WFL Publisher
Science and Technology

Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
e-mail: info@world-food.net

Journal of Food, Agriculture & Environment Vol.7 (2) : - . 2009

www.world-food.net

Genotype and planting date effects on cotton growth and production under south Portugal conditions
III. Boll set percentage, boll location, yield and lint quality

Gonçalo Barradas [1]* and Rafael J. López-Bellido [2]

[1] *Elvas Agricultural School, Polytechnic Institute of Portalegre, 7350 Elvas, Portugal.* [2] ~~*Departamento de Ciencias Agroforestales, University of Huelva, Campus de La Rábida, 21819 Palos de la Frontera, Huelva,*~~ *Spain.*
**e-mail:gbarradas@esaelvas.pt, rafael.lopez@dcaf.uhu.es*

Received 12 January 2009, accepted 2 April 2009.

Abstract

Assimilate diversion of vegetative growth, reinforced by inadequate temperatures to growth and maturation of bolls later set in season, resulted in poor harvest indexes and low retention, mainly at the first fruit positions and on lower fruiting branches. Significant differences of seed-cotton production between genotypes were observed, and higher values were attained by variety Celia, presenting more short season characters. The delaying of the planting date, while allowing better emergence and initial growth of the plants, shorten the available growing season and has a negative impact on seed cotton production. Thus, in Caia region, short season cultivars and early planting dates are best suited to cotton production, also being important to achieve high boll retention in the first positions and fruiting branches, in order to approach the boll growth and maturing period with more favourable environmental conditions. Fiber color grading shows no significant differences between varieties and planting dates, although differences were found in some of the commercial and technological quality measurements.

Key words: *Gossypium hirsutum,* boll retention, fiber yield, fiber quality.

Introduction

Cotton (*Gossypium hirsutum* L.) crops produce many more fruiting sites than mature bolls [1]. Many plants within a population, regardless of the cultivars, did not have a boll to mature at a given fruiting site [2]. Work involving different leaf-type cultivars and plant densities has shown differences between genotypes in retention per fruit position and in the fruiting form in which abscission occur [1]. In general, only the first two or three fruiting positions (FP) in each sympodia are relevant to fiber yield, and high–yielding canopies are, in general, associated with high ratios between the number of FP1 and FP2 bolls to the number of FP1 and FP2 sites, i.e. with high retention rates at FP1 and FP2 [3]. Of the overall upland cotton lint yield 66 to 75% is assured by FP1, 18 to 21% by FP2, and only 3 to 9% by FP>2 plus monopodial branches [4]. The average standards for 'Acala SJ2' in California, USA, are of 47% at FP1, 24% at FP2, 9% at FP3 and 20% the sum of the monopodia contribution [5].

Normal and late-planted cotton often differ in fiber properties, especially in those properties related to fiber secondary wall characteristics [6]. The use of short growing season cultivars can negatively influence fiber quality [7].

In some Mediterranean regions low temperature and somewhat typical rainfalls late in season are major constrains for boll period duration, boll maturation and lint quality [8, 9]. The use of plastic film to permit earlier plantings plays a major role in the Spanish cotton belt [10] and was quite frequent in the past in Greece, but is becoming less popular mainly due to high cost [11] and negative environmental impact [12].

In the USA [13] and in the EU [12] cotton growers are faced with rising production costs and declining returns for their commodity so searching cultural practices and alternative methods to optimize profit are needed.

The purpose of this experiment was to characterize the combined effects of plant genotype and planting date on fruiting pattern, yield and fiber quality of upland cotton sown at Alentejo region, Portugal, using neither plastic cover nor growth plant regulation.

Material and Methods

Cultural details: Experiments were established in 2002 and 2003 to compare final boll retention, yield and lint quality on five normal-leaf ('Carmen', 'Celia', 'Crema', 'Flora' and 'Sonia') and one okra-leaf type ('Lacta') genotypes planted at three planting dates (19 and 30 April and 13 May in 2002, and 20 March, 3 and 17 April in 2003). 'Celia' is classed as early-medium, 'Crema', 'Flora' and 'Lacta' as medium and 'Carmen' and 'Sonia' as medium-late growing season durations. Plots were located at the Comenda Experimental Center, Caia, Alentejo, Portugal (38°54'N, 7°03'W, 169 m altitude), on a sandy Xerofluvent, Fluvent, Entisol.

Sowing was hand made at 5 cm deep and 1 m row-width (18 seeds m^{-2}). Due to delayed emergence, insect pressures and natural plant mortality, averaged genotype and planting dates stand counts at crop maturity reach only 9.5 plants m^{-2}.

Fertilizer was applied broadcast at a rate of 45 kg ha^{-1} N:P:K prior to planting and additional 180 kg ha^{-1} N at first square. Weeds were controlled with trifluralin (48% w/v), benfuresate (40% w/v) and fluometuron (50% w/v) preplant application, and by hand in row and mechanical between row weeding along de growing season.

Soil water content was monitored with watermark soil moisture sensors and loggers (Spectrum Technologies, Inc.) and maintained in adequate available water thresholds to plant growth using drip irrigation. Crop evapotranspiration (ETc), determined by Penman method and adjusted with the cotton crop coefficients[14], was 795 and 767 mm, in 2002 and 2003, respectively, entirely compensated by irrigation. Temperature and relative humidity data were recorded using data loggers (Spectrum Technologies, Inc.) at the experimental site, whilst rainfall data was taken from Centro Operativo e de Tecnologia do Regadio, located near the experimental site (38°55'N, 7°06'W, 202 m altitude).

Insect infestations were controlled as needed with dimethoate (40% w/v), endosulfan (38% w/v), lambda-cyhalothrin (20% w/v) or metomil (20%) w/v) sprays. In spite those insect controls, in both years important damages on squares and bolls were observed due to rough bollworm (*Earias* spp.) and cotton bollworm (*Heliothis* spp.) (Lepidoptera: Noctuidae). In 2003 *Aphis* spp. (Hemiptera: Aphididae) damages were also noted.

Crop termination was achieved with harvest-aid chemical applications to promote plant defoliation and boll opening. Defoliant herbicide thidiazuron (50% w/w) and boll opener ethephon (48% w/v) were used both years.

Once late in season poor weather conditions are a main constrain of cotton maturation and harvest in this region, relative humidity and rainfall data were taken from an automatic station belonging to the Operative Center of Irrigation Technology (38°55'N, 7°06'W, 202 m altitude) in order to explore possible cause-effect relationships between those climate parameters and lint quality results (Fig. 1).

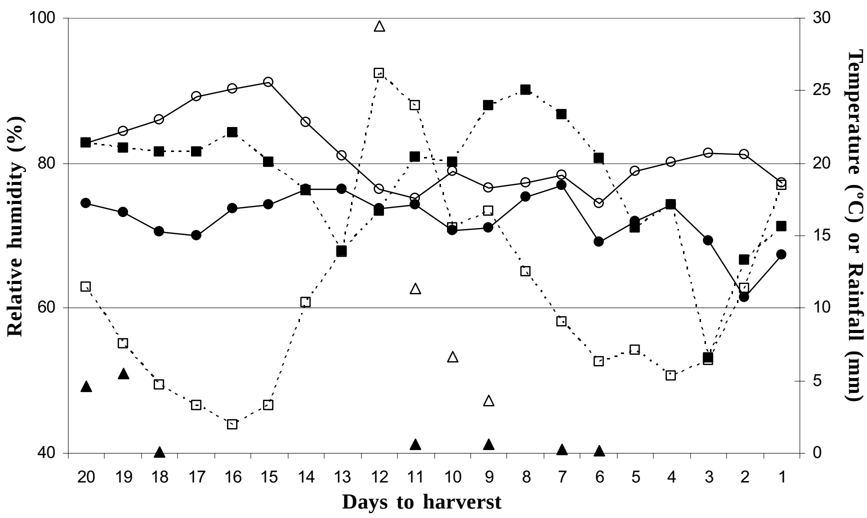

Figure 1. Registered temperature (circles, ºC), relative humidity (squares, %) and rainfall (triangles, mm) 20 days before harvest in 2002 (full symbols) and 2003 (open symbols).

Measurements: A completely randomized design was used, with three replications in plots of 5 x 4 m. One final harvest was made comprising all plants enclosed on the three central rows in each plot (15 m^2), on 9 November 2002 and on 11 October 2003. In all collected plants harvestable boll distribution patterns were determined by documenting boll set by main-stem node number and position in each fruiting branch. Distribution percentages were calculated by dividing the number of harvestable bolls at a given position by the total number of harvestable bolls and multiplying by 100. Main-stem node numbers were grouped as 1 to 5, 6 to 10 and higher than 10 [15]. Boll locations were grouped as first position on a sympodial branch (FP1), second position on a sympodial branch (FP2) and third or greater position on sympodial branch (FP>2). The few bolls from monopodia were determined to be FP1, FP2 or FP>2 and combined with those groups in the main-stem lower node group. Total harvested seed-cotton was weighed for yield accountancy per unit ground area.

After these procedure three seed-cotton samples per each genotype and planting date were taken for water content, lint percentage (fiber weight per 100 g seed-cotton) and fiber index (fiber weight per 100 seeds) determinations. Seed-cotton was ginned in a laboratory saw gin unit 'Platt Saco Lowell' (Platt Saco Loweel Ltd., Accrington, Lancashire, UK).

Lint quality was determined subjecting 50 g fiber samples to high volume instrument (HVI) testing at the Technological Centre for the Textile and Clothing Industries of Portugal (Vila Nova de Famalicão, Portugal). Fiber characteristics reported include micronaire, maturation, length, uniformity index, short fiber index, strength, elongation, reflectance, yellowness and C-grade.

Data analysis: ANOVA's were used for genotypes, planting dates and years analysis, and means were separated using the Tukey test at a significance level of 5%. For C-grade lint classification Qui-square tests were applied. All data analysis was performed using SPSS for Windows standard version 9.0.

Results

Boll set percentage and boll location:

Significant differences were accounted between genotypes and planting dates on the percentage distribution of total cotton bolls by grouped sympodial nodes (Table 1). Under a vertical standpoint, the lower one-third of the plants produced 45 ('Crema') to 53% ('Celia') and the middle one-third produced 35 ('Celia') to 44% ('Carmen') of total bolls. Those two plant horizons were responsible for 85 ('Crema') to 93% ('Carmen') of total bolls. Planting delay results in higher sum of lower and middle one-third sympodia contribution to total bolls, reaching 90-91% in the late and 87% in the early planting. No year-to-year differences were accounted, with both years averaged contributions of 50, 39 and 11% of each vertical plant horizon to total bolls.

Also significant differences were accounted between genotypes, planting dates and years on the percentage distribution of total cotton bolls by FP (Table 1). FP1 were responsible for 47.6 (‘Lacta’) to 59.9% (‘Flora’), FP2 from 23.8 (‘Flora’) to 34.0% (‘Sonia’) and FP>2 from 15.5 (‘Crema’) to 20.9% (‘Lacta’). Planting date delay had a general negative impact on FP1 contribution to total cotton bolls, reduction more markedly observed in sympodia ≥ 6. The contribution of FP2 bolls decreased with planting delay in the lower one-third of the plants and increased in the middle one-third. No differences were accounted in the uppermost one-third FP2 contribution. In both lower and middle one-thirds FP1 and FP2 contributions to total cotton bolls were higher in the first experimental year whilst the reverse ensue with FP>2 contribution.

From the first to the tenth sympodial branch FP1 contribution was very regular (22-23%) decreasing deeply thereafter to the top of the plant (7.1%). In contrary, averaged FP2 and FP>2 contributions decreased continuously with up warding plants horizons. In FP2 from 17 to 11 and 2% and in FP>2 from 7 to 4 and 2%, in the lower, middle and uppermost one-third, respectively.

Significant differences were observed between genotypes, planting dates and years in the percentage of fruiting sites that matured bolls (Table 2). The lower one-third of the plant retained 26 (‘Carmen’) to 34% (‘Celia’) and the middle one-third retained 21 (‘Flora’ and ‘Sonia’) to 24% (‘Carmen’) bolls for the averaged fruiting sites. In the uppermost one-third of the plants boll retention rate of was much lower, ranging from 4 (‘Carmen’) to 8% (‘Crema’). Planting delay resulted in a boll retention rate increase, averaged over FP1 to FP>2, changing from 27 to 30% in the lower one-third and from 19 to 23% in the middle one-third of the plants. In the uppermost one-third the medium and late-season plantings equal 5.5% whilst the early planting plants attained a retention rate of 7.0%. Higher retention rates were achieved in the second year for all studied plant horizons.

Also significant differences were accounted between genotypes, planting dates and years on the retentions rates by FP (Table 2). FP1 sites retained 24.9 (‘Lacta’) to 32.1% (‘Flora’), FP2 from 13.3 (‘Flora’) to 19.5% (‘Celia’) and FP>2 from 8.0 (‘Sonia’) to 12.4% (‘Celia’). Planting delay resulted in lower FP1 retention rates, with 30.1% in early-season and 27.5% in late-season sowings, whereas FP2 (16.4 versus 18.2%) and FP>2 (6.7 versus 13.0%) retention rates increased in that order. Higher FP1 retention rates were achieved in the first experiment year whilst the highest FP2 and FP>2 retentions were obtained in the second year, particularly on the most distal fruiting sites.

Yield, lint percentage and fiber water content: Significant differences were observed between genotypes, planting dates and experiment years on seed-cotton yields (Table 3). ‘Celia’ and ‘Crema’ were the higher and ‘Carmen’ and ‘Sonia’ the lower yielding cultivars. In what concern to growing season durations, the two former genotypes are classed as early-medium and medium, and the two later ones as medium-late genotypes. Early and medium planting dates attained equivalent yields, being both significantly higher than the attained in the late planting treatment. In the second, hottest, experimental year, plants produced more 33.3% seed-cotton.

‘Carmen’ and ‘Crema’ had lower lint percentages (39.2-39.4%) than all the other genotypes (40.4-40.6%), as well as 2003 (39.7%) *versus* 2002 (40.5%) (Table 3).

No significant differences between genotypes or planting dates were found on seed-cotton water content, ranging from 9.6 to 10.9, with a mean value of 10.2%. However, significant differences between experimental years were accounted, with 11% in 2002 and 9.4% in 2003. In the second experimental year, during the last 20 days before harvest, air temperature and relative humidity were much more favorable to lint drying lowing fiber water content, although the total rainfalls of more than 50 mm fallen near the tenth day before harvest (Fig. 1).

According with European Union cotton regulations [16], those lint percentages differences ~~don’t~~ influence price paid to farmers, whereas short and no significant differences between seed-cotton water contents, being in the threshold of the 10% base value, will have penalties of 0.014465 and valorizations of 0.00748 € kg^{-1} seed-cotton.

Fiber quality: Significant differences were noted between genotypes in several fiber quality characteristics, such as micronaire reading, length, strength, maturation and elongation. No differences between genotypes were accounted in uniformity index (all samples classed as very high) or short fiber index. Planting date showed to be a factor with very little influence on fiber characteristics, whereas growing season tended to register differences in almost all of the analyzed parameters (Table 3).

According to the European Union cotton fiber classing standards, ‘Crema’, ‘Flora’ and ‘Lacta’ produced normal to thick fibers (4.5 to 5.0 micronaire reading) whilst ‘Carmen’ and ‘Sonia’ produced normal fibers (4.0 to 4.4 micronaire reading). According to the guide of the USDA [39] all those micronaire readings were classed as base range (4.3 to 4.9). In spite of significant differences in the percentage of mature fibers (88.9 to 90.8%), the absolute differences were small enough to classify all samples as matured. Also in spite of significant differences in fiber lengths (30.3 to 31.2 mm or $1^{3/16}$ to $1^{7/32}$ inches), strengths (31.0 to 33.5 g tex^{-1}) and elongations (3.8 to 4.4%), all samples were classed as long, very strong and with very low elongation. In contrary of the occurred with all those fiber characteristics, in spite of no significant differences between genotypes on short fiber indexes, their absolute values will accomplish to different classing, including ‘Carmen’ and ‘Crema’ in the lower index (d” 9.0) and all the other genotypes as low-medium short fiber index.

Despite reflectance and yellowness significant differences, no significant differences were found on C-grade between genotypes or planting dates. Of the fiber samples 83.4% falls on strict low middling (SLM) class, 12.9% on middling (M) and 1.9% on both strict middling (SM) and low middling (LM) classes. However, a tendency of C-grades differences between genotypes was found (0.05<P<0.10). In fact, ‘Sonia’ apparently presented fibers of higher quality (SM-11%, M-17%, SLM-72%) than ‘Carmen’ (M-5%, SLM-89%, LM-6%) or ‘Celia’ (M-11%, SLM-83%, LM-6%). ‘Crema’, ‘Flora’ and ‘Lacta’ fibers were classed only as SLM (78-89%) and M (11-22%). Significant differences (P<0.01) of fiber classifications were found between years, presenting 2003 wider C-grade classes, ranging from SM to LM, whilst 2002 presented only M and SLM fiber samples. Nevertheless these differences, the most frequent classes were SLM, ranging from 78% (2003) to 89% (2002), and M, ranging from 11% (2002) to 15% (2003).

Table 1. Influence of genotype, planting date, and year on percentage of total cotton bolls by sympodial node and fruiting position.

Treatment	Node 1-5			Node 6-10			Node >10			All		
	[a]FP1	FP2	FP>2	FP1	FP2	FP>2	FP1	FP2	FP>2	FP1	FP2	FP>2
	% of total bolls											
Genotype												
Carmen	22.2bc	16.9 c	9.1 c	25.0 b	11.8 b	7.6 a	5.1 c	1.5 b	0.8 b	52.3 b	30.2 b	17.5bc
Celia	22.0 c	18.2 b	13.1 a	21.1de	9.5 c	4.6 c	7.5 b	3.2 a	0.8 b	50.6 b	30.9ab	18.5 b
Crema	20.8 d	16.5 c	8.0 d	22.1cd	12.3ab	5.7bc	10.0 a	2.8 a	1.8ab	52.9 b	31.6ab	15.5 c
Flora	26.4 a	14.9 d	10.7 b	26.6 a	7.6 e	3.5 d	6.9 b	1.3 b	2.1 a	59.9 a	23.8 c	16.3bc
Lacta	20.2 d	17.3bc	13.0 a	20.9 e	12.0ab	5.9 b	6.5 b	2.2ab	2.0 a	47.6 c	31.5ab	20.9 a
Sonia	23.4 b	19.6 a	7.3 d	23.0 c	12.7 a	3.8 d	6.6 b	1.7 b	1.9 a	53.0 b	34.0 a	13.0 d
Planting date												
Early	23.5 a	19.6 a	8.2 c	23.4 b	9.7 c	2.9 c	9.7 a	2.0 a	0.9 c	56.6 a	31.3 a	12.1 c
medium	21.6 c	16.4 b	9.0 b	24.7 a	10.9 b	7.1 a	5.8 b	2.0 a	2.5 a	52.1 b	29.3 b	18.6 b
Late	22.6 b	15.8 b	13.3 a	21.0 c	12.9 a	5.3 b	5.0 c	2.4 a	1.7 b	48.6 c	31.1ab	20.3 a
Year												
2002	27.0 a	19.2 a	4.5 b	26.2 a	12.1 a	1.5 b	7.0 a	1.8 b	0.7 b	60.2 a	33.1 a	6.7 b
2003	18.2 b	15.3 b	16.0 a	20.1 b	10.3 b	8.7 a	6.1 b	2.5 a	2.9 a	44.3 b	28.1 b	27.6 a

Values within a column and treatment followed by the same letter are not significantly different by the Tukey test (P<0.05). All interactions significant (P<0.05). [a]FP = boll position on a sympodial branch.

Table 2. Influence of genotype, planting date, and year on percentage of fruiting positions maturing harvestable bolls by sympodial node and fruiting position.

Treatment	Node 1-5			Node 6-10			Node >10			All		
	[a]FP1	FP2	FP>2	FP1	FP2	FP>2	FP1	FP2	FP>2	FP1	FP2	FP>2
	% of fruiting positions maturing bolls											
Genotype												
Carmen	33.9 c	26.9 c	15.6 d	39.1 b	18.6 b	13.7 a	7.3 f	1.9 d	1.3 d	26.8 c	15.8 c	10.2 b
Celia	41.1 a	34.4 a	26.4 a	38.7 b	17.9 b	9.6 b	13.7 b	6.2 a	1.3 d	31.2 a	19.5 a	12.4 a
Crema	34.6 c	27.4 c	14.3 e	37.1 c	20.9 a	10.1 b	16.6 a	5.0 b	2.7 c	29.4 b	17.8 b	9.0 c
Flora	41.7 a	24.0 d	20.2 c	42.4 a	13.2 c	6.8 c	12.1 c	2.7 cd	5.4 a	32.1 a	13.3 d	10.8 b
Lacta	32.0 d	27.7 c	21.7 b	32.6 d	20.8 a	10.5 b	9.9 e	3.6 c	4.4 b	24.9 d	17.3 b	12.2 a
Sonia	36.2 b	29.5 b	15.6 d	36.1 c	20.6 a	5.6 d	8.9 e	2.4 d	2.9 c	27.1 c	17.5 b	8.0 d
Planting date												
early	36.9 b	30.6 a	13.7 c	36.9 b	15.3 c	5.0 c	16.4 a	3.2 b	1.4 c	30.1 a	16.4 b	6.7 c
medium	34.8 c	26.8 c	17.5 b	40.3 a	18.0 b	13.2 a	9.3 b	3.2 b	4.3 a	28.1 b	16.0 b	11.7 b
late	38.0 a	27.6 b	25.7 a	35.8 c	22.6 a	10.0 b	8.6 c	4.4 a	3.3 b	27.5 c	18.2 a	13.0 a
Year												
2002	39.1 a	27.9 b	6.5 b	37.9 a	17.9 b	2.0 b	11.7 a	2.4 b	0.7 b	29.5 a	16.1 b	3.0 b
2003	34.1 b	28.8 a	31.5 a	37.5 a	19.4 a	16.8 a	11.0 b	4.7 a	5.3 a	27.6 b	17.6 a	17.9 a

Values within a column and treatment followed by the same letter are not significantly different by the Tukey test (P<0.05). All interactions significantly different (P<0.05). [a]FP = boll position on a sympodial branch.

Table 3. Influence of genotype, planting date, and year on seed-cotton yield and fiber properties.

Treatment	Yield	Lint percentage	Fiber index	Micronaire	Maturation	2.5 % span length	Uniformity index	Short fiber index	Strength	Elongation	Reflectance	Yellowness
	kg ha^{-1}	%	g lint /100 seeds	reading	%	mm	%	%	g tex^{-1}	%	%	Hunter's +b
Genotype												
Carmen	1435 c	39.4 b	10.0 b	4.4 c	89.7 bcd	31.2 a	86.7 a	9.0 a	33.1 a	4.2 ab	74.9 b	7.0 c
Celia	2005 a	40.4 a	11.8 a	4.5 bc	90.3 abc	30.4 b	86.5 a	9.4 a	33.5 a	3.8 d	75.6 ab	7.1 bc
Crema	1815 ab	39.2 b	10.0 c	4.6 b	90.6 ab	30.8 ab	86.5 a	8.9 a	32.7 ab	4.4 ab	75.7 ab	7.5 a
Flora	1609 bc	40.6 a	11.1 ab	4.8 a	90.8 a	30.7 ab	86.5 a	9.3 a	31.4 c	4.0 cd	75.5 ab	7.2 abc
Lacta	1665 bc	40.4 a	10.5 bc	4.6 b	89.5 cd	30.3 b	86.2 a	9.1 a	31.0 c	4.1 b	76.1 a	7.5 a
Sonia	1451 c	40.5 a	11.5 a	4.3 d	88.9 d	30.7 ab	86.5 a	9.1 a	31.7 bc	4.4 a	76.7 a	7.4 ab
Planting date												
early	1773 a	40.0 a	10.7 a	4.5 a	89.9 a	30.5 a	86.5 a	9.1 a	32.0 a	4.1 a	75.8 a	7.2 b
medium	1767 a	40.2 a	10.9 a	4.6 a	90.1 a	30.7 a	86.1 a	9.3 a	32.3 a	4.1 a	75.5 a	7.3 ab
late	1450 b	39.9 a	10.9 a	4.5 a	89.9 a	30.8 a	86.8 a	9.1 a	32.4 a	4.2 a	76.0 a	7.4 a
Year												
2002	1426 b	40.5 a	10.4 b	4.5 a	89.2 b	30.6 b	86.8 a	9.3 a	30.5 b	4.7 a	76.6 a	7.0 b
2003	1901 a	39.7 b	11.2 a	4.5 a	90.8 a	30.8 a	86.1 b	9.0 b	34.0 a	3.6 b	74.9 b	7.6 a
Interactions												
G x PD	no	no	no	yes	yes	yes	yes	no	yes	no	yes	yes
G x Y	no	no	no	yes	yes	yes	no	no	yes	no	yes	no
PD x Y	yes	no	no	yes	yes	yes	no	no	no	no	yes	no
G x PD x Y	no	yes	no	yes	yes	yes	yes	no	no	no	yes	yes

Values within a column and treatment followed by the same letter are not significantly different by the Tukey test ($P<0.05$).

Discussion

Boll set percentage and boll location: Working with 'Stoneville BXN-47' at College Station, Texas, USA, Jost and Cothren [17] observed 44.5 to 47.9% of total cotton bolls at main-stem nodes ≤ 12, coarsely the equivalent of our 45 to 53% obtained in the lower one-third of the reproductive plants parts. In the same experimental conditions 54.3% of total bolls were at main-stem nodes 6-10 and 41.6% of total bolls at FP1, a minor contribution than observed in this study [13]. Ten years of data set for 'Acala SJ-2' with mean values of 51.9, 38.4 and 9.5% of total bolls at fruiting branches 1 to 5, 6 to 10 and above 10, respectively [5] was very similar to our mean results of 49.9, 39.2 and 10.8%. Plant leaf type influence on location of retained bolls was inconsistent and of minor magnitude with larger contributions (53 to 69%) of main-stem nodes ≤ 12 [1]. No differences were found of overall vertical boll distribution between different leaf type genotypes, with the exception of super-okra *versus* normal leaf genotypes[18]. In eight cultivars study held at Stoneville, Mississippi, USA, as few as 11 to 28% of overall open bolls located at main-stem nodes ≤ 12. The node of first fruiting branch was not reported. FP1 contribution to total open bolls represented 69 to 80% and FP2 18 to 24%, that is, they observed that the two proximal FP were responsible for 88 to 98% of total open bolls, a much larger proportion than 79 to 85% observed in our work [1].

For others [2, 19] the differences of fruiting retention and location of bolls between genotypes of different growing season durations are specially noted at sympodia located lower in the plants. The short season cultivars studied by the later authors achieve contributions of 28 to 31% to total bolls in main-stem nodes lower than 9, whilst the long season '2218' and 'Acala SJ-2' achieved only 14 to 18% at these plants horizon. Our higher difference reached 8 percentage points and was observed between 'Celia' (53.3%) and 'Crema' (45.3%), cultivars of early-medium and medium season. The medium-late season 'Carmen' and 'Sonia' results were 48 and 50%, respectively, so our results don't corroborate the observed tendency[2, 19]. Perhaps the growing season durations of the six studied cultivars are not sufficiently different to reflect the differences observed by those authors.

Studying 'Deltapine 41' other authors [20, 21] found that increasing nitrogen fertilization from 0 to 168 kg N ha^{-1} redistributed plant yield decreasing yield contribution of the lower one-third (43 to 28%) and increasing the middle (44 to 48%) and in special the uppermost one-thirds (7 to 22%). Our within-plant boll distribution resembles low N rate results [20, 21], what is out of the expectable since our N rate surpass the higher rate tested by those authors.

In what it concerns to percentage distribution of total bolls by FP, Boquet *et al.* [21] found 62, 28 and 7 for FP1, FP2 and FP>2, respectively, whilst in this study those values corresponds to 52, 31 and 17. That difference, with lower FP1 and higher FP2 and FP>2, reflects the verified production displacement to distal plant fruiting sites. In the northern Greece study (Giannitsa, 40°47'N) [11], where growing season is especially limited, 41% of total open bolls were observed in fruiting branches 1 to 5 and 59% in fruiting branches 6-10 in 'Deltapine 20' against 51% and 49%, respectively, in short season cultivar 'Eva'. Our results resemble 'Eva's' boll distribution pattern by horizons. Concerning boll distribution per sympodial fruiting positions, 44% and 56% was found in 'Deltapine 20' FP1 and FP2 and 41.5% and 58.5% in 'Eva' FP1 and FP2 [11]. Our results were higher in FP1 contribution, much lower in FP2 and much larger in FP>2, distal fruiting position negligible.

Total lint produced from all FP1 bolls ranged from 66 to 75% and lint produced from all FP2 bolls produced from 18 to 21% of total lint yield [4]. New cultivars, that fruit earlier, tended to have more yields on sympodial nodes 1 to 9. In fact, in the present study, sympodial nodes 1 to 10 were responsible for 85 to 93% of total cotton bolls.

According with other work results [2], early season cultivars had a greater percentage of plants that matured a harvestable boll at early nodes. Under this scope the highest earliness measured at FP1 was attained by 'Celia' and 'Flora' (41.1 and 41.7%), at FP2 by 'Celia' and 'Sonia' (34.4 and 29.5%) and at FP>2 by 'Celia' and 'Lacta' (26.4 and 21.7%). Even at FP1 47.3% of the plants did not produce a harvestable boll. That value was 44% ~~for~~ [2].

In Mediterranean conditions, mean values of FP1, FP2 and FP>2 contributions to total bolls are around 60, 30 and 10%, respectively[7]. For the cited data set [5], averaged horizontal retention were 59, 30 and 11%, for FP1, FP2 and FP>2, respectively. Results of fifty years with different genotypes in several sites [22] refer that 80% of total yield is located at FP1 plus FP2 but their individual contributions can range from 43 to 76% at FP1, from 18 to 32% at FP2 and from 3 to 19% at FP>2.

The statement[1] that adjacent fruiting forms compete for nutrients and assimilates was observed only in 'Flora' and 'Lacta', the former with overall high FP1 and low FP2 retention, and the second with overall low FP1 and high FP2 and FP>2 retentions.

Because assimilates for developing fruiting forms are supplied primarily by the subtending leaf or by other leaves located in close proximity, abortion of the fruiting form as a square at FP1 should allow this leaf to supply assimilates to FP2, increasing the probability of boll retention at that adjacent position [23, 24]. Abortion of the first position as a square enhanced the probability of boll retention at the adjacent position[1]. Our results of overall percentage of fruiting positions maturing harvestable bolls do not confirm in absolute that statement, since some genotypes, like 'Celia', attained simultaneously higher FP1, FP2 and FP>2 retentions. Perhaps the abortion at FP1 occurred as young bolls, fruiting forms that, in contrary of squares, do not enhance the probability of boll retention at the adjacent position. In fact, others[1] stated that when young bolls abort due to insect infestations or other stress conditions, previous losses may not be already compensated when favorable conditions are reestablished.

In order to achieve satisfactory seed-cotton yields in the Spanish cotton belt, 55-60% is referred as minimum boll retention percentages [25]. In this study total cotton bolls percentage averaged over all fruiting positions was comprehended between 17.5 ('Sonia') and 21.0% ('Celia'). The okra leaf type genotype attained 18.1%. 'DES 24-8ne' isolines as significant effect of leaf type on boll retention, attaining the okra leaf minus 18 to 23 percentage points than the normal leaf type [26].

Also little inter-annual variations were observed in the percentage of total bolls retained by sympodial node, with 69-72% at FP1and 19-21% at FP2 [1]. However, the FP1 and FP2 contributions were larger and smaller, respectively, than the observed in this study.

Yield and lint quality: The highest seed-cotton yields achieved in this study (1815-2005 kg ha^{-1}) were inferior to the ten years mean recorded in other Mediterranean countries, like Spain (3488 kg ha^{-1}), Greece (3048 kg ha^{-1}) and Turkey (3309 kg ha^{-1}) (FAO statistical databases) and also lower than the obtained in Alentejo/ Portugal in experimental units and with plastic cover [27]. However, our seed-cotton yield results reflect the average Portuguese field grown cotton productivity obtained since 2002. Poor yields can probably be linked with the poor retention results discussed above. In fact, when plants mature less fruit at lower nodes, they are fruiting later in the season at a time which is less desirable from a climatic standpoint [4].

In general, our lint percentages were relatively homogeneous. Observed lint percentages ranging from 34.8% in 'Chirpan 433', a Bulgarian short season genotype, to 40.4% in 'Coker 310' [28]. Lint percentages from 32.4 to 44.5% was obtained studding 10 genotypes [29]. In other work, with 14 genotypes at Alcalá del Río (37°20'N), Sevilla, Spain, lint percentages ranging from 37.1% ('Vulcano') to 42.0% ('Alegria')[30]. More recent Portuguese data also show inter annual differences in lint percentages [27, 31].

In the present study fiber index varied between 10.0 ('Crema') and 11.8 ('Celia') g lint per hundred seeds, higher values than the observed in the old experimented genotypes [29], like 'Beli Izvor' and 'Stoneville 825', which fiber indexes varied between 6.6 and 8.4 g lint per hundred seeds.

Our micronaire and maturation results are in line with the recent results obtained with 'Tabladilla', 'Reina', 'Tauro' and 'Essa's at Safara (38°06'N), in the left margin of the Guadiana River [27, 31], but they were finest and matured when compared with the oldest genotypes analyzed [29]. The abscission of fruiting forms allow higher assimilate availability per retained boll resulting on higher micronaire readings and fiber maturations [32-35].

Modern cultivars are likely to present longer fibers [36, 37]. Actually our fibers lengths though were similar to the obtained recently also in Portugal [27, 31] and in the past decade in Spain were longer[30] than referred thirty years ago [28]. Regarding fiber uniformity index, short fiber index, strength and elongation, our results settle with all Portuguese and Spanish cited references. However, in what concern to elongation data, those results where much lower than the often referred by American authors [32, 33, 36, 38].

Other recent Portuguese experimental data reach similar fiber reflectance but higher fiber yellowness[27, 31] although the twelve genotypes data showed great similarity to our six genotypes results in both fiber quality standards [30].

Conclusions

Attained overall low seed-cotton production in this study can be attributed as a direct consequence of low retention by fruiting branch and by fruiting position, i.e. due to general low boll set. Insect injury and high N fertilization contributed to shifting yield to relatively distal positions, which were not able to mature harvestable bolls due to short grow season duration. Lint quality is acceptable and within the EU cotton standards, being classed as SLM, with no penalties whatsoever.

References

[1]Kerby, T.A. and Buxton, D.R. 1981. Competition between adjacent fruiting forms in cotton. Agron. J. **73**:867-871.

[2]Jenkins, J.N., McCarty, J.C. and Parrott, W.L. 1990b. Fruiting efficiency in cotton: Boll size and boll set percentage. Crop Sci. **30**:857-860.

[3]Heitholt, J.J. 1999. Cotton: Factors associated with assimilation capacity, flower production, boll set, and yield. In Smith, D.L. and Hamel, C. (eds). Crop Yield, Physiology and Processes. Springer Verlag, Berlin, pp. 235-269.

[4]Jenkins, J.N., McCarty, J.C. and Parrott, W.L. 1990a. Effectiveness of fruiting sites in cotton: Yield. Crop Sci. **30**:365-369.

[5]Kerby, T.A. and Hake, K.D. 1996. Monitoring cotton's growth. In Hake, S.J., Kerby, T.A. and Hake, K.D. (eds). Cotton Production Manual. Publication 3352, Division of Agriculture and Natural Resources, University of California, pp. 335-355.

[6]Bauer, P.J., Frederick, J.R., Bradow, J.M., Sadler, E.J. and Evans, D.E. 2000. Canopy photosynthesis and fiber properties of normal- and late-planted cotton. Agronomy Journal **92**:518-523.

[7]López-Bellido, L. 2003. Algodón. In Cultivos Industriales. Mundi-Prensa, Madrid, pp. 243-436.

[8]Bozhinov, M., Dimitrova, L., Kassyanenko, A. and Stepanov, Y. 1998. Problems of growing cotton in marginal regions. Proceedings of the Second World Cotton Research Conference, September 6-12, Athens, Greece, pp. 608-609.

[9]Colomer, M., Lopez, M. and Gutiérrez, J.C. 1998. Physiological effects on cotton plant sown under plastic mulch. Proceedings of the Second World Cotton Research Conference, September 6-12, Athens, Greece, pp. 396-400.

[10]Márquez, F. 1998. Modernas ténicas culturales. In Junta de Andalucía (ed.). Tecnología de la Fibra de Algodón. Cursos Superiores 3/98, Consejería de Agricultura y Pesca, Junta de Andalucía, Sevilla, Tomo II, pp. 483-489.

[11]Veloukas, T., Le Rumeur, C., Laios, V. and Vassilou, G. 1998. Response to Pix of cotton varieties in Greece. Proceedings of the Second World Cotton Research Conference, September 6-12, Athens, Greece, pp. 278-280.

[12]Arrese, M.B., Rodríguez, M.M., Cobos, B.L., Clavero, F.C., Gordillo, T.M., Díaz, R.G., Baeyens, D.P., Villacañas, R.F., Fernández, R.V., Heras, T.P. Jaén, E.S., Gómez, J.C.C. and Negreira, C.R. 2005. Cotton sector diagnostic. (In Spanish). Unidad de Prospectiva, Servicio de Estudios y Estadísticas, Secretaría General de Agricultura y Ganadería, Junta de Andalucía, Córdoba, España.

[13]Jost, P.H. and Cothren, J.T. 2000. Growth and yield comparisions of cotton planted in conventional and ultra-narrow row spacings. Crop Sci. **40**:430-435.

[14]Doorenbos, J. and Kassam, A.H. 1980. Efectos del agua sobre el rendimiento de los cultivos. Estudio FAO Riego y Drenaje nº 33, Roma, 212 p.

[15]Jones, M.A., Wells, R. and Guthrie, D.S. 1996. Cotton response to seasonal patterns of flower removal: II Growth and dry matter allocation. Crop Sci. **36**:639-645.

[16]Morcillo, J.A. 1998. Regulamentación comunitária. In Junta de Andalucía (ed.). Tecnología de la Fibra de Algodón, Tomo I. Cursos Superiores 3/98, Consejería de Agricultura y Pesca, Junta de Andalucía, Sevilla, España, pp. 119-138.

[17]Jost, P.H. and Cothren, J.T. 2001. Phenotypic alterations and crop maturity differences in ultra-narrow row and conventionally spaced cotton. Crop Sci. **41**:1150-1159.

[18]Heitholt, J.J. 1993. Cotton boll retention and its relationship to lint yield. Crop Sci. **33**:486-490.

[19]Kerby, T.A., Cassman, K.G. and Keeley, M. 1990. Genotypes and plant densities for narrow-row cotton systems. I. Height, nodes, earliness and location of yield. Crop Sci. **30**:644-649.

[20]Boquet, D.J., Moser, E.B. and Breitenbeck, G.A. 1993. Nitrogen effects on boll production of field-grown cotton. Agron. J. **85**:34-39.

[21]Boquet, D.J., Moser, E.B. and Breitenbeck, G.A. 1994. Boll weigth and within-plant yield distribution in field-grown cotton given different levels of nitrogen. Agron. J. **86**:20–26.

[22]Mauney, J.R. 1986. Vegetative growth and development of fruiting sites. In Mauney, J.R. and Stewart, J. (eds). Cotton Physiology. The Cotton Foundation Reference Books nº 1, Memphis, Tennessee, USA, pp. 11-28.

[23]Ashley, D.A. 1972. ^{14}C-labelled photosynthate translocation and utilization in cotton plants. Crop Sci. **12**:69-74.

[24]Brown, K.J. 1968. Translocation of carbohydrate in cotton: Movement to fruiting bodies. Ann. Bot. **32**: 703-713.

[25]Gutiérrez-Más, J.C. 1998. Fisiología del algodón. In Junta de Andalucía (ed.). Tecnología de la Fibra de Algodón. Cursos Superiores 3/98, Consejería de Agricultura y Pesca, Junta de Andalucía, Sevilla, Tomo II, pp. 405-416.

[26]Heitholt, J.J. 1995. Cotton flowering and boll retention in different planting configurations and leaf shapes. Agron. J. **87**:994-998.

[27]Amaro, J.T. 2002. Relatório do Projecto PEDIZA 6323 - Estudo da viabilidade da introdução do algodoeiro nos sistemas culturais da área de influência do regadio do Alqueva. Estação Agronómica Nacional, Instituto Nacional de Investigação Agrária, Oeiras, pp. 24.

[28]Pereira, J.R. 1978. A cultura do algodão. Variedades em experimentação. VI Colóquio, Estação Agronómica Nacional, Instituto Nacional de Investigação Agrária, Oeiras, 20 p.

[29]Carvalho, P.P. 1992. Estudo de variedades de algodão com características de interesse económico. Instituto de Investigação Científica Tropical, Centro de Estudos de Produção e Tecnologia Agrícolas, Lisboa, 36 p.

[30]Fernández, A.B. 1998. Variedades. In Junta de Andalucía (ed.). Tecnología de la fibra de algodón, Tomo II. Cursos Superiores 3/98, Consejería de Agricultura y Pesca, Junta de Andalucía, Sevilla, España, pp. 491-498.

[31]Amaro, J.T. 2003. Relatório do Projecto PEDIZA 2002.64.002133.9 - Estudo da adaptação do algodoeiro à área de intervenção do regadio do Alqueva. Estação Agronómica Nacional, Instituto Nacional de Investigação Agrária, Oeiras, pp. 18.

[32]Pettigrew, W.T. 1995. Source-to-sink manipulation effects on cotton fiber quality. Agron. J. **87**:947-952.

[33]Pettigrew, W.T. 2002. Improved yield potential with na early planting cotton production system. Agron. J. **94**:997-1003.

[34]Pettigrew, W.T., Heitholt, J.J. and Meredith, W.R. 1992. Early season floral bud removal and cotton growth, yield and fiber quality. Agron. J. **84**:209-214.

[35]Heitholt, J.J. 1997. Floral bud removal from specific fruiting positions in cotton: Yield and fiber quality. Crop Science **37**:826-832.

[36]Wells, R. and Meredith, W.R. 1984. Comparative growth of obsolete and modern cotton cultivars. III. Relationship of yield to observed growth characteristics. Crop Sci. **24**:868-872.

[37]Basset, D.M. and Kerby, T.A. 1996. Varietal selection. In Hake, S.J., Kerby, T.A. and Hake, K.D. (eds). Cotton Production Manual. Publication 3352, Division of Agriculture and Natural Resources, University of California, pp. 123-133.

[38]Zhao, D.L. and Oosterhuis, D.M. 2000. Cotton responses to shade at different growth stages: Growth, lint yield and fibre quality. Experimental Agriculture **36**:27-39.

[39]United States Department of Agriculture 1995. The Classification of Cotton. USDA-AMS Agriculture Handbook nº 566, Washington, D.C.