

BIOMASS AND FIBER PRODUCTION OF SPANISH CULTIVARS OF HEMP IN THE HUMID COOL AREAS OF SOUTHERN PYRENEES

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Abstract

The objectives of this research was to study the potential of the most recent hemp varieties released in Spain ('Delta-Llosa' and 'Delta-405'), in southern Pyrenees area (cool winter and humid). In 1998, both Spanish varieties and 'Futura 77' (check, from France) were compared at three seeding rates (30, 60 and 20 kg ha⁻¹), four N fertilizer rates (0, 50, 100 and 200 kg ha⁻¹) and harvested at two physiological stages (flowering & seed ripeness). Some results are different than those obtained in a normal season because of the severe drought in 1998 growing season. N fertilization significantly increased total biomass dry matter (AGDM) and stem dry matter yield (STDM). The highest STDM (5324 kg ha⁻¹) was obtained with 100 kg N ha⁻¹, whereas grain production (GDM) increased till 200 kg N ha⁻¹ (549 kg ha⁻¹) and with low seeding rates. AGDM and STDM yield increased with higher seeding rates (in opposition of results obtained in previous trials), just as bark content in stem. Spanish varieties produced higher GDM than Futura, but no significant differences were found in the other parameters, suggesting that, in this area, the Spanish varieties can be adequate for grain as well as for fibre production.

Key words: fibre hemp, grain yield, nitrogen fertilization, seeding rate, varieties

Introduction

Hemp has been grown in Spain, for pulp manufacturing, since 1972. This crop, considered a renewable and friendly resource of industrial products, has been expanding in some cool winter and humid areas of the southern Pyrenees (north-eastern Spain), because of its good adaptation to the conditions and cropping systems of this area (708 mm average rainfall; 400 to 900 m over sea level) (Gorchs & Lloveras, 1998).

Monoecious French varieties, mainly Futura 77, but also Felina or Fibrimon have been used and their fiber and seed yield potential is already known. However there is very little information of the two varieties (Delta Llosa and Delta 405) bred in Spain by CELESA S.L. (a hemp pulp manufacturer), which are supposed to be well adapted. Although the varieties were registered in 1985, and some seed was produced (Meijer, 1995), it was not until 1997 that they were largely released to the market. In

1999, about 46% of 1600 ha in southern Pyrenees have been sown with Delta 405 (604 ha) and with Delta Llosa (100 ha). Both varieties are monoecious and eligible for the EU subsidies for fibre crops. These Spanish varieties should be of longer cycle than Futura 77 and can produce higher grain yields, in spite that they were bred for fibre production (Castells, pers. comm.). The objective of this report is to present the initial results of these promising most recent Spanish varieties in comparison with the commonly used variety (Futura77), at the same time than studying the production potential of the area.

Materials and methods

A field experiment was seeded on April 20, 1998 at Merlès (110 km North of Barcelona, Spain; 42° N, 1° 99'E), in a loamy and basic soil: pH, 8.5 and 1.5% organic matter. Four nitrogen fertilizer treatments (0, 50, 100 and 200 kg ha⁻¹) and three seeding rates (30, 60 and 120 kg ha⁻¹) were compared, with three varieties of hemp, Delta-405 and Delta-Llosa, from Spain and Futura 77, used as a check. The experimental design was a split plot with four replications, with nitrogen rates as main plots and the factorial combination of seeding rates and varieties as subplots. Hemp production was measured at two growing stages, end of flowering and seed ripeness, on August 7 and September 19, respectively. The subplot size was 10 m long by 1.2 m wide, and the harvested area of 1.5 x 1 m at the centre of the plot.

Yield and yield components (AGDM, STDM, leaves, inflorescences and GDM), plant height and stem diameter were determined at each harvest date. The proportion of bark, bark fibre and non-fibrous bark in stem were determined at first harvest (flowering). Quality parameters were evaluated in a sample of 20 air dried plants. The plants were defoliated and separated into bark and woody core by means of a motor driven device consisting of 1 pair of smooth cylinders and two pairs geared cylinders. To achieve a good separation, the stems were processed seven times. The remaining wood was removed by hand and the bark was boiled for 2 h in a 2% NaOH (Meijer *et al.*). The production of bark (kg ha⁻¹) was calculated, by multiplying the AGDM yield by the ratio of stem over AGDM and by the proportion of bark on the stem.

The 1998 growing season, was warmer than average (Table 1) and precipitation was much lower (383 mm compared with the average of 707 mm or with the 995 mm of 1996). Furthermore, a severe drought occurred from mid June to early August (only 81 mm of precipitation from sowing to first harvest or 156 mm from January to first harvest).

Table 1. Average of monthly mean air temperature (0 °C) and rainfall (mm) and deviation from the long-term average (1941-1980) in 1998, at Merlès.

	April	May	June	July	August	September	Year
Mean air temperature	8.1	12.8	17.3	20.5	20.3	17.4	10.8
1998	+1.1	+1.8	+2.2	+2.2	+1.2	+0.9	+1.2
Mean rainfall	59.6	90.8	84.3	57.7	74.2	82.4	707.6
1998	-7.8	-42.8	-63.9	-52.5	9.8	-53.6	-324.3

Results

The effect of nitrogen fertilization rates on plant density, plant height and stem diameter are presented in Figure 1a and 1b, whereas AGDM, STDM and GDM yields at the two harvest dates are presented in Table 2. Quality parameters (bark, bark fibre and non-fibrous bark proportion in STDM) are presented in figures 2 and 3, whereas the proportion of remaining wood in bark after mechanically separating stems into bark and core is presented in figure 4.

Plant morphology

Plant height and stem diameter decreased significantly with increasing seeding rates (Figure 1b), as in previous results from the same area of Southern Pyrenees (Gorchs and Lloveras, 1998). Although plant density was higher in 1998 (130 pl m⁻² on average at flowering) than in precedent years, self-thinning was lower. Possibly, because the lack of rainfall reduced the crop growth and the competition for light, supporting that maximum plant density is a function of yield level (Werf *et al.*, 1995). On the other hand, increasing rates of nitrogen fertilization increased stem diameter and plant height, only up to 100 kg N ha⁻¹ (Figure 1a), opposite to the results of precedent years (Gorchs & Lloveras, 1998), but in agreement with the results obtained by Werf *et al.* (1995).

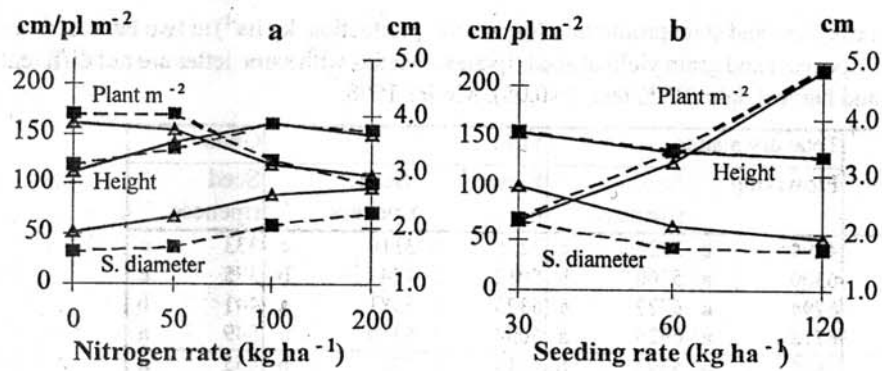


Figure 1. Plant density, plant height and stem diameter as influenced by harvest date (Δ Flowering; \blacksquare Seed ripeness) and: a) nitrogen fertilization; b) by seeding rate and). Merlès 1998.

Yield and yield components

AGDM, STDM and GDM yields increased with increasing nitrogen fertilization rates (Table 2). At flowering, the highest yields of the AGDM and STDM were obtained with 100 kg N ha⁻¹, although they were not statistically different than with 50 kg N ha⁻¹, in opposition with our previous results or other results from Werf (1994) or Venturi & Amaducci (1997). At seed ripeness, STDM yield was also higher with 100 kg N ha⁻¹, but GDM yield increased significantly up to 200 kg N ha⁻¹. However, the STDM production at 200 kg ha⁻¹ N tends to decrease less at seed ripeness than at flowering. Possibly, growth was resumed better at high N rates because they could take better advantage of the precipitation during August.

In 1998 AGDM and STDM yields increased significantly with seeding rate, in contradiction with the results of the three previous years (Gorchs and Lloveras, 1998) and with data reported by Ranalli (1999). The drought that occurred during the middle of the growing season could explain the differences. In this year, because of the lack of rainfall, the growth was reduced during the initial stage (and the self-thinning), and in these conditions, high seeding rates had a positive effect on crop biomass and stem production (Werf et al., 1995).

Table 2. Hemp biomass yield and stem production (dry matter production, kg ha⁻¹) at two harvest dates (flowering and seed ripeness) and grain yield at seed ripeness. Means with same letter are not different for each treatment and harvest date (SNK test, P<0.05). Merlès 1998.

Harvest date		Total dry matter		Stem		Grain			
		Flowering	Seed ripeness	Floweri g	Seed ripeness	Seed ripeness			
Nitrogen Rate ¹⁹ (kg ha ⁻¹)	0	4194	b 3925	c	3225	b 3110	c	333	c
	50	6300	a 5760	b	5012	a 4747	b	375	c
	100	6794	a 6727	a	5323	a 5381	a	441	b
	200	6718	a 6926	a	5094	a 5310	a	549	a
Seeding rate (kg ha ⁻¹)	30	5855	a 5398	b	4419	b 4261	b	455	a
	60	5963	a 5965	a	4651	b 4813	a	404	a
	120	6272	a 6238	a	4994	a 4858	a	412	a
Cultivar	Futura	6132	a 5682	a	4847	a 4659	a	366	c
	Delta 405	5947	a 5942	a	4576	a 4669	a	485	a
	Delta Llosa	6001	a 5964	a	4625	a 4562	a	423	b
Mean		6027	5861		4684	4633		424	
C.V.		16.49	15.80		16.78	16.52		31.34	

1) For all interactions P>0.05, except for GDM, were: N*Sr, P=0.002; Sr*Cultivar, P=0.015

At flowering, the proportion of stem in the AGDM increased significantly with seeding rate by 5% and decreased significantly when applying more than 50 kg N ha⁻¹ (Figure 2a) Comparing the proportions of stem of the hemp varieties, the maximum differences among them (8%) were observed at the rate of 120 kg ha⁻¹ of seed (Figure 2b). Bark yields showed similar behaviour than STDGM, increasing with seeding rate, with highest yields at 120 kg ha⁻¹ of seed. Possibly, the low rate of self-thinning that occurred during the growing season might have had some role.

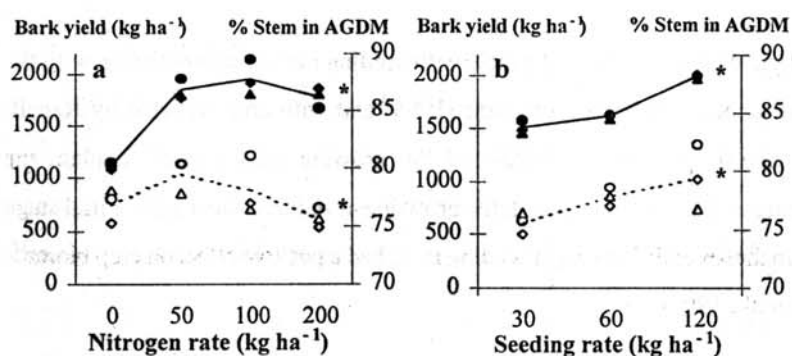


Figure 2. Proportion of stem in AGDM (—, open symbols) and bark dry matter yield (---, black symbols) at flowering as influenced by: a) N fertilization; b) seeding rate for all cultivars (○ Futura 77; △ Delta-405; ◇ Delta-Llosa). Merlès 1998. *: significant effect of treatment p<0.05.

Grain production was higher at low seeding rates (30 kg ha⁻¹ of seed), in agreement with previous results (Gorchs & Lloveras, 1998) and with other authors (Bócsa & Karus, 1998). Opposite to the supposed GDM potential in Southern Pyrenees (Stutterheim *et al.*, 1999), the seed yields in 1988 were low (half the average seed yields of the area), probably because of the drought and in opposition of previous reports.

Delta-405 and Delta-Llosa produced higher seed yields than the traditionally cultivated French variety, Futura 77 (Table 2). No significant differences among varieties were found for AGDM, STDM at both harvests or for bark yield at flowering (Figure 2). However, at seed ripeness, Futura77 produced lower dry matter yields (and the opposite at flowering) and the crop had a higher percentage of dry matter than the Spanish varieties, suggesting a shorter growing cycle in agreement with the information given by the seed company (Castells, pers. comm., 1999). Further research focused on the dynamic of flowering is needed to confirm this.

Fibre content

Proportion of bark and of non-fibrous bark relative to stem, increased significantly with seeding rate by 10% and 27%, respectively, which implies a shorter increase on the proportion of bark fibre in stem (5%) (Figure 3b). Although the N fertilization did not affect bark and bark fibre content significantly, they slightly decreased with nitrogen rates over 50 kg ha⁻¹ because of the increased proportion of non-fibrous bark (6%), in agreement with previous reports showing that N fertilization decreases hemp fiber proportion or hemp quality (Werf *et al.*, 1995; Venturi & Amaducci, 1997). Even after passing the stems through the device used to separate stems into bark and core, a considerable amount of wood remained stuck in the bark (11% on average). The remaining wood (core) fraction in bark decreased significantly with N fertilization (35%) and increased significantly with seeding rate (Figure 4). The proportion of this remaining wood was higher for Futura 77 than for Spanish varieties, suggesting that the longer growing season of these varieties can have a role.

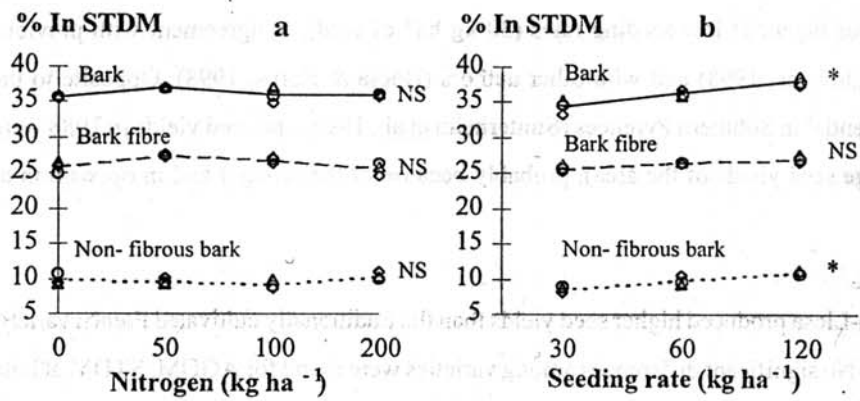


Figure 3. Proportion of bark, bark fibre and non-fibrous bark in stem dry matter at flowering as influenced by: a) N fertilization; b) seeding rate for all cultivars (○ Futura 77; △ Delta-405; ◇ Delta-Llosa). Merlès 1998. NS: $p > 0.05$, *: significant effect of treatment $p < 0.05$.

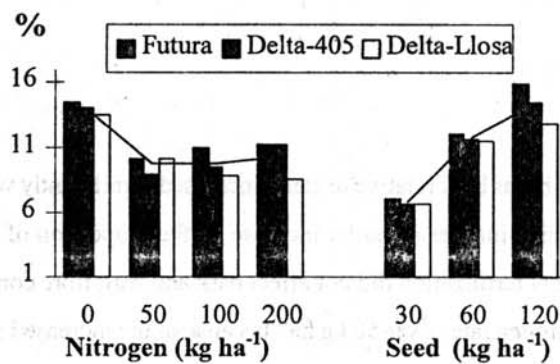


Figure 4. Proportion of remaining woody core in bark (% bark dry matter) at flowering after the separation of stems into bark and core. Merlès 1998.

Conclusions

N fertilization increased AGDM, STDM and bark yields, although rates of nitrogen fertilizer over 50 kg ha⁻¹ decreased the proportion of stem in AGDM and bark fibre content in STDM. Rates of nitrogen between 50 to 100 kg ha⁻¹ seem to be the most appropriate when hemp is grown only for fibre. The results suggest that N rates over 100 kg ha⁻¹ should be applied when hemp is grown for seed and fibre.

Seeding rates of about 30 kg ha⁻¹, seems the most adequate for seed production. However higher seed rates appears to be more adequate for fibre production because of its higher quality. The most suitable seed rate depends on the destination of the hemp production (seed or seed and fibre) and the relative prices of these products

The present results, considered as preliminary, suggest that, in the Southern Pyrenean area, the Spanish cultivars of hemp can be adequate for grain production while still giving good fiber yields. Further research is needed to find the most appropriate varieties.

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