to most regions of Europe. Adaptation of a variety is mainly dependent on the latitude of origin of the variety. Generally the use of varieties originating at southern latitudes can increase DM yields but it will also increase the chance of establishment failures in the first year, and yields may decline over time. Furthermore the quality of the biomass will be reduced if the variety does not mature in the fall. The best variety for a given latitude or geographical area will be a compromise between yield, quality and winter survival. From the limited data on switchgrass grown in Europe it appears that in Europe switchgrass may be grown further north than in North America.

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