Gezira J. of Agric. Sci. 2(**1**): 16-25 (2004)

Effect of Plant Density and Spatial Arrangement on Growth, Quality and Yield of Morphologically Varying Cotton Varieties

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ABSTRACT

Field experiments were conducted at Rahad Research Station for two seasons (2000/2001 and 2001/2002) focusing on how the variation in genotypes, plant density and spatial arrangement affects cotton yield and quality . The combined analysis indicated significant responses due to main effects but their interactions were not. Regression analysis for plant density-yield 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 achieved by planting 3 plants/hill spaced at 30cm intra-row spacing. On average, Acala (93)H out-yielded Barac (67)B and Sudac-K by 22% and 59%, 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, 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, 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 (Nour 93), being hairy, physiologically efficient in compensating for 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 x 50cm intra-row with three plants/hill, is still officially recommended for both cotton species (*Gossypium barbadense* and *G. hirsutum*). Even though, in the early 1950's the current spacing practice (80 x 50 cm with 3 plants/hill) was referred to as being wide and a closer spacing of 80 x 35cm with 3 plants/hill (107000 plants/ha) was suggested to be better (Low, 1953). Experimental evidence, however, failed to support this hypothesis (Fadda,1962; Kheiralla, 1969; Burhan and Taha, 1974) and can best be summarized as being conflicting and indefinite. On the other hand, the recommended plant population in the neighbouring 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 for the newly released cotton varieties of contrasting morphologies. This study has, therefore, been focused on the effects of plant density and spatial arrangement on insect pests build up, yield and quality of three cotton cultivars.

MATERIALS AND METHODS

The study was conducted at Rahad Research Station for two seasons (2000/1)and 2001/02). The physical and chemical properties of the experimental site was fully described by Dawelbeit and Babiker (1997). The experimental variables involved 36 treatments, representing factorial combinations of three varieties (Sudac-K, Barac (67) B and Acala (93) H), three planting densities/hill (1,2 and3) and four intra-row spacings (20, 30, 40 and 50cm) in a 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 0.8m apart and 9m long and the harvested area was (11.2m^2). Cultural practice other than treatments were performed as recommended by the Sudan Agricultural Research Corporation (Anon, 1967). Data were collect on the following:

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l. Plant height (cm): Measured at harvest on five plants in each plot, from the ground surface to the highest point on the main stem.

2. Leaf area Index (LAI): It was calculated by punching and weighing discs of known area from 10- leaf samples per plant for five plants in each plot with three replications per treatment to give specific leaf weight (SLW) in mg/cm2. Then the leaf area was estimated by using SLW data which correlates leaf area to leaf weight. The leaf area index (LAI) was calculated as a total leaf area over ground area.

3. Bell size (boll weight(g)): Calculated as the average weight of 25 unweathered, perfect open bolls randomly picked from the top, middle and bottom fruiting zones of five plants in each plot with three replications per treatment.

4. Seed index (g/ 100 cotton seeds): Weight of seeds in a sample of 100 cotton seeds from five plants in each plot with three replications per treatment.

5. Lint index (g/ 100 cotton seeds): Weight of lint in a sample of 100 cotton seeds from five plants in each plot with three replications per treatment.

6. Fibre quality test: This was carried out by the Fibre Testing and Spinning Laboratory of the Cotton Research Program, ARC، Sudan. The sample size was h kg lint cotton from each plot with three replications per treatment.

7. 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*).

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

RESULTS

The seed cotton yield from the separate and the combined analysis of the two seasons exhibited similar trends. Accordingly, only the combined data averaged across the, two seasons is presented (Table l): Significant effects were obtained for the main treatments of plants/hill, intra-row spacings and variety but their interactions were not. Though significant differences were found due to plant population components (plants/hill and intra-row spacings) as separate main effects,

Table 1. Main effects of intra-row spacing, plant/hill and variety on seed cotton yield (kg/ha)across seasons.

Intra-rows (cm)	Seed cotton yield(kg/ha)	Plants/hill	Seed cotton Yield(kg/ha)	Variety	Seed Cotton yield (kg/ha)
20	3592	1	2950	Sudac-K	2584
30	3456	2	3424	Barac(67)B	3355
40	3246	3	3660	Acala(93)H	4095
50	3084				
SE(±)	49		42		42

their cumulative effect as planting density showed a consistent linear increase in seed cotton yield via increasing the number of plants/ha from 25000 to125000, and thereafter, started to decrease. However, these differences were statistically not significant in the range of 75000 to 187000 plants/ha. Nevertheless, regression analysis exhibited a curvilinear relationship between plant density and seed cotton yield as indicated by the quadratic function of Figure 1. Accordingly، 125000 plants/ha was estimated to be the optimum plant population with a planting density of 3 plants/hill 30cm apart (Table I and Fig l).

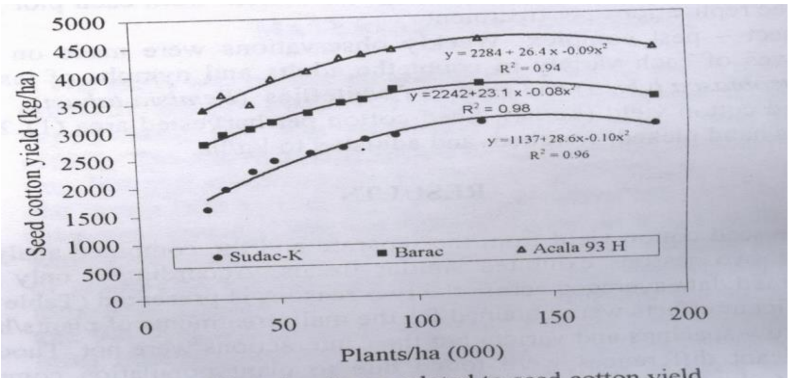

Fig 1 . Plant density as related to seed cotton yield

For the three varieties , the number of the first fruiting node, plant height and stickiness ranges were increased by increasing plant population, 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 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, G.O.T and boll weight were not significant.

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

Variety	Plant Density (000plants/ha)	Seed Cotton (kg/ha)	First Fruiting node	Plant height (cm)	LAL	SLW $(g/cm)^2$	Nodes (no/plant)	Stickiness (no. of sticky Spots/sample
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	0.2	0.1	0.6	

Table 3. Mean growth and yield parameters of cotton varieties.

Variety	LAL	First Fruiting node	Day to the last pick	Plant height(cm)	Seed index(g)	Lint index (g)	GOT (%)	Boll wt. (g)
Sudac-k	2.4	5	130	70	12.0	7.5	38	5.6
Barac			170		2.5			
(67)B	3.0	6	6	67	3.0	39	39	5.8
Acala					3.6			
(93)H	3.8	7	185	92		37	37	5.3
S.E(±)	0.2	0.3	4.7	5	2.6	1.2	2ز1	0.3

Data on insect pests (Table 4) revealed that Acala(93)H had the lowest jassid count 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 were intermediate. The fibre length and strength for Acala (93)H were of better ranges as compared to the other two varieties but of relatively high micronaire value (Table 5).

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. Range of fibre characteristics of three varieties tested at Agricultural Research Corporation Fibre Testing Laboratory.

Variety	Length 2.5%S.L (mm)	UR(%)	Fineness/maturity (Microniare value)	Stelometer (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

DISCUSSION

The effect of plant population on seed cotton yield indicated that differences between a wide range of plant populations (i.e., 75000-187000 plants/ha) were not significant. This was in agreement of earlier work (Burhan and Taha, 1974; Elmahadi, 1986; Lazim, 1988). However, the data presented herein were further analyzed via fitting a response function curve using regression analysis as suggested by (Petersen, 1977). Accordingly, the optimum plant density was computed from the quadratic functions as shown in Fig. l. Therefore, 125000 plants/ha, though not significantly different from 75000 plants/ha was estimated on average to be the optimum for maximum seed cotton yield of 3895 kg/ha. The previous work (Elmahadi,1986; Lazim, 1988), however, was 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, 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 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.

The LAI which can be used as a measurement of light interception efficiency increased via increasing plant density with concomitant yield decrease after the plant population increased above 125000 plants/ha 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 which make a cotton variety more prone to whiteflies 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 management (ICM) system. The superiorty of Acala(93)H in fibre 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 (Table5).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 cropping system 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, labour and management 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 .0n 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

In conclusion, the three varieties responded similarly to the planting density and spatial arrangement, despite their contrasting morphologies. Even though varietal differences in seed cotton yield, insect-pest complex and quality were exhibited. Hence, the high yielding Acala(93)H with its new quality range (HA) is gradually replacing the aging variety Barac(67)B under the commercial name (Nour 93) as an appropriate ICM cultivar for the high input cropping systems. On the other hand, Sudac-K can best be fitted into a reduced system approach, particularly in locations prone to whiteflies infestation. It was suggested that future research should be focused on breeding for high yielding okra-leaf varieties and tailoring the leaf area of Acla (93)H without depressing yield.

ACKNOWLEDGEMENT

Professors A. A. Hamada, H. O. Kanan and A. H. Latif, have been involved in some aspects of this work, and their contributions are acknowledged with appreciation.

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