Plant density spatial arrangement for morphologically varying cotton varieties

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ABSTRACT

Field experiments were conducted at Rahad Research Station for seasons 2000/2001 and 2001/2002, focusing on how the variation in genotypes, density spatial arrangement and their interactions affects cotton yield and stickiness. The combined analysis indicated significant responses due to main effects but their interactions were not. Therefore, plant density spatial arrangement based on one of the three varieties is not appropriate. Hence, regression analysis for plant density yield targeting response curve exhibited a curvilinear relationship with the highest seed cotton yield (3895 kg/ha) achieved at 125000 plants/ha and thereafter started to decrease. Such an optimum density was arranged into intra - rows of either 20 or 30 cm of 2 and 3 plants/hill. On average, Acala (93)H outyielded Barac(67)B and Sudac-K by 22 and 59 percent, respectively. Sticky cotton due to honeydew secretions was thermodetectly measured, with sticky spots for Acala 93H, Barac(67)B and Sudac-K being in the ranges of 6-40, 4-22 and 0-12, respectively. Yet, for each variety the sticky spots range increased concomitantly with the increase in planting density. This was discussed in relation to variability in variety specific traits such as hairiness, glabrousness and plant canopy architecture. Nevertheless, these values were dramatically lower than those recorded internationally for the Sudan Cotton. Days to the last pick were 130,170 and 185 for Sudac-k, Barac (67) B and Acala (93) H, respectively. Accordingly, Sudac-K which is an early maturing, super-okra-leaf (SOL), highly resistant to whiteflies (Bemisia tabaci) but of comparatively low yield has emerged as a suitable choice for a short duration low management system where problems of late irrigation and build up of whiteflies are anticipated. Conversely, Acala (93)H, being hairy, physiologically efficient in compensating yield losses due to late adversities and with stay green character is best fitted into long season high management strategy.

Introduction

For more than 60 years of cotton cultivation in the Sudan, a plant population of 75000 plants/ha arranged into 80 cm inter-row, 50 cm-intra row with three plants/hill is officially recommended for both cotton species (*Gossypium barbadense* and *G. hirsutum*). Even though, in the early 1950's the current spacing practice (80 cm, 50 cm. with 3 plant/hill) was referred to as being wide and a closer spacing of 80 cm, 35 cm with 3 plants/hill (107000 plants/ha) was suggested to be better (Low, 1953). Experimental evidence, however, failed to support this hypothesis and moreover the previous findings of (Kheiralla, 1969; Fadda, 1962; Burhan and Taha, 1974) can best be summarized as being conflicting and indefinitve. On the other hand, the recommended plant population in the neighboring Egypt is 120000-150000 plants/ha with long time average seed cotton yield double that of the Sudan (personal communication). In view of the above, the re-evaluation of the plant population as related to cotton yield is needed, hence, new cotton varieties of contrasting morphologies were released. This study has therefore been focused on how the variation in morphologies of three cotton varieties affects, plant density, spatial arrangement; insects build up, growth, yield and quality parameters.

Experimental procedure

The study was conducted at Rahad Research Station for the 2000/2001 and 2001/2002 seasons. The physical and chemical properties of the experimental site were fully described by Dawelbeit and Babiker (1997). The experimental variables involved 36 treatments, representing factorial combinations of three varieties, three plants/hill and four intra-row spacings, in split-split plot design with three replications. The main plots were assigned to the number of plants /hill, the subplots to varieties and the sub-sub-plots to the intra-row spacings. The sub-sub-plot composed of 4 rows x 9 m x 0.8 m and the harvest area was 2 rows x 7 m x 0.8 m (11.2 m^2). Cultural practices other than treatments were performed as recommended by the Sudan Agricultural Research Corporation (Anonymous, 1967).

Treatments components

Plants/hill Five to seven seeds were hill dropped at sowing (first week of July) and were thinned to the required number (1, 2 or 3 plants/hill) according to treatments at two to three weeks after the effective sowing.

Varieties

Barac(67)B It is the commercial cultivar, glabrous, bushy with moderately closed canopy and medium count (MC) quality.

Acala(93)H It is hairy with closed canopy, high leaf area and of high count (HA) quality as compared to Barac(67)B. Good efforts are being directed towards market promotion of this variety as the commercial replacement for Barac(67)B.

Sudac-K It is of deep lobbing leaves with reduced leaf area representing okra leaf mutants of Upland cotton. It has a super okra leaf (SOL), whose climax leaf is reduced to a single sharp, departs the most from the normal leaf (NL) shape. It is glabrous, of open canopy and with medium count quality.

Intra-row spacings Four intra-row spacings (20, 30, 40 and 50 cm) were used.

Data collection

Plant height (cm) This was measured at harvest on five plants in each plot, from the ground surface to the highest point on the main system.

Leaf area Index (LAI) It was calculated by punching and weighting discs of known area from a 10 leaves samples per plant for five plants in each plot to give specific leaf weight (SLW) in mg/cm^2. Then the leaf area was estimated by using SLW data, which correlates leaf area to leaf weight. Then, leaf area index (LAI) was calculated as a total leaf area over ground area.

Boll size (boll weight (g)) This was calculated as the average weight of 25 unweathered, perfect open bolls randomly picked from the top, middle and bottom fruiting zones of each test plant.

Seed index (g/100 cotton seeds) This is the weight of seeds in a sample of 100 cotton seeds.

Lint index (g/100 cotton seeds) This is the weight of lint in a sample of 100 cotton seed.

Fiber quality test This was carried out by the Fibre Testing and Spinning Laboratory of the Cotton Research Program, ARC. Sudan.

Insect – pest complex Weekly observations were made on 100 leaves of each variety to count the adults and nymphs of jassids (*Jacobiasca lybica*) and adults of whiteflies (*Bemisia tabaci*).

Seed cotton yield (kg/ha) Seed cotton per harvested area (11.2 m^2) was hand picked, weighed and adjusted to kg/ha.

Plant populations The spatial arrangement of per hill treatment (1, 2, 3 plants/hill) and the intra-row spacings (20, 30, 40, and 50 cm) cumulatively resulted into different plant populations (Table 1).

Data analysis

Analysis of variance was computed for all measured attributes to test treatments differences. Regression analysis was also performed for quantifying the relationship between the yield and plant densities to determine the optimum plant density that maximize yield (SAS, 1985).

Results

Data on the seed cotton yield from the separate and the combined analysis of the two seasons exhibited the same trend of results. Accordingly, only the combined data averaged across the two seasons is presented (Table 1). Significant effects were obtained via the main treatments of plant/hill, intra-row spacing and variety but their interactions were not. Thus seed cotton yields of 2950, 3424 and 3660 kg/ha were recorded for one, two and three plants/ha, respectively. Likewise, 2584, 3355 and 4095 kg/ha were found for varieties Sudac-K, Barac (67) B and Acala (93) H, respectively. The corresponding values for 20, 30, 40 and 50 intra-row spacings were 3592, 3456, 3246 and 3084 kg/ha, respectively. Though significant differences were found due to plant population components (plant/hill and intra-row spacings) as separate main effects, their cumulative effect as planting density (Table 1) showed a consistent linear increase in seed cotton yield via increasing the number of plants/ha from 25000-125000, and thereafter, started to decrease. However, these differences were statistically not significant in the range of 75000-187000 plants/ha. Nevertheless, regression analysis exhibited a curvilinear relationship between plant density and seed cotton yield as indicated by the quadratic functions of Figures 1 and 2. Accordingly, 125000 plants/ha was estimated on average fit data to be the optimum planting density with the corresponding maximum seed cotton yield of 3895 kg/ha. For the three varieties, the number of the first fruiting node, plant height and stickiness ranges were increased by increasing plant density, whereas the SLW decreased at the highest plant density, but the number of nodes/plant were not affected (Table 2). Growth and yield attributes of the three varieties (Table 3) showed that Sudac-K had the lowest records of LAI, first fruiting node and days to the last pick as compared to the other two varieties, whereas the corresponding values for Acala (93)H were the highest. However, differences between varieties in seed index, lint index, GOT and boll weight were not significant. Data on insect load (Table 4) revealed that Acala(93)H had the lowest jassid load but the highest build up of whiteflies and was the most sticky, whereas the opposite values were recorded for Sudac-K. The values for sticky spots and whiteflies build up for variety Barac (67) B was intermediate. The fiber length and strength for Acala (93) H was of better ranges as compared to the other two varieties but of relatively high micronaire value (Table 5).

Discussion

The effect of plant population on seed cotton yield indicated that differences between a wide range of plant population (i.e 75000-187000 plants/ha) were not significant. This was in agreement of the earlier work (Burhan and Taha, 1974; Elmhadi, 1986 and Lazim, 1988). However, the data presented herein were further analyzed via fitting response function using regression analysis as suggested by (Petersen, 1977), hence, the experiment was composed of factorial combinations of three treatments at three or more levels. Accordingly, the optimum plant density was computed from the quadratic functions as shown in Figures 1 and 2. Therefore, 125000 plants/ha, though not significantly different from 75000 plant/ha was estimated on average to be the optimum for maximum seed cotton yield of 3895 kg/ha (Figure 2). The previous work (Elmahdi, 1986 and Lazim, 1988), however, only limited to the conventional analysis of variance where data on the optimum plant density were lacking. The decrease in seed cotton with the highest plant population (187000 plants/ha) as indicated by the negative sign of the quardratic coefficient of the curvilinear response function (Figure 2), may be attributed to plant competition at such a high plant density. Thus, the increases in plant growth attributes such as the first fruiting node, LAI, plant height, stickiness and the decrease in SLW values were reflections of rank growth (Table 2). Accordingly, the excessive growth enhanced the shedding of flowers at the lower nodes and increased the internode length via increasing the plant height, since, the numbers of nodes were not affected. Also, the LAI, which can be used as a measurement of light interception efficiency increased via increasing plant density with concomitant yield decrease due to shading. On the other hand, the decrease in SLW with the increase in plant density indicated that leaves of the highest density had less weight per leaf area and therefore were very thin. Accordingly, they behaved like shade leaves because of competition for light. Likewise, a trend of increase in the stickiness with increase in plant density was observed for all varieties, though relative differences between varieties were still there (Table 2). This was attributed to the favourable environment being created by the closed canopy of the highest plant density, which was more appealing to whiteflies.

Based on the data of (Tables 3 and 4), variety Sudak-K being of an open canopy, glabrous, early maturing, with super okra leaf shape and therefore, had the lowest range of stickiness. This was in agreement with Bindra (1985) who reported that switching to cultivars less favourable to the pests and more suited for efficient pesticide application would ease the cotton protection problem, hence, factors that make a cotton variety more porne to whitefly infestation are bushiness, hairiness and large leaf area. Nevertheless, commercial acceptance of the okra-leaf varieties has so far been only reported in Australia and was attributed to the high yield of the Australian-bred normal okra leaf (NOL) varieties (Thomson, 1994). Thus Acala(93)H had the highest stickiness because of hairiness and the large leaf area that provided shelter for the build up of whiteflies. On the other hand, the lowest jassid infestation observed in the Acala (93)H, was due to hairiness. Such a hairy variety may be useful when tested in the well-managed integrated crop mangement (ICM) system. The hair density will reduce the infestation by jassids early in the season offering the opportunity for the buildup of the natural enemies to control the whiteflies, which is a late season pest. This was supported by the fact that whitflies became major pest in late 1950's in the wake of DDT spraying against the cotton jassid *(Jacobiasca lybica)*. Moreover, the superiorty of Acala (93) H in fiber length and strength will widen the quality range of the Sudanese cotton, hence, both Barac (67) B and Sudac-K are of medium count, but data on quality of Acala (93) H represent high Acala (HA) count (Table 5). The low seed cotton yield of Sudac-K as compared to other varieties was also reported by (Hamada and Knapp, 1998). Despite, the low seed cotton yield of Sudac-K, it can best be suited into short duration mangement where late season problems of water shortage and insect pests are anticipated. Such a reduced season approach will maximize the economic yield because; additional costs of late irrigation, pest control, labor and mangement will be avoided. In practice, however, Sudac-K was not commercially adopted due to its low yield, despite its non-sticky lint, therefore future research should be embarked upon breeding for normal okra leaf (NOL) with medium hair (low jassid infestation) and of comparatively high yield than the prevailing Sudac-K of super okra leaf (SOL) type. On the other hand, the potentially high yielding Acala (93)H, can best be fitted into long season cropping system due to its stay green character, high leaf area, better boll retention, adaptation to ICM and, hence, tolerance to late season adversities .

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Figure 1. *Plant density as related to seed cotton yield.*

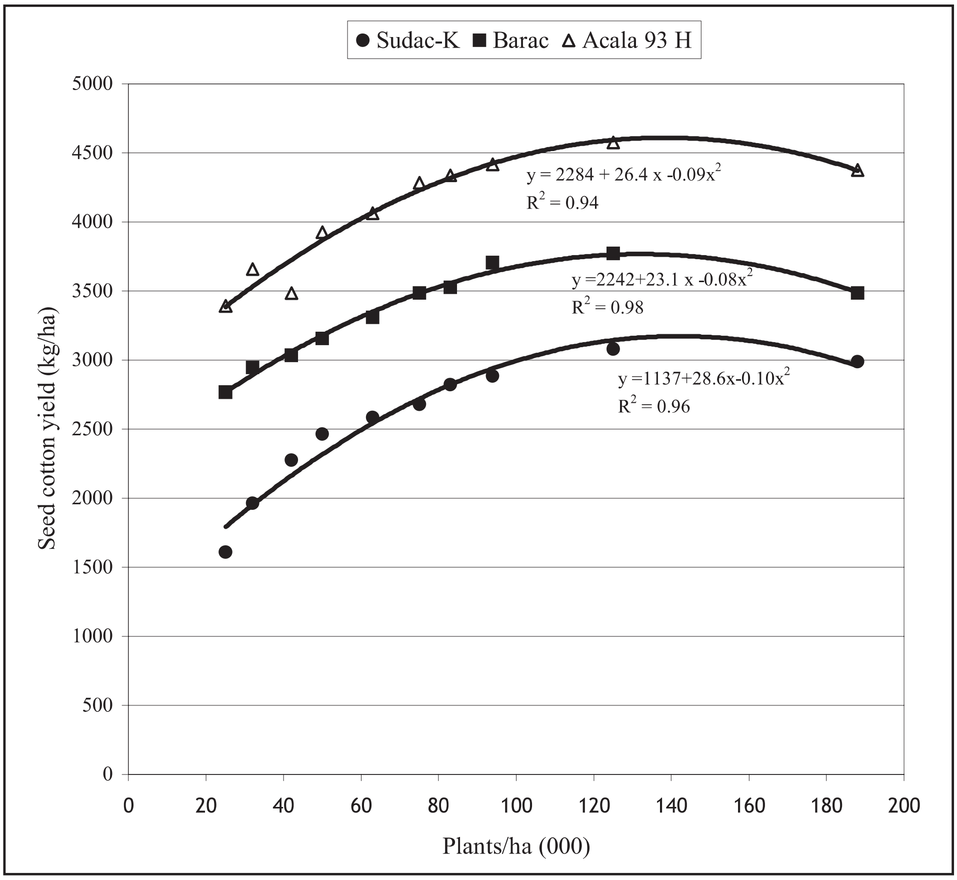

Figure 2. *Plant density as related to seed cotton yield averaged across varieties.*

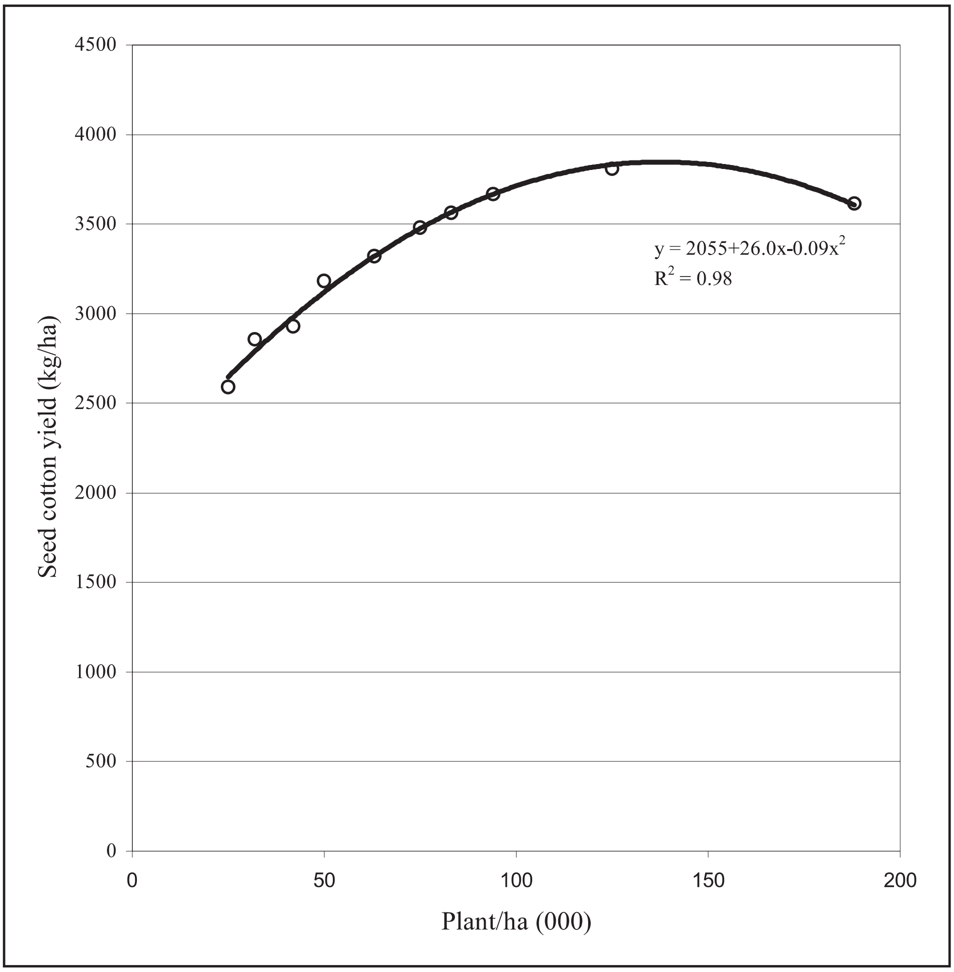

Table 1. Effect of plant density with varying spatial arrangement on seed cotton yield (kg/ha) of three varieties.

Plant density	Spatial arrangement	Variety			Main effects	
(000 plant/ha)	(plant/intra-rows (cm))	Sudac-K	Barac(67)B	Acala (93)H	Intra-rows (cm)	kg/ha
					20	3592
			(±146)		30	3456
					40	3246
25	1 × 50	1607	2768	3392	50	3084
32	1 × 40	1964	2946	3660		(±49)
42	1 × 30	2275	3034	3482		
50	2 × 50	2463	3154	3927	Plant/hill	
63	2 × 40	2500	3302	3838	1	2950
63	1 × 20	2670	3316	4284	2	3424
75	3 × 50	2678	3482	4284	3	3660
83	2 × 30	2820	3525	4339		(±42)
94	3 × 40	2882	3703	4417		
125	3 × 30	3112	3882	4637	Variety	
125	2 × 20	3048	3662	4507		
187	3 × 20	2989	3482	4374	Sudac-K	2584
					Barac(67)B	3355
					Acala(93)H	4095
						(±42)

Table 2. Effect of slected plant densities on growth and yield of three cotton varieties.

Variety	Plant density (000 plants/ha)	Seed cotton (kg/ha)	First fruiting node	Plant height (cm)	LAI	SLW (g/cm^2)	Nodes (No./plant)	Stickiness (No. of sticky spots)
Sudac-K	25	1607	5	64	2.0	2.8	17	0-2
	75	2678	5	70	2.5	3.0	17	3-6
	125	3080	6	76	3.0	3.2	17	4-8
	187	2989	8	84	3.6	3.0	17	7-12
Barac(67)B	25	2768	6	62	2.6	3.2	19	4-9
	75	3482	6	67	3.0	3.5	19	6-11
	125	3772	7	74	3.6	3.9	19	9-13
	187	3482	8	80	4.2	3.5	19	12-22
Acala (93)H	25	3392	7	87	3.5	4.0	22	6-9
	75	4284	7	92	3.8	4.4	22	7-13
	125	4574	8	103	4.2	4.7	22	11-21
	187	4374	8	118	5.0	4.3	22	22-40
S.E(±)	-	146	0.3	5	0.18	0.12	0.6	-

Table 3. *Growth and yield parameters of three cotton varieties.*

Variety	L.A.I	First Fruiting node	Days to the last pick	Plant height (cm)	Seed index (g)	Lint index (g)	GOT (%)	Boll wt. (g)
Sudac-K	2.4	5	130	70	12	7.5	38	5.6
Barac (67)B	3.0	6	170	67	11.8	7.6	39	5.8
Acala (93)H	3.8	7	185	92	11.9	7.1	37	5.3
S.E(±)	0.18	0.3	4.7	5	0.3	0.26	1.2	0.3

Table 4. *Ranges and average numbers per 100 leaves of jassdis, whiteflies and sticky spots.*

Variety	Jassids		Whiteflies		Sticky spots	
	Range	Average	Range	Average	Range	Average
Sudac-K	43-985	164	8-66	38	0-12	4
Barac(67)B	24-950	156	12-160	82	4-22	12
Acala(93)H	8-98	40	16-388	128	6-40	28

Table 5. *Fiber characteristics of three varieties tested at ARC Fiber Testing Laboratory.*

Variety	Length		Fineness/maturity	Stelometer
	2.5%S.L (mm)	UR (%)	(Microniare value)	(g/tex)
Sudac-K	26.3-28.7	47-50	4.2-4.4	20-23
Barac (67)B	26.3-28.6	47-50	4.2-4.4	20-24
Acala (93)H	29.1-30.2	47-50	4.2-4.6	21-25