Article

Productive performance of ultra-narrow groove cotton in acid soils in Colombia

Luis Fernando Campuzano-Duque§
Mario Buenaventura-Baron

Colombian Corporation for Agricultural Research-La Libertad Research Center. Villavicencio, Meta, Colombia. (buenaventura@agrosavia.co).

§Corresponding author: lcampuzano@agrosavia.co.

Abstract

Menegua is the first variety of cotton specifically for acid soils in Colombia with recommendation, in addition to including in the corn-soybean rotation system, as a strategy to expand the cotton frontier in the sub-region ‘altillanura plana’. However, its agronomic management in relation to planting distance requires adjustment as a strategy to improve the competitiveness of cotton in terms of yield, quality and costs. The objective of this study was to determine the effect of the ultra-narrow groove compared to the conventional one in the productive performance and quality of cotton under conditions of an oxisol acid soil in the Colombian altillanura plana. An experiment was carried out in Puerto Gaitan-Meta, during the 2015B agricultural cycle, a randomized complete block design was used with two treatments corresponding to distances between rows in cm): T1 = 0.4 and T2 = 0.8 and four repetitions; the Menegua variety with specific adaptation for acid soils was used and production and fiber quality variables were determined. The change of the conventional distance from 80 cm to 40 cm caused an increase of 13.1% in the height of the plant, a 29.2% reduction in the number of specks plant^{-1} and a decrease of 23.1% and 23.9% in the yield of seed cotton and yield of fiber cotton, respectively, the percentage of fiber extraction and its quality was not affected. It is concluded that in the subregion ‘altillanura plana’ on an oxisol acid soil the ultra-narrow groove compared to the conventional affect the Menegua variety in a negative way the productive behavior without detriment of the quality of the fiber in cotton.

Keywords: *Gossypium hirsutum* L., Colombian altillanura plana, fiber quality, oxisols and acid soils, population density.

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Introduction

Cotton is produced in almost 100 countries, but only a small group concentrates a large proportion of world production (China, 27%; United States of America, 18%; India, 11%; Pakistan, 9% and Brazil, 5%). Colombia occupies the 35th position with a 0.15% share and is mainly cultivated in three departments: Córdoba, Tolima and Valley of Cauca, with 35, 27 and 12% respectively of the national production. The yield in t ha^{-1} in the country increased by 34%, from 1.5 in 1990 to 2.3 in 2016, an increase that places it above the world average and the Andean Community of Nations with 1.9 and 1.5 respectively (OECD- FAO, 2016).

Agrosavia's genetic improvement program in Colombia has focused its objective on the development of Upland-type varieties with adaptation in the Humid Caribbean, Dry Caribbean and the Valle Calido regions of Alto Magdalena (Burbano-Figueroa *et al*., 2018) and for adaptation specific to the sub-region 'altillanura plana', from which Menegua was obtained, which in addition to having adaptation to acidity conditions, can be used as a rotation crop in the corn-soy system (Campuzano *et al*., 2015).

The 'altillanura plana' subregion is characterized by having acid soils of the order oxisol (Riveros, 1983), which in the case of cotton has four comparative advantages in relation to the current producing regions in Colombia: a) availability and good distribution of precipitation during the phenological stages of cotton; b) 20% less in production costs because it is the only region with no weevil and the self-regulation of the height of the plant that makes it possible to omit the use of growth regulators; c) regulation of the weed population that during the corn-soybean cycle causes a reduction in production costs; and d) greater exploration of nutrients and water in the profile greater than 10 cm by its pivoting root system (Campuzano *et al*., 2015).

However, that the genetic improvement allowed to obtain the Menegua variety with competitive attributes of performance and quality of fiber in the edafoclimatic conditions of the 'altillanura plana', there are other strategies to take advantage of the productive potential of this variety. Among one of the cultural practices used for this purpose, there is the sowing density with the use of the ultra-narrow furrow that allows to make efficient the resources available in the development, growth and production of cotton (Langer *et al*., 1987; Palomo-Gil *et al*., 2003).

The spatial modification in cotton, known as narrow and ultra-narrow furrow, was presented in 1920 (Perkins, 1998), a concept that promotes advantages such as the decrease in production costs due to the reduction of tillage, rapid soil cover by foliage (Jost and Cothren, 2001), reduction of weed competition (Perkins, 1998); increase in light interception; soil evaporation reduction Heitholt *et al*. (1994) and induce prematurity without affecting fiber performance and quality (Gaytán *et al*., 2014).

The two main variables in cotton positively and negatively affected by planting distance, especially with the use of ultra-narrow furrow, are the yield and quality of fiber (Langer, 1987; Nichols *et al*., 2004; Estrada *et al*., 2008). Reports in this regard indicate increases between 5% and 11% in the yield of cotton seed and reduction of the cultivation cycle from 7 to 10 days with the use of the ultra-narrow groove (Jost and Cothren, 2001; Cawley *et al*., 2002; Nichols *et al*., 2004; Vories *et al*., 2006), in Argentina, a 10% and 26% increase in yield was obtained with the use of ultra-narrow 50 and 35 cm grooves, respectively, without affecting fiber quality (Estrada *et al*., 2008).

In Colombia, the recommended planting distance for cotton is 80 cm between rows with a population per linear meter of six plants, which allows the establishment of 75 000 plants ha^{-1}. However, there are still no studies on the use of ultra-narrow grooves that allow us to recognize the benefits in conditions of the acid soils of the 'altillanura plana'. For this reason, the objective of this study was to evaluate the effect of using the ultra-narrow groove on the productive performance and fiber quality of the Menegua cotton variety in acidic soil conditions.

Materials and methods

Location and experimental design

This experiment was carried out in the second half of 2015 in the municipality of Puerto Gaitan, department of Meta, at the Taluma Research Center of the Colombian Corporation for Agricultural Research (AGROSAVIA), located at 4° 22' 41" North latitude 72°13'25" west longitude and an altitude of 330 meters above sea level. A randomized complete block design (DBCA) was used with two treatments consisting of two distances between rows 40 and 80 cm and four repetitions. The 40 cm treatment is known as 'ultra-narrow groove' and the 80 cm treatment is the conventional planting distance. The experimental unit was constituted of 10 furrows of 6 m in length with an equal population density for the two treatments of 75 000 plants ha^{-1}.

Climate characterization associated with the phenology of cotton

A precipitation-evapotranspiration plot was constructed during the crop cycle (sowing to harvest) and the maximum, minimum and average temperature data were recorded. The time in days elapsed and the thermal index (IT) were determined as the units of heat accumulated in the stages of vegetative and reproductive development of cotton: 1) vegetative phase (stage of formation of roots, stem, leaves and branches); 2) youth phase (stage of reproductive growth with the appearance of flower buds; 3) early reproductive phase (appearance of buttons, flowers and capsules); 4) full reproductive phase; 5) final reproductive phase; and 6) maturity and harvest phase. The thermal index or heat units was calculated based on the formula: $T_{max} + T_{min}/2-15.5$.

Agronomic management

To know the level of fertility of the soil and derive the recommendation of fertilization, soil samples were taken at three depths in cm (0-10, 10-20, 20-30), in order to determine the physical characteristics: texture (Hydrometer or Bouyoucos method) and chemical: pH (potentiometer method); organic matter (%) (Walkley and Black method); phosphorus (mg kg^{-1}) (Bray II method); calcium (Ca), magnesium (Mg) and potassium (K), expressed in (cmol kg^{-1}) extraction with ammonium acetate pH 7 and quantification by atomic absorption) and base saturation (%) (calculated using the formula Ca + Mg + K/CIC). These analyzes were performed in the AGROSAVIA soil, water and plant chemistry laboratory with the technical quality standard NTC-2005.

A balanced fertilization in kg ha^{-1} of N (140), P (80), K (80), S (1.2), B (0.5), Cu (0.5), Si (3.4) and Zn (3) was applied, applied at different times and fractionated: a) in planting, all phosphorus, one third of potassium and all minor elements were applied together with sulcamag; b) 15 days after the emergence (dde) of the culture, one third of the potassium and 40% of the N dose was applied; and c) a third application with 30% of the N and a third of the potassium was made at 30 days and a fourth fertilization was made at 45 days before flowering 30% of the remaining N.

Agronomic evaluations

The following agronomic, productive and fiber quality variables were determined: 1) plant height determined in 20 random plants, on the main stem, from the cotyledonal knot to the terminal bud of the plant and expressed in centimeters; 2) specks per plant, determined in 20 plants taken at random and expressed in number; 3) cotton-seed yield (RAS), determined by adding the weight of two passes of the eight-row crop, expressed in kg ha^{-1} of seed cotton; 4) yield of cotton-fiber, obtained by ginning the cotton-seed and expressed in kg ha^{-1}; and 5) fiber extraction, determined by the difference in total speck weight and seed weight, expressed as a percentage.

In each experimental unit a sample of 50 grams of cotton fiber was taken to determine: 6) micronaire, as a measure of the fineness and maturity of the fiber with the following classification: extra fine (value less than 3), fine (3- 3.6), average (3.7-4.7), rough (4.8-5.9) and very rough (greater than 5.9); 7) fiber length, as the average length of half composed of longer fibers, in hundredths of an inch with the following classification: Extra short fiber, short, medium, long and extra-long; and 8) fiber length uniformity index, expressed as a percentage and defined with the following classification: very low uniformity (less than 77), low (77 to 79.9), average (80 to 82.9), high (83 to 85) , and very high (greater 85). The quality variables fiber was determined at the Laboratory Fiber Quality, Diagonal-Medellin adjusted to NTC Technical Standard 481-1.

Statistical analysis

With the data of the eight variables, the verification test of the assumptions of the variance analysis was carried out using the Proc Univariate procedure and the analysis of variance with the SAS Proc Anova procedure, version 9.3 (SAS, 2003) and the comparison of means by Tukey test ($p \leq 0.05$).

Results and discussion

Characterization of the environment: soil and climate

The floor of the oxisol order presented saturation greater bases 60% in the first 20 cm soil depth associated with a high content of organic matter and phosphorus. In soil depth greater than 20 cm, the base saturation did not exceed 20% with a low content of organic matter and phosphorus. The acidity condition of 5.8 and 5.6 in the 10 and 20 cm, respectively, of the soil were favorable for root development and cultivation, in accordance with the requirements established for cotton 6 to 7.5 (optimal 5.6) (FAO, 1994) (Table 1).

This condition of soil preceded with a rotation of corn-soybean of three cycles to the sowing of cotton allowed a favorable condition for the proper nutrition of the plant, one of the indicators was the reported yield of corn and soybeans that ranged between 5.6 and 7.2 t ha^{-1} and 1.9 to 2.1 t ha^{-1}, respectively (Campuzano *et al*., 2015).

Table 1. Chemical characteristics of the soil. Puerto Gaitán, Colombia (AGROSAVIA, 2015).

Depth (cm)	pH	Organic material (%)	Phosphorus (ppm)	Calcium (meq)	Magnesium (meq)	Potassium (meq)	Base saturation (%)
0-10	5.8	2.4	36	1.4	0.2	0.2	81.4
10-20	5.6	2	14	0.8	0.1	0.1	67.2
20-30	4.9	1.2	2	0.2	0.1	0.1	20

The subregion 'altillanura plana' presented favorable edaphoclimatic conditions for the vegetative and reproductive development of cotton. The cultivation altitude of 330 meters above sea level was adjusted to the optimum cotton requirement of 0-600 meters above sea level (Robles, 1991; FAO, 1994) and the rainfall during the crop cycle exceeded evapotranspiration favorably during the months of August, September, October and the middle of November, with synchrony of phenological phases with high water requirement (vegetative phase, juvenile, early and final reproductive phase) and evapotranspiration exceeded precipitation in the last two weeks of November and in the months of December and January, favorable condition for the maturation phase of the cotton and harvest speck (Figure 1).

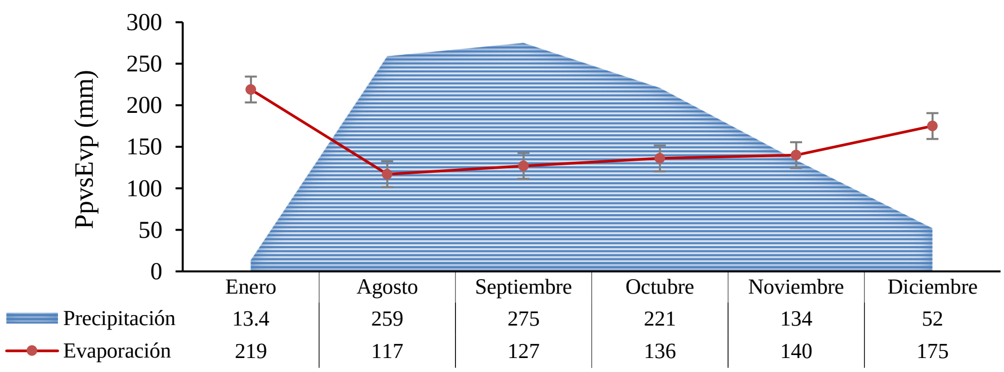

Figure 1. Precipitation and evapotranspiration during the crop cycle of Corpoica Menegua cotton (sowing in August to harvest in January) in Puerto Gaitán (AGROSAVIA, 2015).

During the crop cycle, maximum temperatures were presented in °C from 30.2 to 31.8 in the vegetative and harvest states, respectively, minimum temperature in °C from 20.8 to 22.6 in the juvenile and harvest states, respectively and average temperature in °C from 25.1 to 26.4 in vegetative state and harvest, respectively, values all appropriate for the vegetative development, opening and maturation of acorns (Figure 2) (Baradas, 1994).

The precipitation of 700 mm in all vegetative and reproductive states was satisfied according to the requirement for cotton from 700 to 1 300 mm (Baradas, 1994) and there was no rainfall in the period of development and maturation of acorns. The number of days from sowing to harvest was 140 days with a thermal index of 1 845 appropriate for the growth and development of cotton (Young *et al*., 1980) (Table 2).

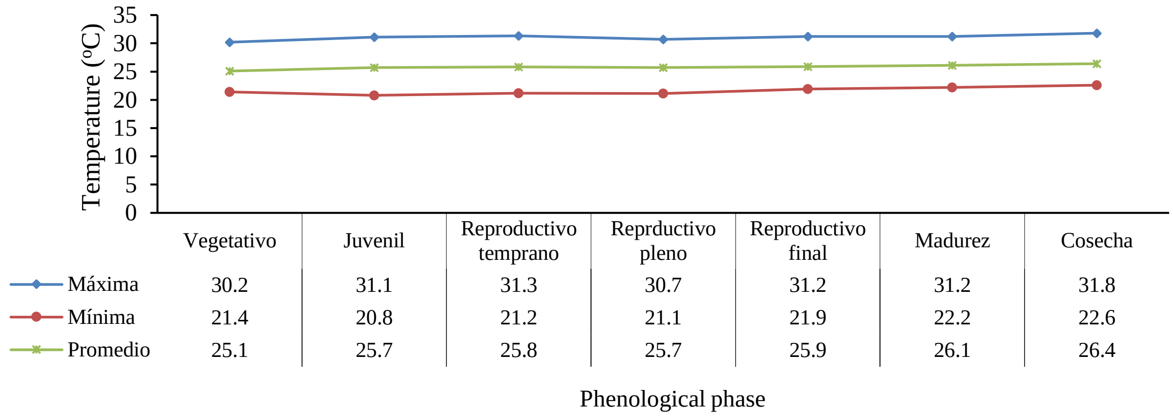

Figure 2. Maximum-minimum-average temperature during the vegetative and reproductive phenological stages of Corpoica Menegiua cotton (AGROSAVIA, 2015).

Table 2. Precipitation (mm) occurred-required, number of days from sowing to harvest and thermal index of Corpoica Menegua in two sowing distances. Taluma-Puerto Gaitán (AGROSAVIA, 2015).

Weather factor	V	J	RT	RP	RF	M	C
Precipitation occurred	241	198	150	96	74	0	0
Precipitation required	226	178	141	87	68	0	0
Sowing days to harvest	23	41	58	72	93	122	140
Thermal index	278	646	856	998	1 263	1 684	1845

Phenological states, V= vegetative; J= juvenile; RT= early reproductive; RP= full reproductive.

Productive behavior: plant height, specks plant^{-1}, yield cotton seed and fiber and fiber extraction

The variables of productive behavior presented highly significant differences for specks/plant, yield cotton seed and fiber, significant for plant height and not significant for fiber extraction. The coefficients of variation in all cases did not exceed 10%, which indicates the good degree of reliability of the data. Plant height, number of spots per plant and seed and fiber yield showed statistically different averages ($p \leq 0.05$) due to the effect of planting distance. The lowest plant height of 98.7 cm was 40 cm apart between rows, statistically different ($p \leq 0.05$) from that obtained with the distance of 80 cm of 113.4 cm (Table 3).

The number of spots per plant was statistically different ($p \leq 0.05$) and higher with the planting distance of 80 cm (18.5) in relation to the narrow groove of 40 cm (13.1). The same situation was presented with the yield of cotton seed and fiber. The conventional planting distance of 40 cm showed a yield of cotton seed in kg ha^{-1} of 2 832 and seed of 1 143 statistically higher ($p \leq 0.05$) than that observed with the narrow distance of 40 cm rows with a yield of 2 181 seed cotton and 869 fiber cotton. The percentage of fiber extraction did not show statistical differences due to the distance between rows. The 40 cm fiber extraction was 40.4% statistically equal ($p \leq 0.05$) to that obtained with the 80 cm distance between rows of 40.9% (Table 3).

Table 3. Plant height, specks per plant, yield of cotton seed, yield of cotton fiber and extraction of fiber by effect of two planting distances (AGROSAVIA, 2015).

Distance between rows (cm)	Plant height (cm)	Specks plant^{-1} (number)	Seed cotton yield (kg ha^{-1})	Cotton fiber yield (kg ha^{-1})	Fiber extraction (%)
40	113.4 b	13.1 b	2 181 b	869 b	40.4 a
80	98.7 a	18.5 a	2 832 a	1 143 a	40.9 a

Fiber quality behavior: micronaire, fiber length and uniformity index

The analysis of variance did not show statistical differences for micronaire, fiber length and uniformity index. The coefficients of variation in all cases did not exceed 5%, which indicates the good degree of reliability of the data. Micronaire presented statistically equal values of 4.21 and 4.20 for the planting distance of 40 and 80 cm. A similar situation was presented for fiber length with values of 1.12 and 1.14 and information index of 82.1 and 81.91 for planting distances of 40 and 80 cm, respectively in each variable (Table 4).

Table 4. Micronaire, fiber length and uniformity index of the Corpoica Menegua Cotton variety due to the effect of two planting distances (AGROSAVIA, 2015).

Distance between rows (cm)	Micronaire (units)	Fiber length (Hundredths of an inch)	Uniformity Index (%)
40 Qualification*	4.21 an average	1.12 a Medium-long	82.1 an average
80 Qualification	4.2 an average	1.14 a Medium-long	81.91 an average

*= Diagonal Quality Laboratory-Medellín.

The change in the distance between furrows in the Menegua cotton variety, from 80 to 40 cm, presented an increase in percentage of plant height of 13.1% and a significant reduction in the number of specks (29.2%), in yield of cotton seed (23.1%) and in the yield of cotton seed (23.9%). The behavior of the height of the Menegua plant in conditions of acid soils in the Colombian altillanura plana is a desirable attribute that was reported by Campuzano *et al*. (2015), which leads to the non-use of the growth regulator as a favorable factor in production costs and environmental sustainability.

This result does not correspond to that reported by Nichols *et al*. (2004) who found that plant height decreased as the distance between rows is shortened. It is possible that this situation is due to differences in the type of plant which, in the case of Menegua, is a low bearing variety with a semi-compact structure (Campuzano *et al*., 2015).

The lower plant height is an important condition for cotton in the loft since it does not allow the use of hormonal control. Similar research in other latitudes shows that narrow furrows do have benefits in cotton production, different from that obtained in this study (Gerik *et al*., 1998; Palomo-Gil *et al*., 2003) without affecting the quality of the fiber by ultra-narrow groove effect. The percentage of fiber extraction, as well as micronaire, fiber length and uniformity index were not affected by the ultra-narrow groove. However (Heitholt *et al*., 1993; Gaytán *et al*., 2004), they indicate otherwise, with a reduction in fiber length and uniformity due to the ultra-narrow groove.

The discrepancy of these results with the report of other authors regarding the higher performance of cotton with the conventional furrow and the absence of differences in micronaire variables, fiber length and uniformity index could be related to the study management conditions. in relation to nutrition and water. It is known that ultra-narrow grooves have a higher nutritional and water requirement (Ramírez-Seañez *et al*., 2012), it is possible that these factors were not satisfied in the treatment of ultra-narrow groove during the crop cycle, in relation to the length of fiber, the maximum temperature as a climate factor that affects the length of the fiber, under the conditions of the study were appropriate.

Conclusions

The change of the distance between furrows in the Menegua cotton variety, of 80 cm as a conventional distance at ultra-narrow furrows of 40 cm, had a negative effect on the productive performance of cotton without affecting fiber quality. In the soil and weather conditions of Puerto Gaitan, Meta, it is recommended to use the conventional planting distance of 80 cm for the Menegua cotton variety.

The attributes of cotton observed in the high performance loft, quality (medium to high fiber length) and percentage of fiber extraction (greater than 40%), plant height (less than one meter) and absence of the weevil (*Antonomus grandis*), added to this result, the use of the conventional furrow, represents an opportunity to incorporate the mechanical harvest, attributes that as a whole give it greater competitiveness and comparative advantage in relation to the producing regions of the interior of Colombia.

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