3 Switchgrass in the Mediterranean region[2]

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3.1 Introduction

Switchgrass (*Panicum virgatum* L.) is an erect warm-season (C4) perennial grass where it occurs naturally from 55°N latitude to deep into Mexico, mostly as a prairie grass. Over the last two decades it has become an important warm-season pasture grass for fodder production when cool season C3 grasses are less productive in summer (Moser and Vogel, 1995). Many reasons are given for using switchgrass as a biomass crop for energy and fibre production. These include the high net energy production per ha,low production costs, low nutrient requirements, 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; Saderson et al. 1996; Samson and Omielan, 1992).

Two ecotypes are generally defined based on morphological characteristics and habitat preferences. Lowland types are generally found in floodplains, they are taller, coarser, have a more bunch type growth habit, and may be more rapid growing than upland types (Moser and Vogel, 1996; Porter, 1996). Upland types are found in drier upland sites, they are finer stemmed, broad based, and often semi-decumbent. It is suggest that lowland types may be better suited as biomass fuel plants (Hultquist et al. 1996).
In Europe the research for switchgrass as a biomass crop for energy and fibre has started in 1998 in the framework of a European network (FAIR 5 CT97 3701). In the view of this work, experimental fields of switchgrass have been established in five European countries, two in the south (Greece and Italy) and three in the north (Germany, Netherlands and UK). Before that some research work on switchgrass had been conducted in UK and Germany (Christian and Elbersen, 1998; Lewandowski et al. 1998). It is estimated that in Europe some of 4 ha of experimental switchgrass fields exist of which 2.5 ha is within the current European Union sponsored switchgrass productivity network (Elbersen et al. 2001).
The main purpose of this work was to test the adaptability and biomass productivity of several switchgrass varieties in the Mediterranean region (Greece and Italy) as well as to test the productivity of five switchgrass varieties under three nitrogen fertilisations rates.

3.2 Methods and Materials

Site and treatments

In 1998, four switchgrass trials were established, two in Greece (Aliartos) and two in Italy (Trisaia). In each country a nursery and a productivity trial were established. The experimental layout in the nursery trial was a randomised complete block design in three replications, while in the productivity trial was a 5x3 factorial complete block design in three replications. A detailed description of all trials (site co-ordinates, treatments, experimental layout, plot size and sowing dates) is presented in Table 1.
Irrigation in both sites was necessary in order to ensure the good establishment of the crop as well as the high biomass yields. In both sites (Aliartos, Trisaia) the climate could be characterised as dry with 400mm/year mean precipitation. In both sites the soil type is SL with relatively low organic matter.

2 This chapter is to be submitted for publication.

Table 1. Description of the switchgrass trials in Greece and Italy.

	Nursery Trials		Productivity Trials	
	Greece (Aliartos)	Italy (Trisaia)	Greece (Aliartos)	Italy (Trisaia)
Sites coordinates	latitude 38^0 22, longitude 23^0 10 altitude 114 m	latitude 40^0 09, longitude 16^0 38 altitude 30 m	latitude 38^0 22, longitude 23^0 10 altitude 114 m	latitude 40^0 09, longitude 16^0 38 altitude 30 m
Treatments	*10 varieties* Caddo Cathage Cave-in-rock Forestburg Kanlow SL 93-2 SL 93-3 SL 94-1 SU 94-1 Summer	*15 varieties* Caddo Cathage Cave-in-rock Kanlow NU 94-2 Pangburn SL 93-2 SL 93-3 SL 94-1 SU 94-1 Summer Sunburst Trailblazer 9005439 9005438	*5 varieties* Alamo Blackwell Cave-in-Rock Kanlow Pangburn *3 nitrogen rates* N_1=0 kg N/ha N_2=75 kg N/ha N_3= 150 kg N/ha	*5 varieties* Alamo Blackwell Cave-in-Rock Forestburg Kanlow *3 nitrogen rates* N_1=0 kg N/ha N_2=75 kg N/ha N_3= 150 kg N/ha
Experimental layout	Randomised complete block design in three blocks		5x3 factorial complete block design in three blocks	
Plot size	3m x 4m	5m x 2.7m	6.5m x 7.5m	6.3m x 7.5m
Sowing date	3/6/98	17/7/98	31/5/98	16/7/98

3.3 Measurements

During all growing periods (1998, 1999 and 2000), in both sites, a series of measurements were carried out including canopy height, number of tillers per square meter and number of tillers per plant. In order to measure the number of tillers per square meter and number of tillers/plant a marked area sized 0.5 x 0.5 m^2 in each plot was used. At the end of each growing season the final harvest took place after a killing frost in order to determine the fresh and dry matter yields and yields components. The harvested area per plot was 4 m^2 in the productivity trial and 2 m^2 in the nursery trial and from the harvested material a quantity of 500 gr was taken and separated into stem and leaves. After the separation the samples from stems and leaves were oven-dried until constant weight for dry matter determinations.

3.4 Results

Nursery Trials

Plant height

Due to earlier sowing in the Greek trial all varieties had the opportunity to develop higher stems compared to the Italian trial (142.6 cm versus to 91.5 cm – mean values). In the second growing season the plant height was increased in both sites (30% in Greece and 64.4% in Italy). In the third year the plant height continued to increase only in the case of Italy (15.15%), while in Greece was decreased (14.24%). As it is presented in Tables 2 & 3 the mean plant height was higher in Greece in the first and the second growing season but in the third growing season this trend was changed.

At the end of the third growing season the plant height in Aliartos ranged from 153.3cm (Cathage, CIR and SU 94-1) to 173.3 cm (SL 93-3). In Trisaia the corresponding values ranged from 140 (Caddo) to 210 cm (SL 93-2, SL 93-3 and SL 94-1). It should be mentioned that the range among the tested varieties was larger in Italy (Tables 2, 3).

Number of tillers per square meter and tillers/plant

In both sites the number of tillers per square meter and tillers/plant was increased from the establishment to the second growing season but in the third year the increase was continued only in the case of the Italian trial (Tables 2 and 3). Thus, at the end of the third growing season the number of tillers per square meter

and tillers/plant was higher in Trisaia. In more detail, the number of tillers per square meter in Trisaia was fluctuated from 1034 (Sunburst) to 2868 (Summer), while the corresponding data in Greece ranged from 1052 (Kanlow) to 2075 (CIR). Regarding the number of tillers/plant (2000) in Trisaia varied from 18.1 (NU 94-2) to 59 (9005439) and in Aliartos ranged from 19.2 (SL 93-2) to 30.3 (SU 94-1).

Yields

In both sites the dry matter yields for all varieties increased from the establishment to the second growing season. The increase in Greece was came up to 53.98%, while in Italy was 225.96%. Between the second and the third growing season the dry matter yields were continued to increase in Trisaia (73.11%), while in Aliartos the dry matter yields averaged overall varieties were almost the same.

Table 2. Growth characteristics (plant height, number of tillers/m², number of tillers/plant) and dry matter yields (t/ha) in Aliartos, Greece (1998, 1999 & 2000).

Varieties	Final canopy height (cm)			Number of tillers/m²			Number of tiller/plant			Dry matter yields (t/ha)		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Caddo	153.3	187.7	166.7	1174	1402	1107	9.2	27.5	21.7	10.7	20.1	20.1
Cathage	155.0	190.0	153.3	1190	1761	1613	9.6	25.7	23.5	15.2	18.9	17.5
CIR	146.3	186.7	153.3	1067	1920	2075	9.1	23.5	25.4	11.8	15.8	17.9
Forestburg	143.3	190.0	156.7	1056	1132	1337	9.8	20.0	23.6	13.2	19.0	18.4
Kanlow	133.3	180.0	160.0	832	1145	1052	10.0	25.6	23.5	10.4	17.1	21.3
SL 93-2	140.0	180.0	156.7	1070	1700	1229	9.4	26.5	19.1	11.6	16.8	16.7
SL 93-3	143.3	186.7	150.0	1090	1936	1428	10.1	30.3	22.3	12.4	19.0	17.8
SL 94-1	138.3	190.0	173.3	1070	1104	1153	9.2	21.6	22.6	9.4	15.8	18.8
SU 94-1	130.0	180.0	153.3	1032	1434	1544	8.1	28.1	30.3	8.5	14.0	11.3
Summer	143.3	183.3	166.7	989	1028	1053	8.7	24.2	24.8	12.1	21.1	19.3
Mean	142.6	185.4	159.0	1057	1456	1359	9.3	25.3	23.6	11.53	17.76	17.91

Table 3. Growth characteristics (plant height, number of tillers/m², number of tillers/plant) and dry matter yields (t/ha) in Trisaia, Italy (1998, 1999 & 2000).

Varieties	Final canopy height (cm)			Number of tillers/m²			Number of tiller/plant			Dry matter yields (t/ha)		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Caddo	90	140	140	-	1047	2068	-	16.9	33.3	2.31	7.59	10.10
Cathage	80	163	180	-	1020	1134	-	19.6	21.8	2.51	7.60	9.42
CIR	100	143	160	-	960	2268	-	18.5	43.6	2.53	7.11	11.37
Kanlow	100	133	190	-	1141	1067	-	25.9	24.2	1.36	4.71	15.30
NU 94-2	90	190	150	-	1080	1467	-	13.3	18.1	2.98	8.33	10.83
Pangburn	110	217	200	-	600	1668	-	14.6	40.7	2.42	8.50	11.91
SL 93-2	100	200	210	-	1080	1367	-	27.7	35.0	2.03	8.50	20.16
SL 93-3	100	107	210	-	747	1401	-	16.2	30.4	2.05	14.62	26.08
SL 94-1	100	117	210	-	867	1301	-	16.4	24.5	2.38	9.96	14.90
SU 94-1	90	130	160	-	627	2868	-	7.4	33.7	2.99	10.35	15.76
Summer	75	147	150	-	900	1234	-	16.1	22.0	1.31	6.28	7.79
Sunburst	75	147	160	-	540	1034	-	10.6	20.2	0.87	3.45	8.20
Trailblazer	80	143	170	-	1261	2468	-	24.7	48.3	2.84	5.78	10.67
9005439	-	133	150	-	1167	1534	-	44.8	59.0	-	1.71	5.63
9005438	-	147	160	-	1141	1134	-	24.2	27.0	-	2.59	7.28
Mean	91.5	150.5	173.3	-	945	1601	-	16.1	32.1	2.19	7.14	12.36

As it is shown in Figures 1 and 2 the range among the tested varieties in terms of dry matter yields in all years was quite large in Italian trial. More specifically, at the establishment year the dry matter yields in Italy ranged from 0.87 t/ha (Sunburst) to 2.99 t/ha (SU 94-1), while in the following year ranged from 1.71 t/ha (9005439) to 14.62 t/ha (SL 93-3) and in 2000 varied from 5.63 t/ha (9005439) to 26.08 t/ha (SL 93-3). It should be noted that in 1999 and 2000 the same varieties gave the highest and the lowest dry matter yields.

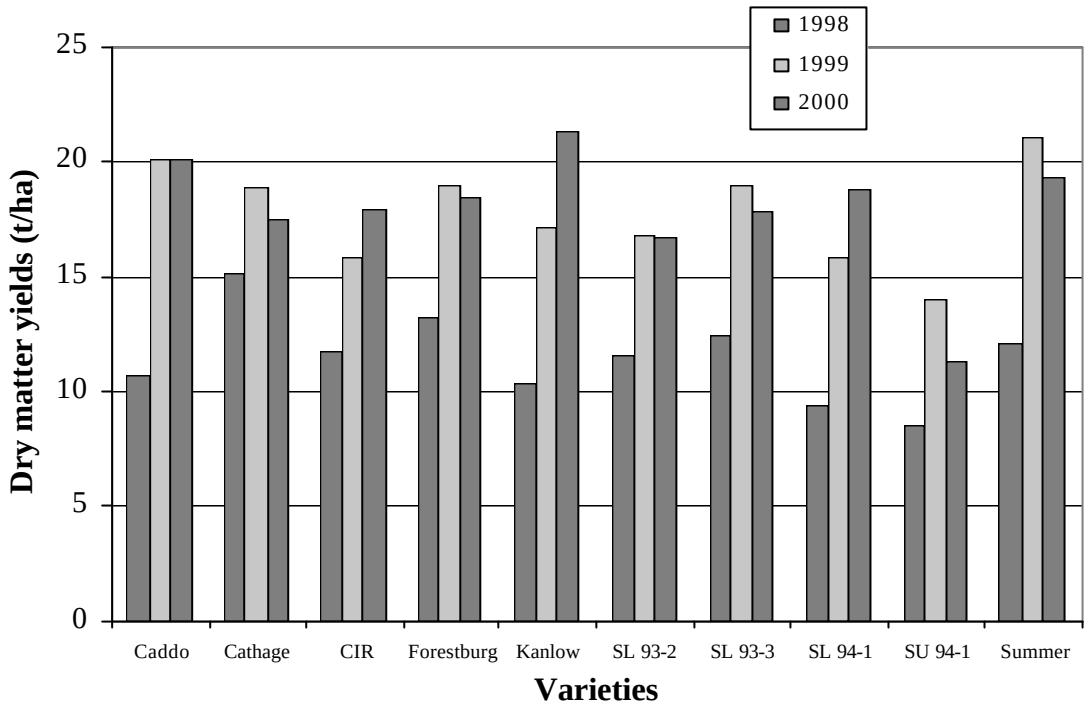

Figure 1. Dry matter yields (t/ha) for the tested varieties in Greece (1998, 1999 and 2000).

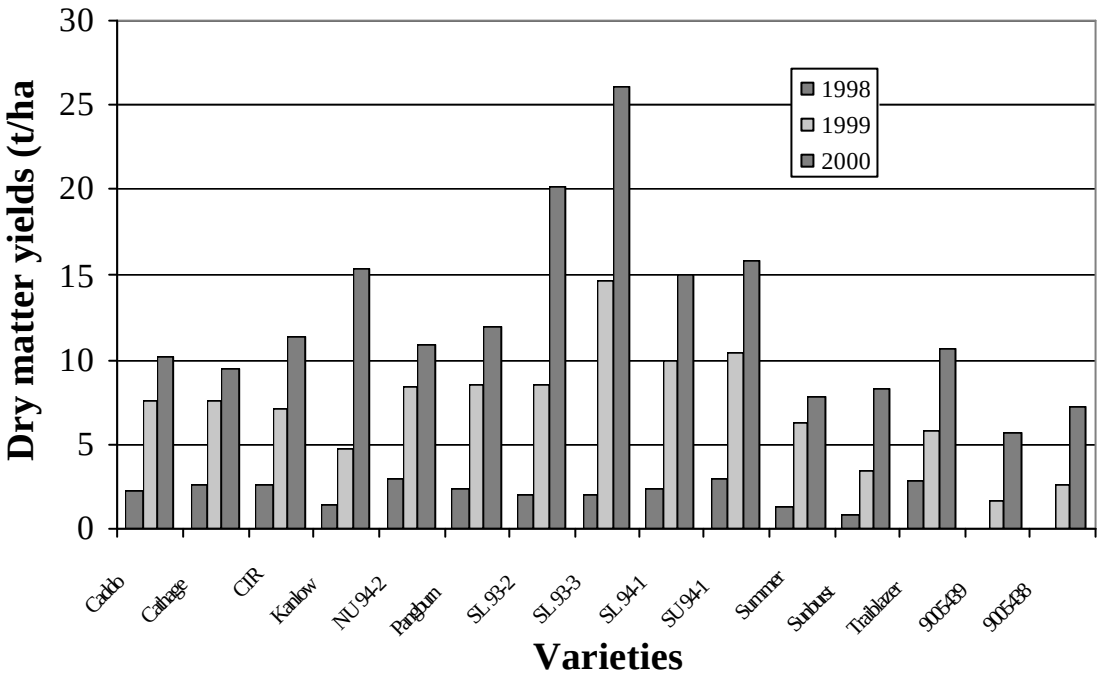

Figure 2. Dry matter yields (t/ha) for the tested varieties in Italy (1998, 1999 and 2000).

Productivity Trials

Plant height

At the end of each growing seasons the canopy height in the Italian productivity trial varied from 50 cm (Forestburg N_2 and N_3) to 105 cm (Alamo N_1 and N_2), 103 cm (Forestburg N_3) to 187 cm (Alamo N_3, Kanlow N_2 and N_3) and from 110 cm (Forestburg N_3) to 200 (Alamo N_2 and Kanlow N_2) in the first, second and third years, respectively. The corresponding values in the Greek trial ranged from 142 cm (CIR) to 179 cm

(Kanlow), 157 cm (CIR N_1) to 210 cm (Kanlow N_3) and 143 cm (Blackwell N_1) to 213 cm. (Pangburn N_3) in the first, second and the third years, respectively.

In the first year the plant height in the Greek trial was higher as compared to the Italian trial. This was due to the earlier sowing in Greece that all varieties had the opportunity to develop the stems higher as compared to the Italian trial where the sowing was delayed for about two months. However, in the second year the plant height increased in both sites (87% in Italy and 228% in Greece). But in the third year it continued to increase in Italy (11%), while in Greece it was decreased to 5%. However, the mean height in Greece was always a little higher (168 cm) than in Italy (163 cm). It is worth mentioning here that the height of switchgrass plants tends to get stabilized from the third year of its cultivation.

Number of tillers per square meter and tillers per plant

In both sites and all the treatments, the number of tillers per square meter and tillers per plant was increased from the establishment to the second growing season. However, in the third year the increase continued in most of the treatments in case of the Italian trial. At the end of the third growing season the number of tillers per square meter in Italy ranged from 734 (CIR N_2) to 1901 (CIR N_1), while the corresponding data in Greece fluctuated from 780 (Pangburn N_1) to 2534 (Blackwell N_3). Regarding the number of tillers per plant (in the year 2000), the mean value in Greece trial was higher (17) as compared to the Italian Trial (15).

Yields

The dry matter yields in both sites for all the tested varieties increased from the establishment to the second growing season. The average increase in Italy was come up to 224%, while in Greece it was 121%. In the third growing season the dry matter yields continued to increase in Italy (28%), while in Greece it was decreased to 22% averaged overall varieties. The percentage increase in dry matter yield in Italy was 8 times more from the first to the second year than from the second to the third year of the trial. Moreover, the range among the tested varieties in terms of dry matter yields in each year was comparatively large in the Italian trial, as is shown in Table 5. In the establishment year it ranged from 0.64 t/ha (Forestburg N_1) to 5.33 t/ha (Alamo N_3), in the second year from 4.09 t/ha (Forestburg N_3) to 16.11 t/ha (Alamo N_2), while in the third year from 6.36 t/ha (Forestburg N_1) to 18.67 t/ha (Alamo N_2) (Figure 3). It should be noted that in all the growing years the same varieties gave the lowest and the highest dry matter yields.

In the Greek trial the range of the dry matter yields among the tested varieties was comparatively less (Table 4). In the first year it ranged from 6.8t/ha (CIR) to 12.3 t/ha (Alamo), in the second year from 11 t/ha (CIR N_1) to 25 t/ha (Pangburn N_3), while in the third year from 11.4 t/ha (CIR N_1) to 18.1 t/ha (Pangburn N_3) (Figure 4). The most productive variety in the third growing season was the genotype Alamo in Italy and Pangburn in Greece. As regards the less productive one among the tested varieties, it was Forestburg (6.6 t/ha) in Italy and Kanlow (14.3 t/ha) in Greece.

Table 4: Growth characteristics (plant height, number of tillers/m2, number of tillers per plant) and dry matter yields (t/ha) in Greece (Greece) in 1998, 1999 and 2000.

Varieties	Final canopy height (cm)			Number of tillers/m^2			Number of tiller/plant			Dry matter yields (t/ha)		
	1st	*2nd*	*3rd*	*1st*	*2nd*	*3rd*	*1st*	*2nd*	*3rd*	*1st*	*2nd*	*3rd*
Alamo	160.5	192.2	164.4	922	1190	1068	10.0	14.7	16.0	12.27	23.64	15.96
Blackwell	145.5	170.0	148.9	1016	1707	2252	11.4	14.2	20.3	8.22	19.00	15.14
CIR	142.2	166.7	155.5	1001	1374	1546	9.9	14.2	17.0	6.77	14.87	14.33
Kanlow	175.1	201.1	186.7	786	937	920	9.5	10.5	15.0	8.71	20.91	16.87
Pangburn	178.8	206.7	182.2	878	1002	1019	9.1	11.9	16.0	8.81	21.55	15.08
0 kg N/ha	-	191.7	160.7	-	-	1280	-	-	15.2	-	19.46	13.88
75 kg N/ha	-	187.3	164.7	-	-	1271	-	-	17.2	-	19.02	15.52
150 kg N/ha	-	183.0	177.3	-	-	1530	-	-	18.2	-	21.52	17.03
Mean	160.4	187.3	167.5	880	1242	1360	9.9	10.3	16.9	8.95	19.99	15.48

Table 5: Growth characteristics (plant height, number of tillers/m², number of tillers per plant) and dry matter yields (t/ha) in Trisaia (Italy) in 1998, 1999 and 2000.

Varieties	Final canopy height (cm)			Number of tillers/m²			Number of tiller/plant			Dry matter yields (t/ha)		
	1st	*2nd*	*3rd*	*1st*	*2nd*	*3rd*	*1st*	*2nd*	*3rd*	*1st*	*2nd*	*3rd*
Alamo	100.3	179.0	190.0	-	1472	1179	-	10.1	12.3	4.83	15.46	17.96
Blackwell	78.3	122.0	136.7	-	765	1423	-	7.6	14.7	2.61	7.75	8.86
CIR	74.3	124.6	163.3	-	1005	1245	-	7.5	12.3	2.03	6.13	8.52
Forestburg	60.0	112.3	140.0	-	960	1467	-	11.5	26.7	0.64	4.59	6.63
Kanlow	82.7	182.3	186.7	-	765	1134	-	9.7	14.7	1.49	7.86	11.69
0 kg N/ha	-	148.4	174.0	-	1185	1387	-	11.4	13.8	-	8.16	9.95
75 kg N/ha	-	145.6	168.0	-	904	1201	-	11.6	15.2	-	8.96	11.16
150 kg N/ha	-	146.8	148.0	-	891	1281	-	9.6	17.4	-	7.96	11.09
Mean	79.1	146.9	163.3	-	993	1289	-	10.9	15.5	2.32	8.36	10.73

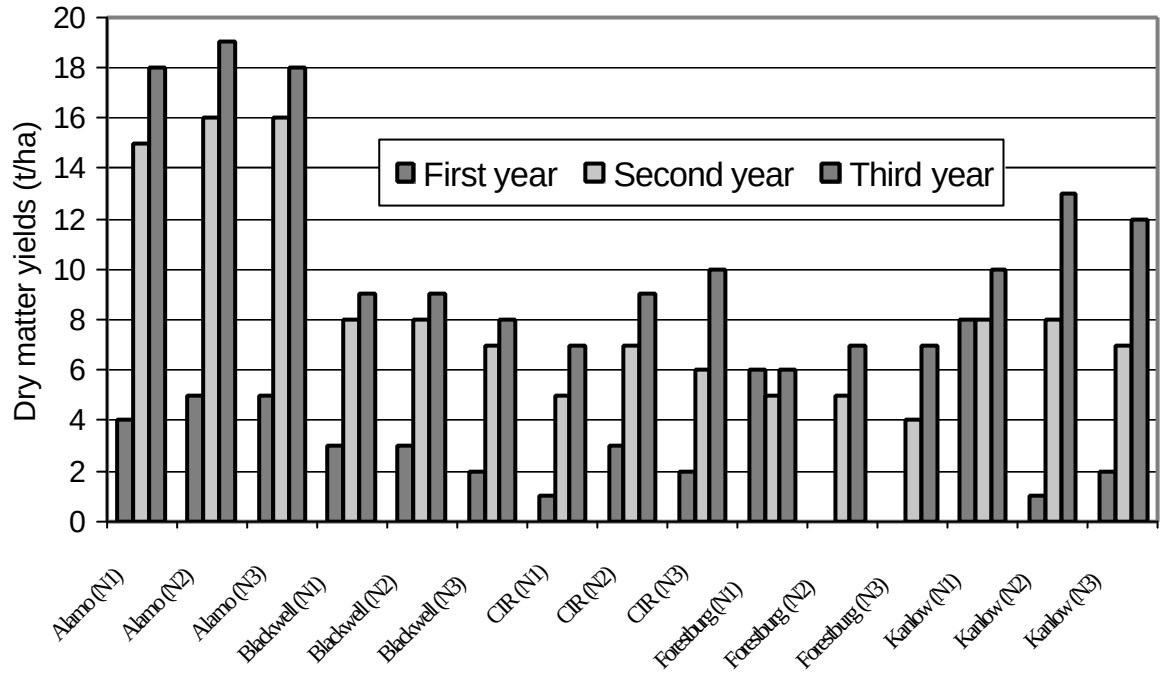

Figure 3. Dry matter yields (t/ha) for the period 1998-2000 in Trisaia (Italy).

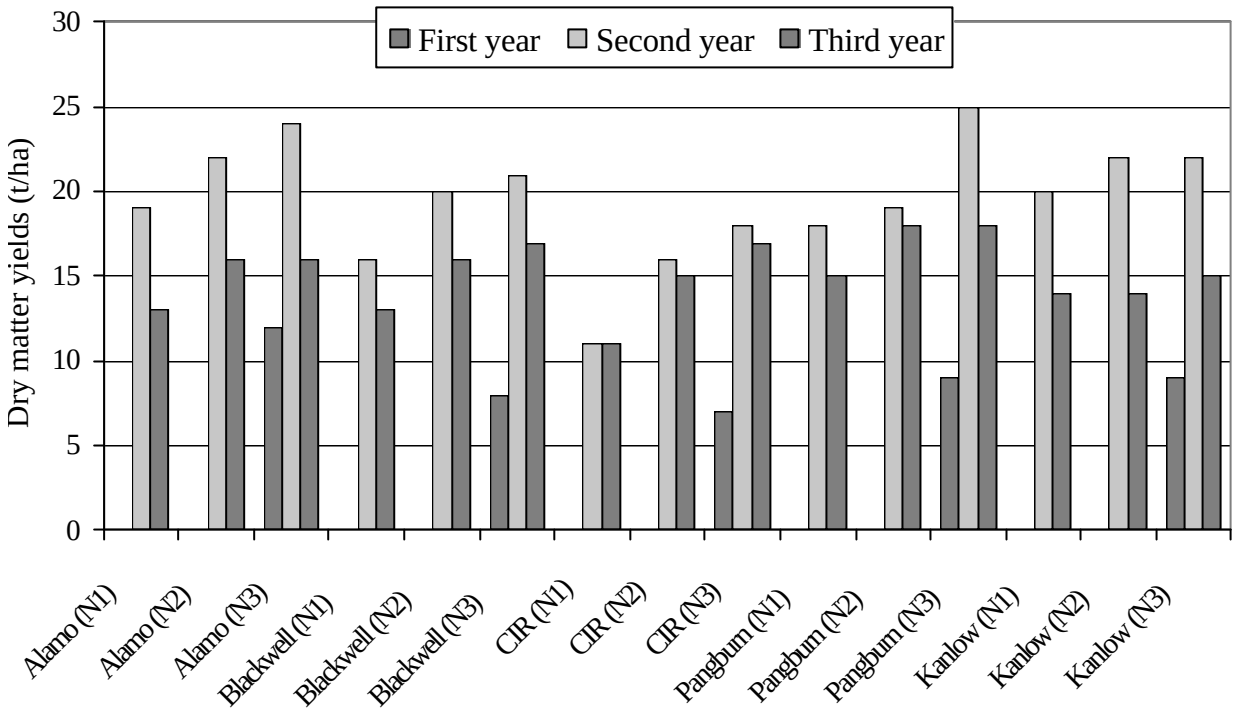

Figure 4. Dry matter yields (t/ha) for the period 1998-2000 in Aliartos (Greece).

3.5 Conclusions

Nursery trials

The adaptability and biomass productivity for the varieties was quite good in both Mediterranean countries. The only exception to that were two varieties that were cultivated in Italy (9005439 and 9005438). The establishment for these varieties was not very good and so at the establishment year the biomass productivity was quite low and for this reason they did not harvested. Their productivity improved in the following two years (1999 and 2000) but still continued to be the varieties with the smallest productivity among the tested varieties in Italy.

Comparison of the yields between the two countries showed that the most of the common tested varieties yielded higher in Greece than Italy.

It should be pointed out that in Italy the yields continued to increase until the third growing season, while in Greece the yields had been stabilised from the second growing season.

It was also noticed that peak values for dry matter yields were recorded from different varieties in each country.

Productivity trials

The establishment, a key factor for switchgrass cultivation, was quite successful in all the trials at both sites.

The weeds were a problem only during the initial stages of the first year of the experiment. Soon after the plants were able to compete with the weeds.

Regarding the effect of different nitrogen fertilisation rates, no any significant effect on fresh and dry matter yield was observed. Only in the case of the Greek trial statistically significant (LSD Test, $P<0.05$) higher yields were recorded under higher nitrogen rates during the third growing season.

Concerning the productivity, the variety Alamo in Italy and Pangburn in Greece were the most productive ones in terms of fresh and dry matter yields. On the other hand, the lowest yields in Italy were recorded in all years by the variety Forestburg, while in Greece were recorded by the variety CIR.

3.6 References

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