6 Switchgrass establishment

6.1 Introduction

Development of effective establishment methods for switchgrass is an important requirement for succesful introduction of switchgrass as a biomass crop in Europe. In the current project experiments were executed to test the effect of a number of important variables on switchgrass crop establishment under European conditions. At experimental sites in Braunschweig Germany and at Trisaia, Italy the effect of drilling date, seedling rate and weed control was followed over two seasons. The results are presented in chapter 6.2.

Other experiments were carried out at Bologna, Italy, to test the effect of seedbed preparation on emergence of switchgrass seedlings. Results can be used to develop methods for establishing switchgrass more cost effectively especially in sloping areas. The results have been published (Monti et al., 2001) and an abstract of the results is presented in chapter 6.3.

6.2 Effects of different seeding rates, drilling dates and weed control on establishment of switchgrass (*Panicum virgatum* L.) varieties in northern Germany and Southern Italy[5].

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Abstract

Establishment of switchgrass, a native species of the North American Great Plains, was evaluated under contrasting climatic conditions in Germany and Italy. The effects of drilling dates, seeding rates and weed control on growth and dry matter production of two contrasting switchgrass varieties was evaluated at two sites in Europe. The varieties were Cave-in-Rock, Alamo and Kanlow, drilling dates were April and June 1999 in Germany and April and May 1999 in Italy. Seeding densities were 200 and 400 pure live seed (PLS)/m^2. Plots had either no weed control or chemical control with the herbicide 2.4-D. The higher seeding rate resulted in greater plant density but did not affect dry matter yield. The early drilling date (April vs June) in Germany significantly increased dry matter yield while the late drilling date in Italy (May vs April) increased yield. Generally northern upland-ecotypes of switchgrass are more adapted to cooler northern climatic conditions. Results show that the lowland-ecotype Kanlow could overwinter and establish near Braunschweig in Germany. Weed control resulted in increased biomass yield in Italy but not in Germany Yield in Italy may have been affected by summer drought as irrigation was necessary in both years. Up to 12-16 t DM/ha were harvested in Germany compared to maximum yield of 8 t/ha in Italy. Biomass yield resulting from the different treatments ranged from 5.09-8.9 tonne DM/ha in 1999 and 10.6- 16.6 in 2000. In Italy, yield ranged from 1.63-15.36 tonne DM/ha.

Keywords: switchgrass, seeding rate, weed control, Europe, drilling date, biomass yield

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

Introduction

Switchgrass (*Panicum virgatum* L.) is a tall grass species native of the Northern American Great Plains [13]. Switchgrass has been cultivated and investigated in North America. Varieties have been identified that can grow under similar climatic conditions in Europe and the Middle East [8, 9]. Switchgrass can grow to heights of more than 2 m and produce up to 30 t DM/ha [2]. The biomass is suitable for energy production and paper pulp [6].

The wide distribution of switchgrass in different North American climatic regions suggests that there are also varieties to be found that may be productive under European climatic conditions. Switchgrass can be established at low cost using seed [2] and the species requires little input of fertiliser and herbicides once the crop is established. Development of reliable establishment methods is essential for introduction of switchgrass as a biomass crop in Europe. Important factors determining success of establishment are seeding rate and drilling date. These factors have only been investigated in North America [11,12,13]. The North American literature shows different recommendations for drilling date under contrasting climatic conditions [10]. The effect on yield resulting from weed competition has been investigated in America where it was found that weed control is an essential factor during establishment (7). The effect of seeding density, weed control measures and drilling date have not previously been investigated in Europe. In this report the effect of different drilling dates, seeding rates and weed control measures will be presented. Experiments have been conducted at Braunschweig in north Germany under cool climatic conditions and at Trisaia in southern Italy under warm, dry Mediterranean conditions. Here we present the results of experiments conducted over two growing seasons in 1999 and 2000.

Material and Methods

The experiments were located at the Federal Research Centre of Agriculture, Braunschweig in North-west Germany and at the ENEA experimental station at Trisaia, Southern Italy. The soils at Braunschweig and Trisaia are loamy sand and sandy clay respectively. The field trials in Germany were established in 1999 on the 28th April (early date) and 23rd June (late date). In Italy the plots were drilled on 21st April 1999 and 21st May 1999. In both countries the seed rates compared were 200 and 400 pure live seed (PLS)/m^2. The experimental plots have been treated either with no herbicide or with 0.5 kg ai /ha 2-4-D applied in April of each year. The fields were fertilised with 75 kg N/ha. The experimental treatment plot size was 7 m^2. The experimental design at both sites was randomised blocks with three-fold replication. Statistical analysis was carried out using ANOVA of the SAS programme. In Italy irrigation was necessary, during the vegetation period 240 mm and 210 mm water were applied in 1999 and 2000 respectively.

Three switchgrass varieties were used: Cave-in-Rock (CIR, upland/lowland ecotype) in both countries and Kanlow (lowland-ecotype) in Germany and Alamo (lowland-ecotype) in Italy. The seeding rates were for CIR: 1.113 g/m^2 (400 PLS) and 0.556 g/m^2 (200 PLS), for Kanlow: 1.304 g/m^2 (400 PLS) and 0.652 g/m^2 (200 PLS) and for Alamo: 0.562 g/m^2 (400 PLS) and 0.281 g/m^2 (200 PLS).
Crop development and biomass production were recorded during the years 1999 and 2000. The weather details in Germany and Italy during the experiment are presented in Table 1. During 1999 and 2000 very dry weather occurred in both countries. A summer drought in Italy made irrigation necessary.

Table 1. Weather details at the two experimental sites.

Location	Braunschweig, Germany		Trisaia, Italy	
Year	1999	2000	1999	2000
Air-Temperature °C	10,4	10,6	16,6	17,4
Sunshine duration, hr	1730	1569	2807	3028
Precipitation, mm	536	544	176	345
Evaporation, mm	689	637	1477	1623
Difference, mm	-153	-93	-1061	-1068

* Yearly average, all other data calculated as yearly total
** Calculated as sum from January until November

Results

Germany:

Due to the late drilling date (June, 1999) the growth period was quite short in Germany, nevertheless plants established well (Table 2) and reached a height of 122 cm. The crop stand rating was scored once in July 1999 during the vegetation period. There were more gaps present in the stand of Kanlow than in Cave-in-Rock (Table 2). A higher seeding rate also resulted in a higher shoot density. Cave-in-Rock had 407 shoots per m^2 as compared to Kanlow (max. 437) in 1999 and shoot density was also greater in 2000 (Table 2). Maximum shoot density for both varieties was measured in 2000 in plots drilled in June 1999 .

Plant height and shoot density were not affected by weed control measures (herbicide treatment or control, no herbicide). In 2000 switchgrass varieties grew up to 140 to 180 cm, which is taller than in the previous year (Figure 1). Shoot height was greater in the April-sown crop compared to the June-sown and on plots with the lower plant density; Kanlow had the tallest shoots.

Biomass yield was greater in 2000 than 1999 (Table 4). Between 5 and 8.9 t DM/ha were harvested in 1999 compared with 10.6 and 16.6 t in 2000. Significantly lower yield was obtained from June-sown plots. There was no statistically significant difference between low and high seeding rate treatments. In 1999 and 2000 Kanlow was more productive than Cave-in-Rock (CIR) although in 2000 the difference was only on the 200 PLS/m^2 treatment.

Italy:

In the Italian study the variety Kanlow was replaced by Alamo. Shoot density, plant height and crop stand score are presented in Table 3. Shoot density was higher in plots drilled with 400 PLS/m^2 than in plots drilled with 200 PLS/m^2. The highest plant density was measured in Cave-in-Rock (CIR) for 400 PLS/m^2. The shoot density was higher in the May-sown compared to the April-sown treatment. Weeds affected plant growth, particularly during the first year. Weed control with 2.4-D lead to increased plant density in both varieties.

Compared with plant heights in Germany, Cave-in-Rock (CIR) in Italy grew only 110 cm tall in the first year 1999 (Figure 2). Plants grew taller in the late-drilled compared to the early drilled treatment. Alamo was taller than CIR in both 1999 and 2000. In 2000 both the early and late drilled Alamo treatments were taller than the Cave-in-Rock plots (Figure 2). No significant treatment differences were present between the plots that received herbicide compared to the control.

Switchgrass grew very slowly in 1999 and could not compete with the weeds. Yields were very low and are not presented in the tables. During the second year, the highest yields for both drilling dates were obtained from Alamo (Table 5). The yields reached up to 15.4 tonne DM/ha in the herbicide treated Alamo plots. Yields were consistently higher in plots drilled in May 1999 compared to April.

Discussion

Although in Germany frost occurred during winter and the growing period was shorter than in Italy, switchgrass productivity was comparable for both varieties. In both countries higher seeding rates increased shoot density. In Germany this did not result in higher yield while it did increase yields in Italy. A lower plant density and shorter plant height was observed in Italy for Cave-in-Rock.

Yields in Germany were comparable with those in the USA [2]. In Germany Kanlow grew more slowly, had later shoot growth in spring but produced more biomass than Cave-in-Rock. Alamo produced the highest biomass in Italy.

In the first and second year the late (June) drilled treatment showed lower DM yield than the early drilling treatments (April). This was the case for both varieties in Germany. There was very little or no effect of drilling rate on yield. Contrasting results were observed in Italy, where higher yields were obtained on the later seeding dates but again no significant differences were recorded between early and late drilling date treatments. Longer day length together with higher temperatures might have promoted growth in plots drilled in May in southern Italy [4].

A key factor for switchgrass cultivation is the establishment. For most of the varieties and treatments under study establishment was successful although weed competition was observed during the first year. It is recommended to continue the experiments for at least 5-6 years in order to assess yield potential and best adapted switchgrass variety in Germany as well as in Italy.

5. Conclusions

Different drilling densities did not affect dry matter yields also under contrasting climatic conditions in northern Germany and southern Italy. Higher intra-specific competition in plots with high drilling rates might reduce stem weight but needs to be proved in further experiments. Earlier drilling resulted in taller plants and higher yields in northern Germany. In southern Italy the effect the other way round with later established plots doing better than the earlier established plots. Explanations may lie in weed competition in the earlier established plots.

Weed competition occurred especially during the first year in northern Germany but disappeared during the following year. Warmer climatic conditions led to severe weed competition in Italy, which led to low dry matter yield in the first year.

In Italy, switchgrass stand recuperated well in the second season. In the first year establishment was complex and plant growth was affected by summer drought. Under climatic conditions in Italy, switchgrass plants have grown much better for late sowing dates in May compared to earlier dates in April.

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Table 1: Weather conditions at Braunschweig (northern Germany) and Italy in the years 1999 and 2000 (yearly sums and average)

Table 2: Shoot density and plant establishment ratings during the vegetation period in the years 1999 and 2000 for switchgrass varieties Cave-in-Rock (CIR) and Kanlow under 200 or 400 Pure Live Seeds (PLS)/m² seeding rates, drilled early (April) or late (June) under no weed control (K) or chemical weed control (C) measures. (Location: FAL, Germany).

	21-7-1999		3-5-2000	21-6-2000
Variety/date	Shoot density tillers / m^2	Establishment rating (1 to 6)	Shoot density tillers / m^2	Establishment rating (1 to 6)
Drilled in April				
CIR 200 K	228	4	1089	5
CIR 200 C	214	5	1096	4
Kanlow 200 K	220	4	1044	4
Kanlow 200 C	170	4	1033	4
CIR 400 K	382	5	1340	5
CIR 400 C	402	5	1399	6
Kanlow 400 K	189	5	938	5
Kanlow 400 C	214	5	1012	5
Drilled in June				
CIR 200 K	218	5	1326	5
CIR 200 C	201	5	1319	6
Kanlow 200 K	271	4	1153	6
Kanlow 200 C	273	4	1078	5
CIR 400 K	294	6	1623	6
CIR 400 C	328	6	1710	5
Kanlow 400 K	433	6	1655	6
Kanlow 400 C	437	6	1456	5

Table 3: Shoot density and plant establishment ratings during the vegetation period in the years 1999 and 2000 for switchgrass varieties under 200 or 400 Pure Live Seeds (PLS)/m² seeding rates, drilled early (21 April 1999) or late (21 May, 1999) under no weed control (K) or chemical weed control (C) measures. (Location: ENEA Trisaia, Italy)

	21-7-1999		21-7-2000	
Variety/date	Shoot density tillers / m²	Establishment rating (1 to 6)	Shoot density tillers / m²	Establishment rating (1 to 6)
Drilled in April				
CIR 200 K	246	3	300	4
CIR 200 C	280	3	367	4
Alamo 200 K	242	5	300	3
Alamo 200 C	272	3	467	3
CIR 400 K	344	4	567	4
CIR 400 C	390	3	467	4
Alamo 400 K	260	2	567	3
Alamo 400 C	324	4	500	4
Drilled in May				
CIR 200 K	276	2	333	5
CIR 200 C	360	3	534	5
Alamo 200 K	147	1	534	4
Alamo 200 C	336	4	734	5
CIR 400 K	356	5	433	5
CIR 400 C	456	3	734	5
Alamo 400 K	350	6	567	6
Alamo 400 C	310	3	500	6

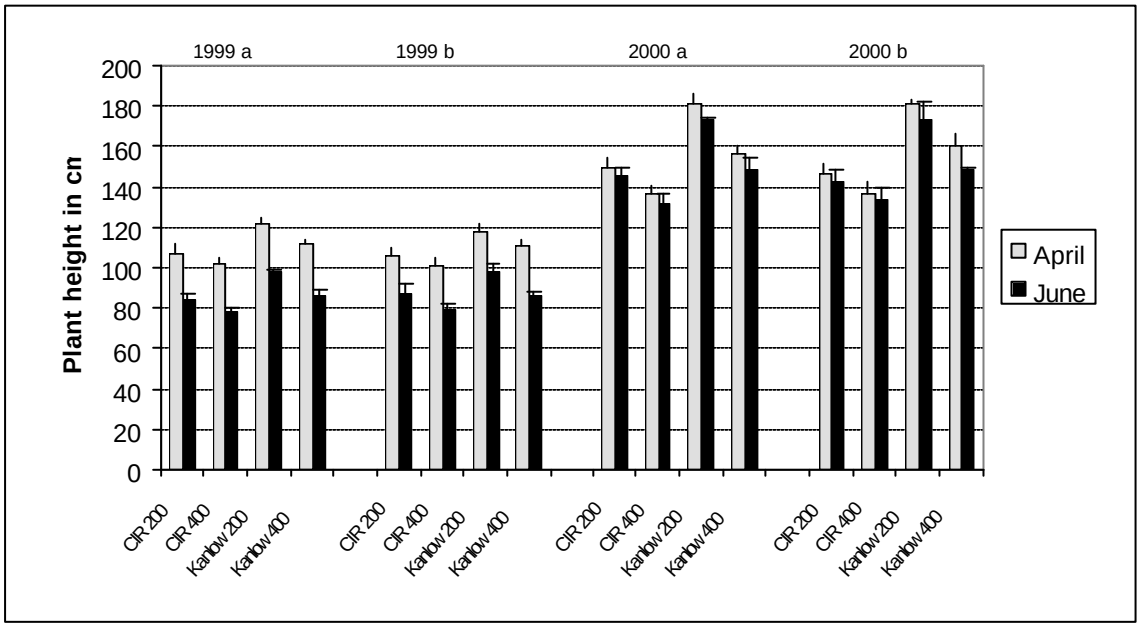

Figure 1: Plant height of switchgrass varieties Cave-in-Rock (CIR) and Kanlow in 1999 and 2000 under 200 or 400 Pure Live Seeds (PLS)/m² seeding rates, drilled early (April) or late (June) under no weed control (a) or chemical weed control (b) measures. (Braunschweig, Germany).

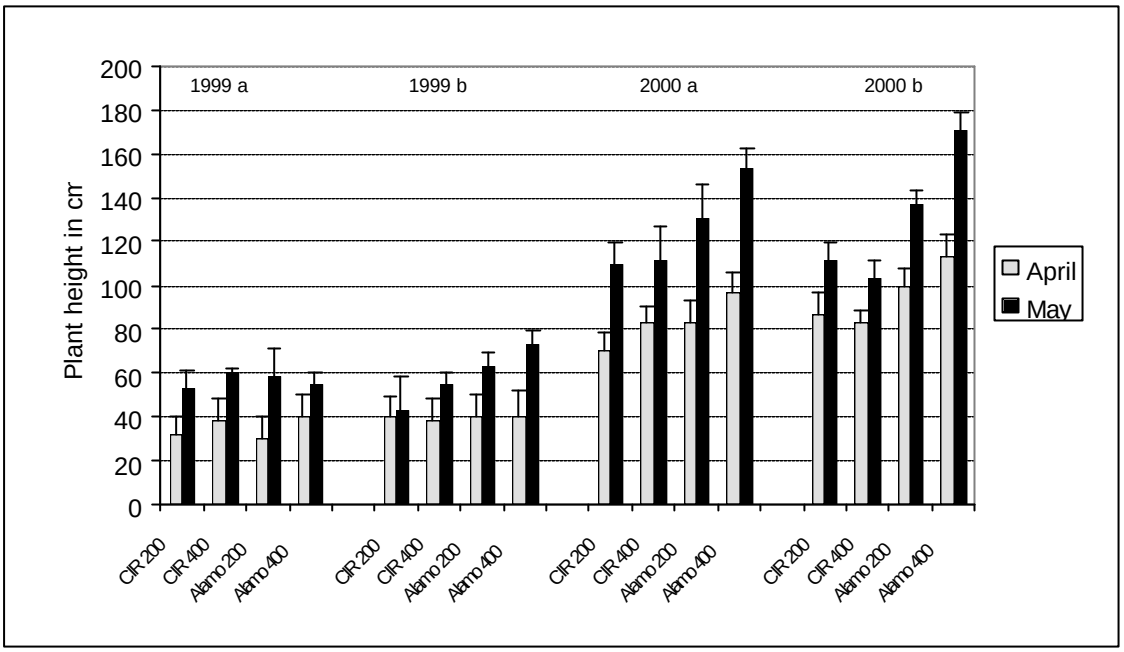

Figure 2: Plant height of switchgrass varieties Cave-in-Rock (CIR) and Alamo in 1999 and 2000 under 200 or 400 Pure Live Seeds (PLS)/m² seeding rates, drilled early (21 April 1999) or late (21 May, 1999) under no weed control (a) or chemical weed control (b) measures. (Trisaia, Italy)

Table 4: Biomass yield in tonne DM/ha calculated from experimental plots of switchgrass varieties in northern Germany at 200 or 400 Pure Live Seeds (PLS)/m² seeding rates, drilled early (28 April 1999) or late (23 June 1999) under chemical weed control or no weed control measures. (mean with standard deviation and LSD for p=0,05%)

Treatment	CIR 200	CIR 400	Kanlow 200	Kanlow 400
1999				
April K	6,9±0,7	6,4±0,6	8,9±1,1 a	8,7±0,1 a
April C	6,5±0,5	6,9±0,5	8,6±0,8 a	8,6±0,4 a
June K	5,1±0,3 b	5,2±0,2 b	6,1±0,3 a b	6,8±0,2 a b
June C	5,2±0,3 b	5,5±0,3 b	5,3±0,3 b	6,8±0,1 a b
LSD 0,05, variety	0,41 a=significant	LSD weed control	no significance	
LSD 0,05, date	0,29 b=significant	LSD density:	no significance	N=48
2000				
April K	15,4±2,9a	16,6±2,3	16,4±1,1	16,4±0,7
April C	13,8±1,0 a	15,6±2,3	16,5±1,5	15,7±0,9
June K	11,8±1,9 b	10,6±0,6 a b	13,0±0,9 b	11,8±1,1 b
June C	11,8±0,8 b	10,7±1,5 a b	12,3±1,2 b	12,7±0,9 b
LSD 0,05, variety	0,78 a=significant	LSD weed control:	No significance	
LSD 0,05, date	0,56 b=significant	LSD density:	No significance	N=48

K = no weed control; C = chemical weed control
Seeding density: 200 or 400 PLS/m^2

Table 5: Biomass yield in tonne DM/ha calculated from experimental plots of switchgrass varieties in southern Italy at 200 or 400 Pure Live Seeds (PLS)/m² seeding rates, drilled early (April) or late (June) under chemical weed control or no weed control measures in the year 2000 (mean and standard deviation).

Treatment 2000	CIR 200	CIR 400	Alamo 200	Alamo 400
April K	1,6±0,7	2,8±0,4	2,8±0,4	3,0±0,5
April C	2,4 0,7	2,7±1,0	2,7±0,5	5,9±1,1
May K	3,9±1,3	5,3± ,6	7,4±1,4	10,6±2,4
May C	4,2 ±1,1	5,7±1,3	12,9±1,1	15,4±2,2

K = no weed control; C = chemical weed control
Seeding density: 200 or 400 PLS/m^2

6.3 Evaluation of the establishment of lowland and upland switchgrass (*Panicum virgatum* L.) varieties under different tillage and seedbed conditions in northern Italy[6]

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Abstract

Information is needed on potential biomass crops for marginal lands in southern Europe. The objective of this study was to investigate switchgrass establishment in four seedbed preparation treatments (sowing, rolling before sowing, rolling before and after sowing and no till) for two varieties (small and large seed types). A 4x2 split-plot factorial design with four blocks was adopted over a 2 years period. Trials were conducted in Bologna (latitude 44°33'N, longitude 11°21'E, 32 m a.s.l.), in a silt loam soil (Udic Ustochreps fine silty, mixed, mesic). In general, emergence was lower in the autumn trials than in the spring one. Emergence on rolled soil (single and double) was statistically higher than tilled unrolled soil. Cumulative analysis of the two autumn trials including no till showed a significant ($P \leq 0.05$) interaction between treatment and varieties: the large seed variety had a better performance only with no till, particularly in the first year. Overall, if no till was not considered, no significant interactions between variety and tillage treatments were found for final seedling numbers. The statistical analysis on both varieties was therefore combined. Although the double rolled tillage treatment consistently showed a slightly higher average seedling emergence than the single rolled treatment, the final number of emerged seedlings was never significantly different. In all cases, the rolled treatments (single and double) had significantly higher final emergence rates than the treatment with no soil compaction. The average emergence index of unrolled plots was 20 % lower than rolled plots. A function was calculated to predict the seedling numbers at the end of emergence based on the seedling numbers at the beginning of emergence. Generally rolling was needed to obtain best switchgrass performances. In northern Italy both varieties had a good emergence when soil conditions were appropriated..

Keywords: Switchgrass, *Panicum virgatum*, Seedbed preparation, Seedling establishment, Northern Italy.

[6] Monti, A., P. Venturi and H.W. Elbersen (2001) Evaluation of the establishment of lowland and upland switchgrass (*Panicum virgatum* L.) varieties under different tillage and seedbed conditions in northern Italy. Soil & Tillage Research 63 (2001) 75-83.