5 Switchgrass variety choice in Europe[4]

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5.1 Summary

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. Some 20 different varieties have been 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 (high nutrient and moisture content) and winter survival. 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 and quality and long term winter survival.

Key words: Switchgrass, *Panicum virgatum*, quality, latitude, mineral composition.

5.2 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. 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). Since the early 1990s the crop has been developed by the United States Department 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. These include the high net biomass production per ha, low production costs, low nutrient requirement, relatively 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 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. The data from this project have been used in the current Chapter. Here 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.

[4] This chapter is to be submitted for publication.

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

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
Pangburn	lowland	Tetraploid	Arkansas 34°	96
Pathfinder	upland	Octoploid	Nebraska / Kansas 40°	187
REAP 921	upland	Tetraploid	Southern Nebraska 41°	90
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.

5.4 Variety choice

Winter survival

It is known that varieties that are moved too far north from their origin will fail to mature in fall and have reduced winter survival. This is illustrated in Figure 1 for switchgrass varieties differing in latitude of origin grown in the Netherlands. Southern varieties did not flower in the fall and were still partially green when while northern varieties had flowered and were mature (brown). A frost killed the above ground (green) parts of the southern varieties in November. The failure to winter harden before a killing frost lead to reduced re-growth in spring (Figure 1). The delayed re-growth can then have a negative effect on the yield as discussed below.

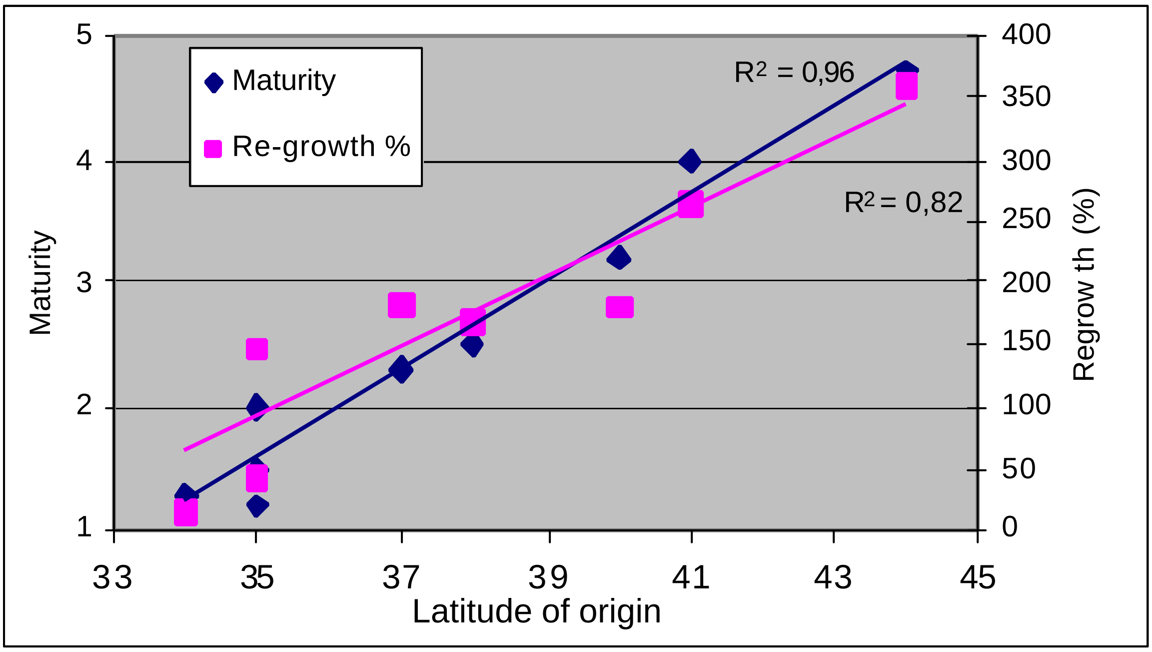

Figure 1. Relationship between latitude of origin of switchgrass varieties and maturity rating in fall and re-growth in early spring. First (establishment) year at Wageningen (NL)

Yield

The most important 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 Texas, and Canada, 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 2A. Southern varieties matured later and had higher yields than northern varieties.
At northern sites (Figure 2B) intermediate varieties appeared to have highest yields in the second year. The lower yields for the southern varieties at Rothamsted (UK) and Noordoostpolder (NL) can be explained by lower winter survival and re-growth of southern varieties in the first (establishment) and subsequent years. Southern varieties mature too late to winter harden and translocate nutrients before winter sets in, leading to reduced re-growth in spring and lower yields. This is illustrated in Figure 2. (Figure 2B).

Quality

Quality of biomass for energy purposes depends on the type of application. Generally low moisture contents are required to reduce transportation costs and make storage possible. Furthermore low ash and nutrient contents are required when the biomass is used for combustion. K and Cl lower biomass quality by lowering the ash melting point and increasing corrosion problems in combustion systems. Nitrogen content increases NOx 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 2C and D, where northern varieties had lower moisture content at harvest both at southern and west European sites.

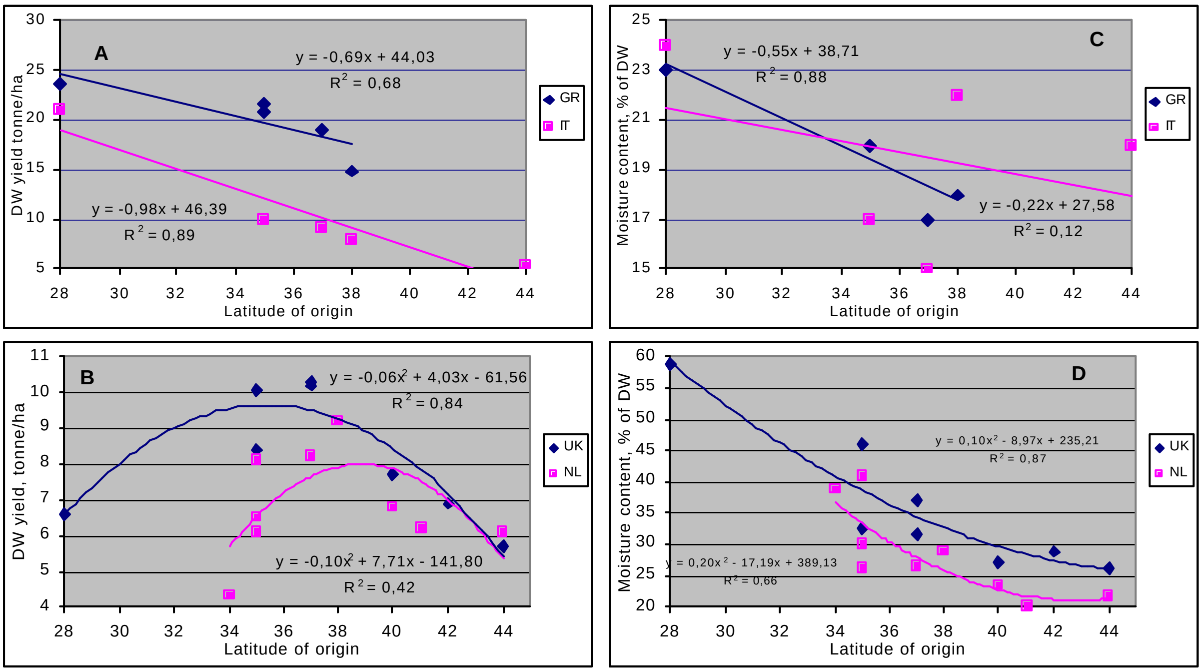

Figure 2. Relationship between latitude of origin of switchgrass varieties and second year biomass yields (A and B) and moisture content of the biomass (C and D). The experimental sites were located at 38 degree north (Aliartos, Greece); 40 degree north (Trisaia, Italy); 52 degree north (Rothamsted, UK) and 52 degree north (Wageningen, the Netherlands). Harvests were made in winter or early spring.

Southern varieties that mature very late in fall will fail to translocate nutrients to the below ground parts before winter sets in. This is illustrated by the results of nutrient analysis in the Netherlands (Table 2) in the second year after establishment.

At a clay and a sandy site in two consecutive years varieties originating at northern latitudes (Forestburg, Summer) consistently had lower Cl and K contents than the southern variety Carthage while the intermediate varieties had intermediate Cl and K contents (Table 2). N and P, nutrients which are not mobilised as easily, were also relatively low in the northern variety Forestburg but here the effects of latitude was less evident, especially in the 2000/2001 season (Table 2). The relationship is also illustrated in Figure 3 where a clear and consistent negative correlation is found between the latitude of origin of a variety and the content of N. P, K and Cl of the biomass for a clay and a sandy site over two years in The Netherlands.

In 2000 heavy lodging of switchgrass, especially at the clay site, impeded trans-location of nutrients to the below ground parts also for northern varieties, which may have reduced the relationship between nutrient content and latitude of origin of a variety. At the clay site much higher ash contents were measured. This is expected as on clay soils silica uptake tends to be higher. This illustrates that apart from latitude of origin also other variables are important in determining biomass quality (and yield).
Thus it is likely that at NW European sites southern varieties contain more nutrients especially K, Cl and to a lesser extent N and P which will reduce biomass quality for energy and fibre applications. At more northern latitudes southern varieties will also require more fertiliser than northern varieties.

Table 2. Ash and nutrient content of switchgrass varieties differing in latitude of origin. The plots were established in 1998 on a clay soil type (Noordoostpolder) and on a sandy soil (Wageningen). The latitude of the two sites is approximately 52 and 53 degree north. Plots were harvested after a killing frost in winter.

1999-2000		Noordoostpolder, clay site					Wageningen, sandy site				
	Latitude	Ash	Cl	N	P	K	Ash	Cl	N	P	K
	°north	% DW	kg/tonne				% DW	kg/tonne			
Forestburg	44	5,83	0,32	4,13	0,52	1,06	1,60	0,41	4,26	0,61	1,36
Summer	41	4,87	0,27	4,06	0,54	1,23	1,80	0,27	4,31	0,58	1,03
CIR	38	5,51	0,97	6,69	0,67	4,38	2,20	1,10	4,56	0,58	2,46
Blackwell	37	5,80	0,86	5,27	0,69	2,93	2,60	0,83	4,66	0,66	2,34
Carthage	35	5,30	1,48	6,56	0,88	5,61	2,60	0,83	5,86	0,75	3,31

2000-2001		Noordoostpolder, clay site					Wageningen, sandy site				
	Latitude	Ash	Cl	N	P	K	Ash	Cl	N	P	K
	°north	% DW	kg/tonne				% DW	kg/tonne			
Forestburg	44	8,90	0,35	7,55	0,88	1,74	2,20	0,23	7,37	0,83	1,40
Summer	41	7,88	0,36	8,73	1,03	2,43	2,20	0,24	7,22	0,81	2,03
CIR	38	8,51	0,59	9,55	1,05	3,47	1,20	0,46	8,05	0,86	2,76
Blackwell	37	10,20	0,51	8,55	1,03	2,61	2,60	0,49	9,11	1,13	2,70
Carthage	35	8,50	0,54	8,83	1,12	3,35	2,00	0,52	7,39	0,99	2,72

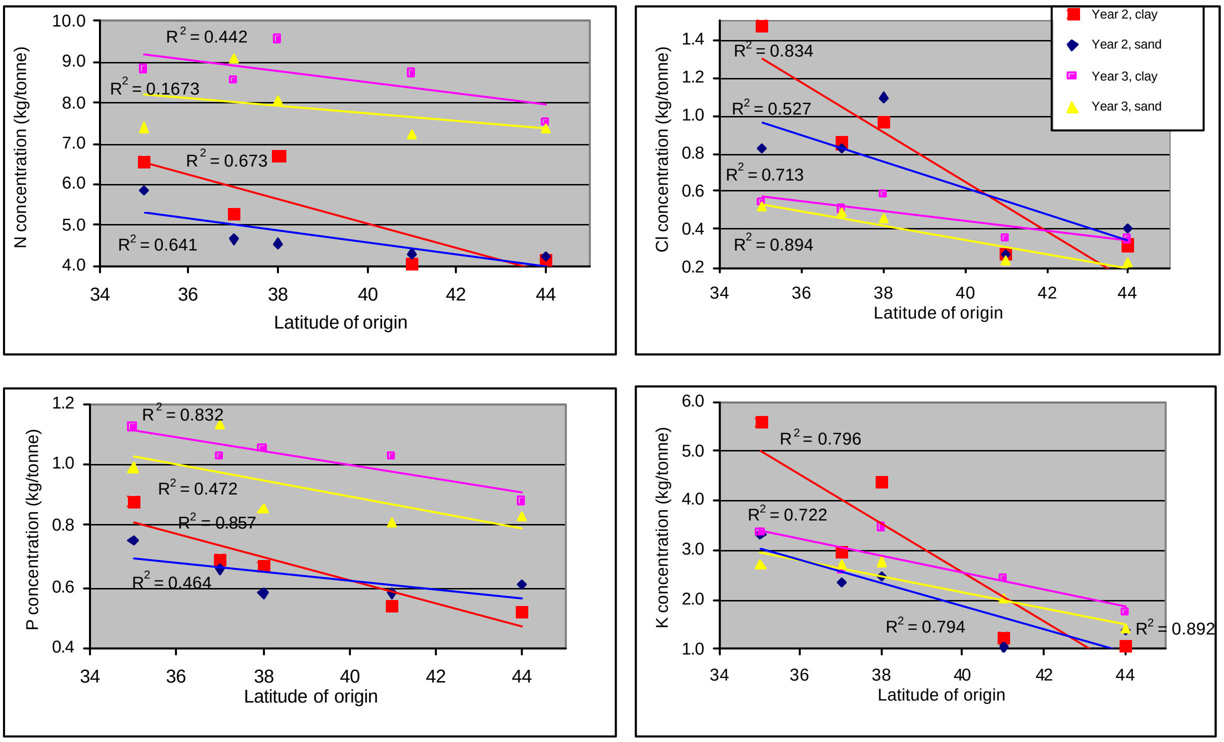

Figure 3. Relationship between the latitude of origin of 5 switchgrass varieties (Forestburg, 44 degree north; Summer, 41 degree north; Cave in Rock 38 degree north; Blackwell 37 degree north; Carthage 35 degree north) and the nutrient content of the harvested biomass over the second (1999) and third (2000) growing season on a clay and a sandy site in The Netherlands.

5.5 Conclusions

It is possible to find switchgrass varieties that are adapted to most regions of Europe. The latitude of origin of a variety is the most important aspect determining the area of adaptation of a 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 a decline in yields over time. Furthermore the quality of the biomass will be reduced (high moisture and nutrient content) 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 current data on switchgrass grown in Europe it appears that switchgrass may be grown further north than in North America.

5.6 Acknowledgements

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5.7 References

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