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Response of cotton (*Gossypium hirsutum* L.) seeding the ultra-narrow grooves and high population density

Respuesta del algodón (*Gossypium hirsutum* L.) a la siembra en surcos ultra-estrechos y altas densidades poblacionales

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Abstract

The cotton planting (*Gossypium hirsutum* L.) on narrow rows instead on conventional rows to 75 cm, show to be an alternative to increasing crop yield and to reduce production costs. The objective of this research was to study the effects of ultra-narrow rows and plant density on the biomass production and fiber quality. Three-row spacings and three plant densities were evaluated in the Comarca Lagunera, México. Ultra-narrow rows 50 and 35 cm, apart and conventional rows spaced to 75 cm, were used. The population densities were 80,000, 100,000 and 120,000 plants ha-1. The conventional variety Fiber max 98 was used. The nine treatments were assigned to a randomized complete block design with three replications in a split plot arrangement. Row spacings were assigned to main plots and the population densities to subplots. Seed-cotton and lint yield were evaluated in kg ha^{-1}, yield components (boll weight, lint percentage and seed index), fiber quality (length, resistance and fineness) and the plant growth indexes, leaf area index (LAI), net assimilation rate (NAR), crop growth rate (CGR), specific leaf area (SLA), leaf weight fraction (LWF) and leaf area ratio (LAR). Seed-cotton yield was different ($P<0.01$) to 75, 50 and 35 cm, row spacings, with 4,504, 5,377 and 6,259 (Kg ha^{-1}), respectively. The highest yield was obtained in 35 cm, row spacing, which was higher 15 and 29% to the obtained on 50 and 75 cm, row spacings, respectively. The fiber quality was not affected by row spacings and plant density. Row spacing did not affected the plant growth indexes measured. The cotton production system on 35 cm rows with a plant density of 120,000 plants ha^{-1} can be an alternative to increasing yield and to reduce production costs, without yield reduction. Getting more profit for the producer.

Fiber quality, Cotton yield, Growth rates

Resumen

La siembra de algodón (*Gossypium hirsutum* L.) en surcos más estrechos que los convencionales a 75 cm o más, sugiere ser una alternativa para aumentar el rendimiento y reducir los costos de producción. Con el objeto de conocer el efecto que los surcos ultra-estrechos y la densidad poblacional tienen sobre el potencial productivo, de biomasa y calidad de fibra, se estudiaron tres distancias entre surcos en la Comarca Lagunera, México. Se utilizaron las distancias a 50 y 35 cm como surcos ultra estrechos comparados con el testigo a 75 cm, combinados con tres densidades de población a 80, 100 y 120 mil plantas ha^{-1}, con la variedad convencional Fiber max 98. Los nueve tratamientos se distribuyeron al azar en un arreglo de parcelas divididas y tres repeticiones. Las distancias entre surcos se asignaron a la parcela mayor y, las densidades de población a la parcela menor. Se evaluó el rendimiento de algodón en hueso y pluma (fibra) en kg ha^{-1}, componentes de rendimiento (peso de capullo, porcentaje de pluma e índice de semilla), calidad de fibra (longitud, resistencia y finura) y seis índices relacionados con el crecimiento. El rendimiento en hueso fue significativamente diferente ($P<0.05$) para los distanciamientos 75, 50 y 35 cm con 4,504, 5,377 y 6,259 (Kg ha^{-1}) respectivamente. La superioridad a 0.35 cm en rendimiento se relacionó con una mayor densidad poblacional. La calidad de fibra no fue afectada por la distancia entre surcos ni por la densidad poblacional. El sistema de producción a 35 cm es una alternativa para incrementar los rendimientos y reducir costos de producción.

Calidad de fibra, Rendimiento de algodón, Índices de crecimiento

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Introduction

A traditional and recurrent problem for cotton producers is the reduced profitability of their crop, due to the constant increases in production costs and the low price of the fibre on the international market, since the price of the fibre is subject to production, reserves and world demand for it. In view of this situation, new alternatives have been explored to increase unit yields and make the crop more profitable.

Increasing unit productivity and reducing costs require genotypes with greater photosynthetic efficiency and new production systems. Work is currently underway to induce morphological changes (number of nodes, plant height) and physiological changes (earliness, synchronisation between vegetative and reproductive weight ratio) to increase the efficiency of fibre production. This is sought through the adaptation or modification of cultivation practices and the reduction in the application of inputs, as long as productivity is not affected.

As a result of this research, the ultra-narrow furrow cotton production system with high stocking densities was developed. The concept of ultra-narrow furrows (furrows less than 75 cm apart) dates back to 1920, Perkins et al. (1998). The objective at that time, as it is today, is to reduce production costs. Lewis (1971) concluded that the reduction of production costs with the ultra-narrow furrow system could be derived from the shortening of the crop cycle.

Because the cotton plant fruits in an orderly and sequential manner, emitting a flower at regular 3-day intervals on successive fruiting branches and at 7-day intervals between flowers on the same fruiting branch, with the ultra-narrow furrow production system and increased stocking density, fewer fruits per plant would be required to maintain current yields.

Therefore, if fewer acorns are needed to maintain these yields, the time required to obtain them would be less than in the conventional planting system (furrows spaced 75 to 100 cm apart).

Lewis (1971) pointed out that in the ultra-narrow furrow production system, plants could exhibit their fruiting structures at very identical stages of development throughout the cycle. This growth characteristic contrasts with that of the conventional planting system which exhibits fruiting at widely varying stages of development during the flowering and acorn ripening period. A more synchronised flowering pattern would lead to more efficient chemical pest control, and the regulation of plant growth with phyto-regulators would increase the possibility of increasing unit production.

Allen (1998) points out that shortening the crop cycle would lead to a reduction in the number of insecticide applications to protect fruitlets. Reduced row spacing and increased stocking density induces earlier crop closure than in conventional rows George, (1971). Faster ground cover reduces the critical period of weed competition Snipes, (1996), increases solar radiation interception and decreases evaporative water loss Kreig, (1996).

In West Texas, it was determined that in the conventional planting system (90 to 100 cm furrows), 40% of the water available to the crop is lost by evaporation, so the use of ultra-narrow furrows would allow more water to be absorbed by the plant, instead of being lost by evaporation. Gerik *et al.* (1998) report that sowing in ultra-narrow furrows increases yield by up to 37 % and reduces the crop cycle by 12 days compared to sowing in 76 cm furrows. While Cawley et al. (2002) report more modest yield increases (5 to 11 %) with a 7 to 10 days reduction in the crop cycle compared to planting in 0.92 m furrows. Prince et al. (2002) point out that with this technology it is possible to increase unit yields, reduce the crop cycle, control excessive plant growth, reduce production costs, etc. Gaytán et al. (2004) found no differences in yield when sowing in furrows spaced at 50 and 76 cm, nor between population densities that ranged between 80 000 and 200 000 plants ha-1, but indicated that sowing in 50 cm furrows reduces the crop cycle by seven days. Earliness and/or shortening of the crop cycle is a characteristic that confers resistance (pseudo-resistance) to pest damage by allowing the plants to escape damage from later generations of damaging insects.

Another quality of earliness, and the shortening of the crop cycle, is that of escaping adverse environmental conditions such as low temperatures or rainy periods that can affect yield and fibre quality. However, some researchers indicate that fibre quality can be affected by moisture or N deficiencies. Mark et al. (2002), or by differences between varieties, stocking density, row spacing, year effect, or any of their interactions. Mohamad et al. (1982).

Methodology

The research was carried out at the Experimental Field of the Universidad Autónoma Agraria Antonio Narro, Laguna Unit, in Torreón, Coah. It is located between parallels 25° 42' and 24° 48' north latitude and meridians 103° 31' and 102° 58' west longitude at an altitude between 1 000 and 2 500 m. INEGI (2009). Three furrow spacings were studied; 0.75 (control), 0.50 and 0.35 m (ultra narrow furrows) and three stocking densities, 80,000, 100,000 and 120,000 plants ha^{-1}.

The variety used was Fiber max 989, the treatments were distributed in a split plot arrangement, locating the distances between rows in the large plot and the stocking densities in the smaller plot. The large plot design was a randomised block design with three replications. The large plot consisted of 8 furrows of 5 m in length and the useful plot, for yield and biomass production and distribution data, consisted of 6 furrows of 4 m in length. Planting was carried out on dry soil. Fertilization was done with the formula 100-30-00 (N-P-K), then one sowing irrigation and three auxiliary irrigations were applied at 73, 93 and 108 dds.

During the cycle, the problem pests were the armyworm (Spodoptera exigua), which was controlled by applying a mixture of cypermethrin at a rate of 0.5 L ha-1 together with chlorpyrifos at a dose of 1.5 L ha-1 and the silverleaf whitefly (*Bemisia argentifolii*), for which Endosulfan was applied at a dose of 2.3 L ha-1. The weeds were controlled manually. Crop closure was estimated from measurements of horizontal plant growth, in cm. Crop closure was considered when the branches of the plants were joined together. The earliness at the beginning of flowering was evaluated in days after sowing (DDS). From the appearance of the first flower buds, the growth dynamics in height were recorded weekly.

The cotton yield in stone (RAH) and feather (RAP) in kg ha^{-1} was estimated. For this variable, two 6 m long rows per plot were harvested manually. In a sample of 20 cocoons taken at random per plot, the following yield components were evaluated: cocoon weight (CW), fibre percentage (FP), and seed index (SI), which is the result of the weight of 100 seeds. The sample of 20 cocoons was de-seeded by separating the fibre from the seed, which was used to determine the percentage by weight of the 20 cocoons. For the determination of fibre quality, the dehulled sample of the 20 cocoons harvested per plot was sent to the fibre laboratory of CIRNOC INIFAP, where they were analysed to obtain the values for fineness, fineness and quality (MIC) by means of micronaire, fibre length (LEN) in mm and fibre strength (STR) in (KNm kg^{-1}).

The dynamics of dry matter production and its allocation were measured in three destructive samplings at 74, 94 and 136 dds. In each sampling, two plants per plot were taken in full competition and divided into four subsamples; stem, branches, leaves and fruitlets. Each subsample was placed in a separate paper bag. The subsamples were taken to dry weight for which they were placed in a drying oven at a temperature of 65oC for a period of 72 hours. They were then weighed to obtain the dry weight. The sum of the weights of stem, branches and leaves indicated the amount of biomass accumulated in the vegetative organs. The sum of the dry weights of vegetative and fruiting organs gave the total dry weight per plant. To obtain the leaf area per plant, the area of subsamples of leaf laminae was measured in groups of different sizes and the dry weight of each group was also determined. With the information obtained, a simple regression analysis was carried out in which the dependent variable (Y) was the leaf area and the independent variable (X) was the dry weight of the subsamples.

With the dry matter values, the following growth rates were calculated, according to Radford (1967 and Hunt (1978). Crop growth rate (CGR), measures the increase in biomass per unit time, Net assimilation rate (NAR), estimates the photosynthetic efficiency of the plant, Leaf Area Ratio (FAR), is an indicator of the size of the photosynthetic apparatus of the plant, and is obtained by dividing the leaf area of the plant by the total dry weight of the plant, Specific Leaf Area (SFA), measures leaf thickness and represents the leaf area per gram of leaf dry weight, Leaf Weight Ratio (LWR), determines the distribution of assimilates to the leaves, and is an indicator of plant leafiness and Leaf Area Index (LAI), is the leaf area per unit of soil surface area, generally 1 m^2. The data were analysed with the SAS statistical programme, using the combined analysis of variance procedure including distance between rows and population density. The DMS test ($P \leq 0.05$) was used for the comparison of means.

Results

Yield, yield components and growth indices

The analysis of variance showed significant effect ($P<0.05$) for yield which was not the case for the other factor interactions.

Row spacing showed significant difference ($p<0.01$) in boll cotton yield (RAH) and feather cotton yield (RAP); for boll weight (BW), % fibre (FP), seed index (SI) and plant height (PA), it was not statistically significant (Table 1). These results coincide with those reported by Palomo, (2007), who found significantly higher yields of seed cotton, feather cotton and cocoons per m^2 for the 35 cm row spacing compared to the 50 and 75 cm spacings. Estrada, (2008), in consecutive years found higher and statistically different yields ($P \leq 0.05$) when sown in 35 cm furrows than in 50 and 75 cm furrows, whose average yield at 35 cm spacing was 10 % higher than at 50 cm and 26 % higher than at 75 cm (control). Vories and Glover, (2006), found higher yields for cotton planted at 19 cm compared to 97 cm rows, where the cocoons per m2 component determined the yield advantages of seed cotton and seed cotton of 35 cm rows over 50 and 75 cm rows. Palomo et al. (2007), concluded that ultra-narrow furrows yield 16% more seed cotton than planting in 75 cm furrows.

The boll weight and seed size tend to decrease as the row spacing is reduced and they claim that the transgenic and conventional varieties have the same potential.

Groove distances (cm)	Performance (Kg ha^{-1})		Cocoon Weight (g)	% of fibre	Seed rate	Plant height (cm)
	Bone	Pen				
75	4504.1 c	1967 c	5.8 a	43.8 a	9.1 a	76.4 a
50	5377.0 b	2396.1 b	6.0 a	44.5 a	9.1 a	77.4 a
35	6259.1 a	2733.1 a	5.9 a	43.6 a	8.0 a	70.5 a
Media	5380	2365	5.9	43.9	9	74.7

Table 1 Yield (kg ha^{-1}) and components at three row spacings
Similar letters are statistically equal DMS ($P \leq 0.05$).

The population density did not show significant difference between boll cotton yield (BHY) and seed cotton yield (YYP), nor for cocoon weight (CW), % fibre (FP), seed index (SI) and plant height (PA). However, it is observed that the density of 100,000 plants ha^{-1} shows the highest values (Table 2).

Palomo et al. (2007) found that planting in 35 cm furrows at a stocking density of 98,000 plants ha^{-1} showed the highest yields, which yielded 22 % more than planting in 50 cm furrows at 80,000 plants ha^{-1} and 27 % more than planting in 75 cm furrows at 67,000 plants ha-1, with the exception of bud weight, the other yield components were not affected by the production system. Gaytán *et al.* (2004) found no statistically significant differences for the values of yield components, boll weight and seed index and also confirmed the absence of response for cotton yield at the different row spacings and stocking densities evaluated. Palomo et al. (2007) found that population densities do not affect yield and its components in their study only there was difference in seed index which decreased with increasing population density and conclude that reduction of row spacing and in conjunction with increase in population density increase biomass production and yield of cotton.

Plants (m^2)	Performance (Kg ha^{-1}) Pen Bone	Cocoon Weight (g)	% of fibre	Seed rate	Plant height (cm)
8	5391.4 a 2361.4 a	6.0a	43.9a	9.1a	75.7a
10	2403.9 a 5493 a	5.9a	43.6a	8.9a	72.0a
12	5255 a 2331.4 a	5.9 a	44.3 a	9.1a	76.6a
Media	5379 2,365	5.9	43.9	9.0	74.7
Similar letters are statistically equal DMS ($P \leq 0.05$).					

Table 2 Yield (kg ha^{-1}) and components at three stocking densities

Fibre quality only showed a significant difference in the fineness component, where the 50 and 35 cm spacings were better than the 75 cm spacing, with a better trend observed in the 50 cm spacing. While in stocking density, a significant difference was observed for fibre strength where the 75 and 50 cm spacings were better than the 35 cm spacing. Palomo et al. (2001) mention that generally in years with high temperatures, fibre with lower length and strength but greater thickness is obtained. The results found by Chavarría (1998), coincide with the results obtained where fibre strength had a tendency to decrease as plant density increased.

Variation factors Row spacing (cm)	Length (mm)	Resistance (KNm kg^{-1})	Fineness (Micronaire)
75	1126.0 a	27.0 a	4.3 b
50	1121.0 a	27.2 a	4.5 a
35	1134.2 a	27.1 a	4.4 a
Average	1127	27.1	4.4
Stocking density			
Plants (m^{-2})	1127.3 a	27.0 a	4.4 a
10	1135.4 a	27.5 a	4.4 a
12	1118.4 a	26.7 b	4.4 a
Media	1127	27	4.4
Similar letters are statistically equal DMS ($P \leq 0.05$)			

Table 3 Average cotton fibre quality variables for the main sources of variation at three row spacings and three stocking densities.

The analysis of variance for all growth indices only showed a significant difference in the leaf weight ratio (LWR), which determines the distribution of assimilates to the leaves and is an indicator of the leafiness of the plant. The distance of 75 cm was the best to those of 50 and 35 cm, (table 5). The other indices did not show any difference.

It is necessary to comment that from the first sampling (74 dds) to (136 dds), the 35 cm distance showed a tendency to be better by obtaining higher crop growth rate (CGR) and net assimilation rate (NAR) than the other indices (table 4). It is observed that the highest values of leaf area ratio (LAR) and leaf weight ratio (LWR) occurred in the early stages of plant growth, and that they tend to decline with increasing crop age. This is due to the fact that in the early stages of growth, plants invest most of the photoassimilates in the establishment of their photosynthetic apparatus, an amount that gradually decreases as the plant accumulates more carbohydrates in other plant organs, especially in the reproductive organs. Palomo et al. (2003).

INDEXES	SAMPLING			
	plants (m^{-2})	1° 0-74	2° DDS 74-94	3° 94-136
TCC (g m^{-2} day $^{-1}$)	8	24.3a	15.9a	10.5a
	10	25.2a	18.5a	12.5a
	12	26.9a	15.4a	10.4a
TAN (g ms m^{-2} day $^{-1}$)	8	12.8a	12.7a	11a
	10	12.6a	13.4a	12.1a
	12	14.5 a	13a	12.7a
IAF (cm^2 g^{-1})	8	1.1a	2.4a	2a
	10	1.1a	2.5a	1.9a
	12	1 a	2.5a	1.7a
Similar letters are statistically equal DMS ($P \leq 0.05$).				

Table 4 Growth rates of conventional Fiber Max 989 cotton at ultra-narrow furrows and high stocking densities.

INDEXES	DS (cm)	Plants (m^{-2})	SAMPLING		
			1°	2° DDS	3°
			0-74	74-94	94-136
RAF (cm^{2}g^{-1})	75	8	51.3a	36.7a	16.0a
	50	10	53.4a	38.6a	14.2a
	35	12	51.8a	36.9a	13.8a
AFE (cm^{2}g^{-1})	75	8	117a	116.1a	116.1a
	50	10	117a	116.1a	116.1a
	35	12	118a	116.1a	116.1a
RPF (gg^{-1})	75	8	0.43a	0.31a	0.13a
	50	10	0.45a	0.33a	0.12b
	35	12	0.44a	0.31a	0.12b
Similar letters are statistically equal DMS ($P \leq 0.05$)					

Table 5 Growth rates of conventional cotton Fiber Max 989 at ultra-narrow furrow planting and high population densities

Conclusions

The highest yield was obtained in furrows at 35 cm and a stocking density of 120,000 plants ha-1. Fibre quality was not affected by row spacing or stocking density.

Row spacing did not affect most of the growth rates determined. Except for the distance of 75 cm, which obtained better values in RPF than the other distances, thus a greater magnitude of the photosynthetic apparatus in these plants, and a greater efficiency in the distribution of photoassimilates.

The 35 cm furrow production system is an alternative to increase yield, reduce production costs, without reducing quality.

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