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Performance of cotton under varied plant densities and spatial arrangements

P. Elobu, J.F. Orwangga, J.R. Ocan and G.W. Opolot
National Agricultural Research Organisation(NARO), P.O. Box 295 Entebbe, Uganda
Serere Agricultural and Animal Production Research Institute (SAARI), P.O. Soroti, Uganda

Abstract

Cotton (*Gossypium hirsutum* L.) Cv. SATU 85, was grown at five row spacings, three intra-row spacings and thinned to either one or two plants per stand at Serere Agricultural and Animal Production Research Institute (SAARI), Uganda during the 1993 and 1994 cotton seasons. Plants spaced widely within the rows produced more monopodia, sympodia and bolls per plant, but fewer per m^2. Fewer fruiting bodies aborted with the widely spaced rows. Leaf area indices (LAI) were highest with narrowly spaced plants and LAI decreased with increased row and intra-row widths. Total seed cotton yields from the row spacings of 60, 75 and 90 cm did not differ significantly but yield was higher and lower respectively, with 105 cm and 45 cm row spacings. Graded ("safi") seed cotton yield was not significantly affected by row spacing. Seed cotton yield, both total and graded, decreased as intra-row spacing increased.

Key words: *Gossypium hirsutum,* plant density, row spacing, , seed cotton

Introduction

In Uganda, cotton is produced in two distinct production zones; the Bukalasa Pedigree Albar (BPA) zone in southern and western Uganda and the Serere Albar Type Uganda (SATU) zone in northern and eastern parts. Zonal cultural practices differ because of differences in climate, soil type, vegetation and farming systems(Walton, 1962). In the BPA zone the recommended spacing is 90 x 30 cm while in the SATU zone it is 60 x 30 cm. Walton (1962) recommended high plant populations in sprayed cotton to take advantage of the reduced number of insect pests. He also argued that high plant populations reduced bolls per plant, consequently reducing the duration of picking, besides quick development of a full canopy that suppressed weeds. These recommendations preceeded more recent variety releases and were based on purely monocrop systems.

The current situation is different; insecticide use is lower, current commercial varieties appear to be poorly adapted to high plant populations under which vegetative growth is excessive, and cotton is commonly intercropped to reduce risks associated with poor marketing. Walton (1962) also recommended the planting of at least five seeds per hole, but current scarcity of improved seed makes this recommendation uneconomical. Ways of improving the yield per seed planted in order to increase the seed out turn from the current 18% to at least 30% need to be devised.

Elsewhere, various reports are available about the effects of spacing on cotton performance. Sastrosupadi and Oesman (1977) reported a quadratic relationship between plant density and yield, and concluded that cotton tolerates a wide range of row and intra-row spacings and plant densities. Kerby and Buxton (1981) reported increased boll abortion with increased plant populations. Tharp (1960) indicated that close spacing between plants led to smaller bolls but increased yield primarily through more bolls per m^{-2}. Marani et al. (1974) tested six upland cotton cultivars under varying intra-row spacings and reported that plant spacing had no significant effect on boll weight, boll retention, fibre length, uniformity, fibre strength or fibre fineness. Bilro (1981) using intra-row spacings of 5, 10, 15, 20 and 25 cm at constant 100 cm row spacing, obtained reduced lint yield with wider spacing in three of five years, and bolls per plant increased with wider spacing. Galanopoulou-Sendouka et al. (1980) compared row spacings of 100, 50 and 25 cm all at intra-row spacings of 10 cm and found reduced leaf efficiencies, more fruit shedding and smaller boll size with the high density, and more consistency and high yield compared with medium density.

The objective of this research was to review the recommended row and inter-row spacings with one new cotton variety and changing weather patterns for improved yield and quality, and increased yield per seed planted.

Materials and methods

Cotton, Cv. SATU-85, was planted at SAARI on 27th April and 14th June 1993, and on 11th April and 11th May 1994 at different plant densities and spatial arrangements. Prior to planting the land was ploughed, reploughed and disc harrowed to produce a fine seed bed. Plots measured 7.2 x 6.0 m. SATU-85, a recently released variety is moderately resistante to bacterial blight (*Xanthomonas malvacearum*), grows to 1.5 metres and matures in five to six months.

Row spacings were 45, 60, 75, 90 and 105 cm and intra-row spacings were 15, 30 and 45 cm. At 14 days after planting (DAP), plants were thinned to either one or two plants per stand. A split-split-plot design was used with row spacing in the main plots, intra-row spacing in the sub-plots and plants per stand in the sub-sub plots. The experiment was replicated four times except in the second planting in 1993 where it was replicated three times.

Data was analysed using MStat Computer programme and mean separation done by least significant difference(LSD)

Starting 60 DAP, squares, flowers and bolls were counted to determine earliness in boll setting. Leaf area indices (LAI) were determined using the disc method described by Edje and Osiru (1987) at 60 and 120 DAP. At harvest time monopodia, sympodia, bolls and all fruiting positions (FPs) were counted from four plant stands in the middle rows of each plot. Data on number of bolls that contributed to final seed cotton yields, and FPs were used to determine percentage abortion of squares and young bolls: Abortion = (FPs-Bolls)/FPsx100.

Thirty five plants were tagged in each plot and all seed cotton picked, sorted and weighed to determine total and graded seed cotton yields. Total seed cotton yields did not distinguish between the clean "safi" and the stained "fifi". This yield is important as an indicator of the total seed production potential of cotton, since even "fifi" cotton contains seed, though of lower viability due to pest damage and immaturity. Graded "safi" yield reflects farmers' revenues as cotton buyers pay much more for "safi" compared to "fifi" cotton.

Results and discussion

Irrespective of treatment, square formation started 45 DAP and with full bloom around 60 DAP. Boll formation

Table 1. The effects of five row and three intra-row spacings(IRS in cm) on number of cotton monopodia per plant when thinned to two or one plant(s) per stand at SAARI in 1993 and 1994

IRS (cm)	Row spacing (cm)										mean
	45		60		75		90		105		
	Plants per stand										
	2	1	2	1	2	1	2	1	2	1	
15	0.4	0.9	0.8	1.6	1.0	1.7	1.1	1.6	1.3	1.7	1.2c
30	0.6	1.2	1.1	1.7	1.1	1.8	1.2	2.1	1.5	2.1	1.4b
45	0.7	1.5	1.3	2.1	1.3	1.9	1.2	2.1	1.6	2.2	1.6a
Stand mean	0.6	1.2	1.1	1.8	1.1	1.8	1.2	1.9	1.5	2.0	
Row mean	0.9y		1.5x		1.4x		1.5x		1.7w		

abc. Means bearing the same letter in a column are not significantly ($P \leq 0.05$) different.
wxy. Means bearing the same letter in a row are not significantly ($P \leq 0.05$) different.
Data are means of the four seasons in 1993 and 1994.

Table 2. Effects of five row and three intra-row spacings (IRS in cm) on cotton plant height (cm) at SAARI in 1993 and 1994

IRS(cm)	Row spacing (cm)					Mean
	45	60	75	90	105	
15	109.6 c	114.9 c	123.7 b	131.0 b	132.0 a	122.2 c
30	118.9 b	127.0 b	127.6 b	147.0 a	127.5 b	128.8 b
45	133.8 a	131.7 a	143.8 a	132.5 b	127.9 b	133.9 a
Mean	120.8 z	124.5 yz	131.7 x	136.8 w	127.6 xy	---------

abc. Means bearing the same letter in a column are not significantly ($P \leq 0.05$) different.
wxyz. Means bearing the same letter(s) in a row are not significantly ($P \leq 0.05$) different.
Data are means of the four seasons 1993 and 1994. LSD between interaction means=8.3.

continued to 180 DAP, while soil moisture was available, but the later formed bolls were smaller. Bolls formed between 60 and 90 DAP constituted the major proportion of the yield.

Widening row and intra-row spacings significantly ($P \leq 0.05$) increased monopodia $plant^{-1}$ (Table 1). Main effects of number of plants per stand and their interactions with the other factors were not significant, but monopodia $plant^{-1}$ were always more with one plant per stand.

Plant height was less with higher plant density, and was greatest from 90 cm row spacing (Table 2).

Both row spacing and plants per stand did not affect sympodia and FPs $plant^{-1}$. However, increasing the intra-row spacing significantly reduced the numbers of sympodia and FPs per plant and significantly ($P \leq 0.05$) increased them on per area basis (Table 3).

Increasing both row and intra-row spacings, and thinning to one plant always significantly ($P \leq 0.05$) increased the number of bolls per plant (Table 4). Although the number of bolls per unit area got reduced with increase in both row and intra-row spacings, the main effects of row spacings was not significant (Table 5).

Row spacing and number of plants per stand did not significantly affect abortion of fruiting bodies, although abortion was significantly ($P \leq 0.05$) higher at the 15 compared to the 30 and the 45 cm intra-row spacings (Table 3). Inspite of this high degree of abortion at the 15 cm intra-row spacing, the yields were higher (Tables 6 and 7) mainly as a result of the increased number of bolls per unit area. These observations confirm earlier findings (Kerby and Buxton, 1981; Walton, 1962) that competition between the individual plants is so high at the high plant densities resulting into reduced formation of fruiting bodies. Nevertheless, the high number of plants at such densities augment the competition, leading to increased performance of the plants on per area basis.

At 60 DAP, the closely spaced plants and thinned to two plants per stand had higher LAI values compared to the widely spaced plants and thinned to one plant per plant (Table 8). At 120 DAP the trends were similar except

Table 3. Effects of three cotton intra-row spacings(IRS in cm) on abortion of fruiting bodies, numbers of sympodia per plant and per square metre, and number of fruiting positions (FPs) per plant and per square metre at SAARI in 1993 and 1994

IRS(cm)	Abortion (%)	Sympodia		Fruiting positions	
		$plant^{-1}$	m^{-2}	$plant^{-1}$	m^{-2}
15	74.6 a	11.8 c	154.3 a	22.1 c	270.2 a
30	72.9 b	14.9 b	95.4 b	27.3 b	174.2 b
45	72.5 b	16.1 a	73.5 c	33.9 a	146.7 c
Mean	73.3	14.0	107.7	27.8	197.0
LSD	1.0	0.9	12.1	1.8	12.1

abc. Means bearing the same letter in a column are not significantly ($P \leq 0.05$) different.
Data are means of the four seasons in 1993 and 1994.

Table 4. Effects of five row and three intra-row spacings(IRS in cm) on number of cotton bolls per plant when thinned to two or one plant(s) per stand at SAARI in 1993 and 1994

IRS (cm)	Row spacing (cm)										Mean
	45		60		75		90		105		
	Plants per stand										
	2	1	2	1	2	1	2	1	2	1	
15	1.6	3.3	3.1	5.8	4.0	7.1	4.9	8.5	7.0	11.4	5.7 c
30	2.9	5.5	5.0	8.3	5.4	9.4	6.1	11.6	7.4	11.6	7.3 b
45	4.1	6.8	5.9	10.9	6.2	11.5	6.7	12.3	8.0	18.0	9.0 a
Stand mean	2.9	5.2	4.7	8.3	5.2	9.4	5.9	10.9	7.4	13.7	------
Row mean	4.0 z		6.5 y		7.3 x		8.3 w		10.6 v		

abc. Means bearing the same letter in a column are not significantly ($P \leq 0.05$) different.
xyz. Means with the same letter in a row are not significantly ($P \leq 0.05$) different.
LSD between stand means 0.9. Data are means of the four seasons in 1993 and 1994.

Table 5. Effects of five row and three intra-row spacings(IRS in cm) on number of cotton bolls/m2 at SAARI in 1993 and 1994

IRS (cm)	Row spacing (cm)					Mean
	45	60	75	90	105	
15	48.0 a	66.8 a	66.8 a	67.6 a	80.5 a	65.9 a
30	41.5 b	50.6 b	45.0 b	44.2 b	41.9 b	44.6 b
45	37.0 b	42.0 c	35.5 c	31.6 c	36.0 c	36.9 c
Mean	42.1 ns	53.1 ns	49.1 ns	47.8 ns	52.8 ns	-------

abc. Means with the same letter in a column are not significantly ($P \leq 0.05$) different.
LSD between interaction means = 6.2. Data are means of the four seasons in 1993 and 1994.

Table 6. Effects of five row and three intra-row spacings (IRS in cm) on total seed cotton yield (kg ha^{-1}) when thinned to two or one plant(s) per stand at SAARI in 1993 and 1994

IRS (cm)	Row spacing (cm)										Mean
	45		60		75		90		105		
	Plants per stand										
	2	1	2	1	2	1	2	1	2	1	
15	1102.0	2148.9	2356.3	2547.7	2227.6	2439.7	2839.4	2457.5	3004.1	3024.3	2414.7 a
30	1450.3	1613.2	2102.5	2041.3	2056.1	2187.4	1970.2	2112.2	2879.9	2798.0	2121.1 b
45	1366.3	1499.9	1898.9	1770.1	2041.6	1831.1	1827.4	1639.8	2270.9	1814.6	1796.1 c
Mean	1306.2	1754.1	2119.3	2119.7	2108.4	2152.7	2212.3	2069.8	2718.3	2547.7	
Row mean	1530.8 z		2119.5 y		2130.6 y		2140.13 y		2631.0 x		

abc. Means bearing the same letter in a column are not significantly ($P \leq 0.05$) different.
xyz. Means with the same letter in a row are not significantly ($P \leq 0.05$) different.
LSD between stand means = 138.4 Data are means of the four seasons in 1993 and 1994.

Table 7. Effects of five row and three intra-row spacings (IRS in cm) on "safi" seed cotton yield (kg ha^{-1}) when thinned to two or one plant(s) per stand at SAARI in 1993 and 1994

IRS (cm)	Row spacing (cm)										Mean
	45		60		75		90		105		
	Plants per stand										
	2	1	2	1	2	1	2	1	2	1	
15	1263.6	1615.8	2054.4	2220.8	1959.7	2074.0	2328.0	2083.7	1806.6	1889.8	1929.6 a
30	1060.4	1248.6	1751.2	1674.6	1722.2	1855.6	1696.4	1879.1	1783.4	1555.6	1623.0 b
45	851.0	1221.3	1593.1	1514.6	1769.5	1722.4	1511.1	1366.5	1338.4	1102.5	1399.0 c
Mean	1058.3	1361.9	1800.5	1803.3	1817.1	1884.0	1845.1	1776.1	1642.8	1516.0	----------
Row Mean	1210.1 ns		1809.9 ns		1850.6 ns		1810.8 ns		1579.4 ns		---------

abc: Means with the same letter in a column are not significantly ($p \leq 0.05$) different .
LSD between stands means=141.5. Data are means of the four seasons in 1993 and 1994.

LAI values were lower (Table 9), suggesting increased senescence of the older leaves or reduced size of the newly formed ones, or both. This was probably due to an increase in number and size of bolls leading to priority in assimilate partitioning being given to the bolls. Results here are in agreement with Galanopoulo-Sendauka et al.(1980) who concluded that some of the advantages of the high plant densities were higher LAI values and earlier canopy closure.

Change in row spacing did not have significant effect on "safi" (Table 7). Yields increased with increase in row widths to 75 cm spacing and then progressively declined, although the differences were not significant ($P \leq 0.05$). In northern and eastern Uganda, this insignificant yield response to different row spacings could be important because the wider rows of 75 and 90 cm might permit more successful planting of food crops between the cotton rows compared to the recommended 60 cm spacings. An earlier study (Elobu, et al., 1995) showned a good recovery of cotton after bean harvest when the two are intercropped, especially at wider row spacings.

Total seed cotton yield was least at 45 cm row spacing with two plants per hole but at 60, 75 and 90 cm spacings, differences were not significant. The highest total seed cotton yield was recorded with the 105 cm row spacing where plants were larger and produced more branches, hence more bolls (Tables 1 and 4) over a longer period of time. However, the late formed bolls under this wide spacing were of low quality due to increased pest population and termination of further growth with the onset of drought. The former led to more staining of the cotton while the latter resulted into a bigger proportion of immature bolls. These essentially contributed more to "fifi" than to "safi" yields. But "fifi" cotton contains useful seed implying that

Table 8. Effects of five row and three intra-row spacings(IRS in cm) on leaf area indices of cotton at 60 DAP when thinned to two or one plant(s) per stand at SAARI in 1993 and 1994

IRS(cm)	Row spacing (cm)										Mean
	45		60		75		90		105		
	Plants per stand										
	2	1	2	1	2	1	2	1	2	1	
15	3.9	3.1	3.8	3.2	3.2	2.5	3.1	2.6	3.8	2.4	3.1 c
30	2.4	1.9	2.7	2.1	2.3	1.9	2.0	1.8	1.8	1.4	2.0 b
45	1.9	1.3	2.0	1.3	1.8	1.3	1.4	1.3	1.2	1.0	1.5 c
Stand mean	2.7 x	2.1y	2.9 x	2.2y	2.5x	1.9 z	2.1y	1.9 z	2.3y	1.6 z	-
Row mean	2.4 ns		2.5 ns		2.2 ns		2.0 ns		1.9 ns		2.2

abc: Means with the same letter in a column are not significantly($P \leq 0.05$) different.
xyz: Means with the same letter in a row are not significantly ($P < 0.05$) different.
LSD between stand means = 0.3. Data are means of the four seasons in 1993 and 1994.

Table 9. Effects of five row and three intra-row spacings(IRS in cm) on leaf area indices of cotton at 120 DAP when thinned to two or one plant(s) per stand at SAARI in 1993 and 1994

IRS(cm)	Row spacing (cm)										Mean
	45		60		75		90		105		
	Plants per stand										
	2	1	2	1	2	1	2	1	2	1	
15	3.5	4.1	3.3	3.1	3.3	3.1	3.2	2.8	2.5	2.2	3.1 c
30	2.9	2.2	2.4	2.4	2.6	2.1	2.6	2.2	1.5	1.3	2.2 b
45	3.1	2.5	1.8	2.1	1.9	1.9	1.6	2.0	1.0	0.9	1.9 c
Stand mean	3.1	3.0	2.5	2.5	2.5	2.4	2.5	2.3	1.7	1.4	-
Row mean	3.0 x		2.5 y		2.4 y		2.4 y		1.6 z		2.4

abc: Means bearing the same letterin a column are not significantly ($P \leq 0.05$) different.
wxyz. Means with the same letter in a row are not significantly different($P \leq 0.05$).
Data are means of the four seasons in 1993 and 1994.

when the primary objective is seed multiplication, the use of wide spacing may be advantageous. However early planting is required to allow adequate time for late formed bolls to mature. Trials at Namulonge (Innes, 1970) indicated that, although bigger and more mature cotton seeds from sorted cotton germinated better and produced seedlings of higher vigour in BPA and SATU compared to seed from unsorted cotton, the trend was different with yields. He observed that in BPA, when cotton was grown from sorted seed, yields were higher than those from unsorted seed. But for SATU the reverse was reported, although yields were insignificantly different.

Total and "safi" seed cotton yields had good correlations with numbers of monopodia m^{-2} ($r = 0.62$ and 0.59 respectively) and number of bolls m^{-2} ($r = 0.51$ and 0.68 respectively). LAI at 60 DAP was also highly correlated to "safi" seed cotton yield (0.55) but not to total seed cotton yield ($r = 0.36$).

In conclusion, therefore, if "safi" seed cotton is the primary production objective in the SATU area, cotton should be spaced 75 cm between rows, 15 cm within rows and thinned to one plant per stand. One seed per hole could be dropped during planting at such narrow intra-row spacing especially if machine planted, hence reducing on seed wastage and cutting off thinning costs. If on the other hand, the primary production objective is seed multiplication, rows as wide as 105 cm can lead to a higher seed out turn in early planted cotton.

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