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Fruiting Pattern in Narrow-Row Cotton[1]

D. R. Buxton, L. L. Patterson, and R. E. Briggs[2]

ABSTRACT

Previous research with narrow-row cotton (*Gossypium hirsutum* L.) has concentrated on end-of-season effects on yield and fiber characteristics with little attention given to seasonal fruiting patterns. Our objective was to monitor the seasonal fruiting pattern of cotton planted at various combinations of row spacings and plant densities. 'Deltapine 16' was grown 3 years on one or two rows per beds that were either 76 or 102 cm from center to center with densities of 7.4, 14.8, and 22.2 plants/m². The plots were divided into flower tagged (tagged plots) and yield portions (yield plots). In the tagged plots, flowers were tagged daily with the date of anthesis. Open bolls were harvested weekly and assigned to weekly flowering intervals before being analyzed for boll and fiber properties. Before harvesting the yield plots, we also took open boll samples to be analyzed for boll and fiber properties. At equivalent plant densities in the yield plots, two rows per bed resulted in up to 11% more seedcotton than one row per bed. Plant density had no significant effect on yield. In the tagged plots, seasonal flower and boll production was higher from two rows per bed than one row per bed with differences ranging from 8 to 22% more flowers and 2 to 12% more bolls, depending upon bed size and plant density. The seedcotton yield advantage of two rows per bed was near maximal from bolls that were set (flowered) by late July; thereafter the production rate on one and two rows per bed was similar. Boll period (time from flowering to open boll) was increased slightly by high plant density. Boll size, lint index, seed index, fiber strength, and fiber fineness from the yield plots were all significantly reduced by increases in plant density, although the average effects were less than 5%. While fruiting pattern and yield were primarily influenced by row spacing, plant density had the greatest influence on boll and fiber properties.

***Additional index words:* *Gossypium hirsutum*, Narrow rows, Flower tagging, Nitrate nitrogen, Boll period, Seedcotton yield, Boll size, Lint index, Seed index, Fiber strength, Fiber fineness, Boll set.**

NARROW-ROW culture is a promising practice for increasing cotton (*Gossypium hirsutum* L.) yield and/or reducing production costs (4, 10, 11, 14, 15, 18, 23, 24, 25). Although all U.S. cotton producing regions have experimented with the production system, the more promising results have occurred in arid regions where irrigations can be timed to control vegetative growth, where growing seasons are short, or where environmental stresses such as salty soils or diseases limit vegetative growth. Yield enhancement from narrow-row cotton has been inconsistent in the southeastern rainbelt of the U.S. (1, 9, 27).

Most boll and fiber properties have been relatively unaffected by plant densities and row spacings commonly used in narrow-row culture (1, 4, 5, 6, 14, 19). The most common effect is a reduction in fiber fineness and boll size as a result of increased plant density.

At equivalent plant densities, narrow-row culture offers the advantage of a more satisfactory spatial arrangement with less interplant competition and greater solar radiation interception early in the season than conventional plantings with rows about 1-m apart. Most work with narrow-rows has concentrated on final yield and end-of-season boll and fiber properties with little attention given to seasonal fruiting patterns. In addition, in many of these studies the effects of row width have not been evaluated independent of the effects of plant density. In our study, boll set was monitored throughout the fruiting season which allows a detailed evaluation of the dynamic influence of both plant density and row spacing on yield and boll and fiber properties. This information should be helpful for making decisions regarding narrow-row cotton management.

MATERIALS AND METHODS

Three studies were conducted at the University of Arizona Cotton Research Center at Phoenix. 'Deltapine 16' was planted at a high seeding rate on 7 Apr. 1970, 30 and 31 Mar. 1971, and 20 and 24 Mar. 1972 in a fine loamy, mixed hyperthermic family of Torrifluventic Haplustolls (Avondale clay loam) after preplant irrigations. Nitrogen was applied preplant at 67, 90, and 84 kg/ha in 1970, 1971, and 1972, respectively. In addition, 28 kg/ha of N was applied 6 June 1972. Weeds were controlled with preplant applications of trifluralin (α,α,α,-trifluoro-2, 6-dinitro-*N*, *N*-dipropyl-p-toluidine), diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea], and handweeding as necessary.

One or two rows per bed were planted on beds that were either 76 or 102 cm from center to center. The two rows per bed were 15 cm apart on the 76-cm beds and 30 cm apart on the 102-cm beds in 1970 and 36 cm apart on the 102-cm beds in 1971 and 1972. After the first true leaves appeared in May, the plants were thinned to 7.4, 14.8, and 22.2 plants/m². Cotton planted one row per 102-cm bed at a density of 7.4 plants/m² is similar to conventional plantings.

The experimental design in the field was a randomized split-split-plot with bed size as the whole plot, number of rows per bed as the first split, and plant density as the second split. Each plot was four beds wide with four replications of the treatments. The subplots were divided into flower tagged (tagged plots) and yield portions (yield plots). Yield plots consisted of four beds and were 15.2, 13.7, and 12.2 m in length in 1970, 1971, and 1972, respectively. The flower tagged plots were one of the interior beds and 3.09 m² in size. In these areas, flowers were tagged with the date of anthesis during the periods 21 June to 15 Aug. 1970, 20 June to 14 Aug. 1971, and 7 June to 19 Aug. 1972. Open bolls were harvested weekly and assigned to weekly flowering intervals before being analyzed for boll and fiber properties at the University of Arizona Cotton Fiber Laboratory. Bolls produced from flowers that bloomed after the end of each tagging period were harvested and also analyzed for boll and fiber properties. The last flowers to produce mature bolls bloomed near the end of the 1st week in September during each year. Data collected at the Fiber Laboratory included seedcotton weight per boll, percent lint (lint weight divided by seedcotton weight from which it was ginned and multiplied by 100), lint index (g lint/100 seed), seed index (g/100 seed), seed per boll, 50% span-length (average length

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[2] Former professor (now professor, Malheur Exp. Stn., Oregon State Univ., Rt. 1, Box 620, Ontario, OR 97914), research associate, and professor, Dep. of Plant Sciences, Univ. of Arizona, Tucson, AZ 85721.

Table 1. Effect of plant spacing on seedcotton yield. Data are averaged for 3 years.

Plant spacng	1 row/bed	2 rows/bed	Increase 2 rows:1 row
	g/m²†		%
76-cm beds			
7.4 plants/m²	389‡(95)	414 (95)	6.3
14.8 plants/m²	386 (103)	414 (101)	7.1
22.2 plants/m²	392 (97)	395 (102)	0.7
102-cm beds			
7.4 plants/m²	392 (90)	436 (90)	11.2
14.8 plants/m²	392 (99)	422 (100)	7.7
22.2 plants/m²	384 (98)	408 (103)	6.4

† Numbers in parentheses are yield of flower-tagged plots as a percentage of nontagged plots. ‡ L.S.D.$_{0.05}$ for seedcotton yield is 23 g/m².

of the longest 50% of the fibers), fiber strength (measured by Pressely instrument with 3.18-mm gauge), and fiber fineness (measured by Micronaire instrument). A comparison of open bolls with tagged flowers allowed calculation of boll retention percentages.

For each harvest date of the tagged plots, we determined the flowering date which was closest to having 50% of the mature bolls harvested by that date (cumulated from previous harvest dates). Only plots that produced at least eight mature bolls from all flowering intervals were used. The number of days between the flowering and harvest dates is the average boll period. Enough bolls were present in all plots to make determinations for only three harvest dates in 1970 and 1971 and 10 harvest dates in 1972. More complete sets of boll periods occurred in 1972 because of higher yield and more bolls.

Irrigations were applied so as to limit excessive vegetative growth by allowing mild, visual water stress when required. Insecticides were used on a regular basis but moderate to heavy pink bollworm [*Pectinophora gossypiella* (Saunders)] infestation occurred in 1970. Petiole samples were taken from recently expanded leaves from both the mainstem and branches on two dates in 1970 and four dates in 1971 and evaluated for NO_3 at the Univresity of Arizona Soil and Water Testing Laboratory as previously described (12).

Before harvesting the yield plots, open boll samples (10 per subplot in 1970 and 25 in 1971 and 1972) were taken and analyzed for boll and fiber properties. In 1970 the two center beds of the yield plots were hand-picked twice; the latter part of September and again between late October and early November. A finger-type stripper was used to harvest the center beds in late October of 1971 and 1972. These plots were gleaned by hand and yields adjusted accordingly. Mature plant height was taken by measuring the height of five randomly selected plants in each yield plot.

All data were analyzed using standard analysis of variance techniques. In the case of the flower-tagged plots, flowering dates (or intervals) were treated as the final subplot. Data for the yield plots were analyzed both within years and combined for the years. Responses to treatments was similar during each of the 3 years with few statistically significant interactions with years in the combined analysis. As a result, most data are presented averaged for years. Treatment effects discussed are significant at the 0.05 or less level. Correlation coefficients were determined among the boll and fiber properties of the tagged plots. These comparisons were made using data for the various time intervals of individual subplots with over 335 observations for each correlation within each year. Pooled comparisons over years included over 1,000 observations. Correlation coefficients discussed are significant at the 0.01 level unless otherwise stated.

RESULTS AND DISCUSSION

Seedcotton Yield

Yields were slightly below normal for Phoenix in 1970, near normal in 1971, and considerably above normal in 1972. Averaged seedcotton harvested from the yield plots was 3,089, 3,997, and 4,920 kg/ha during the 3 years, respectively. The only statistically significant main effects in the combined analysis of seedcotton yields for the 3 years were years and rows per bed.

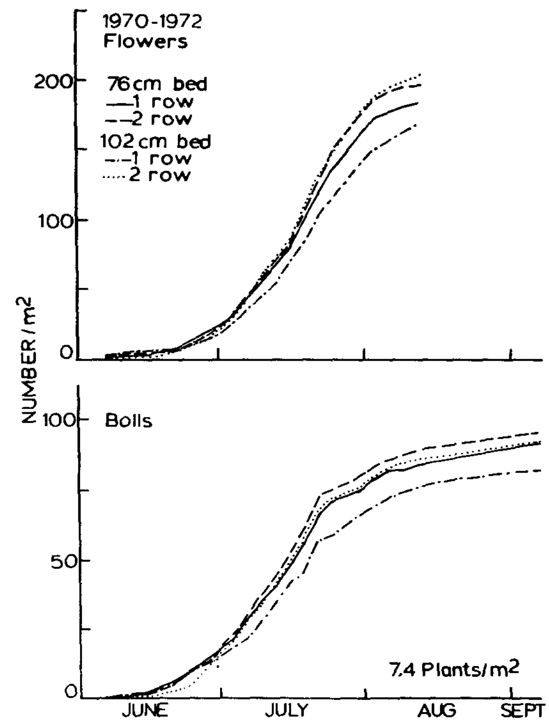

Fig. 1. Cumulative flower production and boll set as influenced by planting pattern with 7.4 plants/m².

Two rows per bed resulted in significantly more seedcotton at all plant densities on 102-cm beds and at all but the highest density on 76-cm beds (Table 1). This likely resulted from more solar radiation interception and canopy photosynthesis by two rows per bed before canopy closure (17). Plant density had no consistent effect on yield, except that the largest difference between one row per bed and two rows per bed generally occurred at the lower plant densities.

Single-row plantings on 76-cm beds had yields similar to single-row plantings on 102-cm beds (Table 1). This was unexpected since the former should reduce interplant competition because of the greater distance between adjacent plants within rows and have greater interception of solar radiation early in the season. We have no logical explanation for these results.

Seedcotton yields from the tagged plots were similar to those from the yield plots (Table 1). At 7.4 plants/m², the tagged plots produced less seedcotton than the yield plots; the differential being 5% for 76-cm beds and 10% for 102-cm beds. At the other plant densities there was no consistent yield differential between the two types of plots.

Seasonal Fruiting Pattern and Seedcotton Production

The effect of plant spacing on flower production of the tagged plots was similar for each of the 3 years. Main effects were statistically significant for row per bed, plant density, and date of flowering as were the interactions for rows per bed × flowering date and

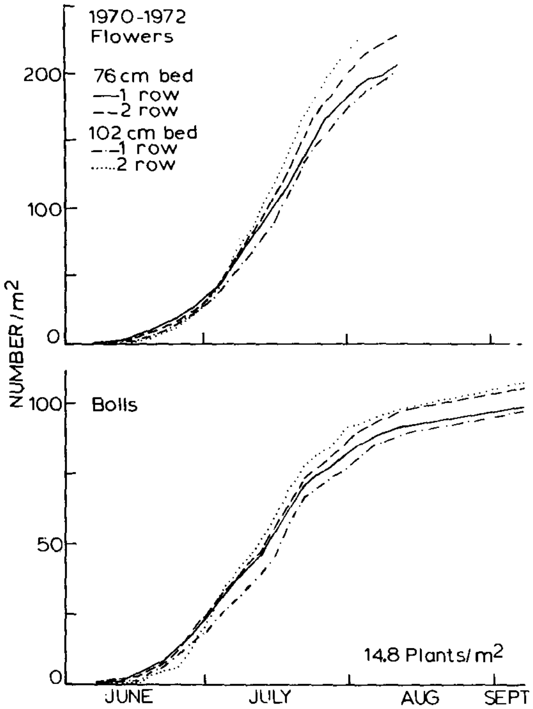

Fig. 2. Cumulative flower production and boll set as influenced by planting pattern with 14.8 plants/m².

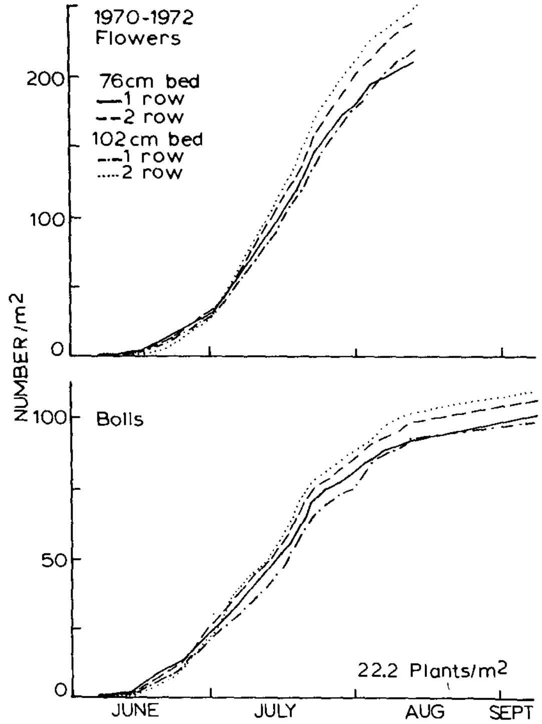

Fig. 3. Cumulative flower production and boll set as influenced by planting pattern with 22.2 plants/m².

plant density × flowering date. These interactions are reflected in the divergence in cumulative flower production among the plant spacing treatments as the season progressed (Fig. 1, 2, 3). By the end of the season, two rows per bed consistently resulted in more flowers than one row per bed. On 76-cm beds the increase was 8, 10, and 14% for plant densities of 7.4 14.8, and 22.2 plants/m², respectively. Similar increases on 102-cm beds were 22, 20, and 15%. Averaged over bed size and rows per bed, increasing plant density from 7.4 to 14.8 plants/m² increased total flowers by 15%. Increasing plant density to 22.2 plants/m² increased flower production by an additional 7%.

Significant treatment effects on mature boll production were similar to those on flower production with a reduced magnitude of response (Fig. 1, 2, 3). Percentage increase of two rows per bed over one row per bed ranged from 2 to 7% on 76-cm beds and from 9 to 12% on 102-cm beds. Averaged over other treatments, increasing plant density from 7.4 to 14.8 plants/m² increased total bolls by 11%, with boll production increased an additional 3% by changing from 14.8 to 22.2 plants/m².

Averaged over the season, two rows per bed generally had a lower percentage of flowers developing into mature bolls than one row per bed. We expected that early in the season two rows per bed would have a higher boll retention percentage than one row per bed because of reduced interplant competition and greater interception of solar radiation. There was, however, no consistent effect of rows per bed on boll retention early in the fruiting cycle (data not presented). During the latter part of the fruiting cycle, percent boll retention was generally lower for two rows per bed than with one row per bed, resulting in lower overall seasonal boll retention.

Seasonal seedcotton production differed significantly for the flowering periods in agreement with previous studies (22) with a significant rows per bed × flowering period interaction for each of the 3 years. During the first 2 weeks of flowering, one row per bed produced more seedcotton than two rows per bed at all plant densities on both bed sizes (Fig. 4). Inspection of Fig. 1, 2, and 3 reveals that during this time with an equivalent bed size and plant density, both flower and boll production from two rows per bed lagged that from one row per bed. We suspect that herbicide damage occurred to plants located near the bed shoulders with two rows per bed which restricted early plant growth although we did not note greaer visual damage. The preplant herbicides were applied over the beds and incorporated with a rotary mulcher before the beds were shaped by flattening the top. This procedure probably resulted in more herbicide near the shoulders than at the center of the beds. Despite the early delay in fruiting, however, two rows per bed outyielded one row per bed by the end of the season in all cases.

Generally the yield advantage of two rows per bed over one row per bed, when plant density and bed size were equivalent, was near maximal from bolls set by late July (Fig. 4). Thereafter, the rate of seedcotton production on one and two rows per bed was similar, resulting in near parallel production curves. Ehlig and Donovan (11) speculated that fruiting curves of narrow-row and conventionally planted cotton are similar after leaf canopy closure. This demonstrates why the most consistent yield increase with narrow-

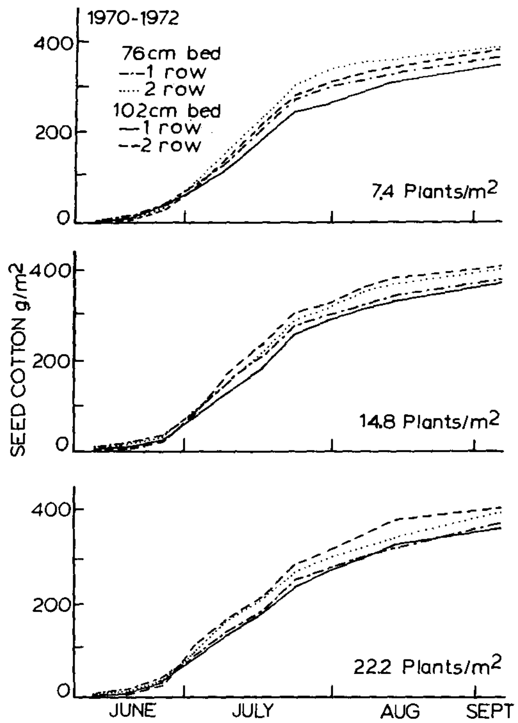

Fig. 4. Cumulative seedcotton production as influenced by planting pattern and plant density. The dates are time of boll set of bolls from which the seed cotton was harvested.

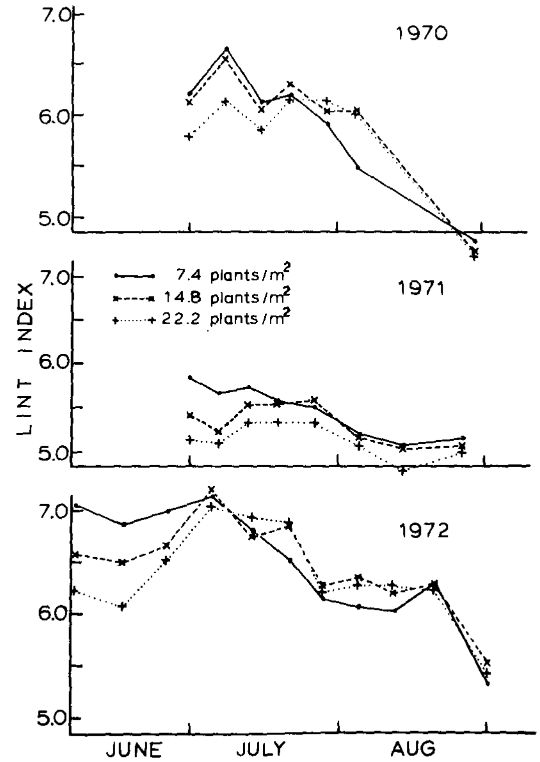

Fig. 5. Effect of plant density on lint index at various flowering dates. Data was averaged over other treatments.

row cotton over conventionally planted cotton have been in the Texas High Plains where the growing season is short. In addition there may be greater yield loss due to insects and disease in long-season, narrow-row cotton because of earlier canopy closure, greater foliage development, and high associated humidity.

Reduction of length of the production season has long been a desirable goal. The reasons vary among cotton-producting areas, but the more important are greater flexibility in cropping pattern, adjustment to short growing seasons, avoidance of drought, reduction in late-season damage from insects and diseases, and curtailment of the high cost of late-season production because of insecticide and irrigation requirements. The reported effect of narrow rows on earliness has been inconsistent. Colwick and Barker (8) found that narrow-row cotton reached 60% open bolls 3 to 10 days earlier than conventional row spacings in 2 of 3 years in Mississippi. Although Waddle and Pennington (27) found no yield increase from narrow rows in Arkansas, they reported an advancement in crop maturity of 7 days. On the other hand, Johnson et al. (18), noted that fruiting period was not shortened appreciably with an indeterminate Acala cultivar planted in narrow rows in California. Brashears et al. (4) found that narrow rows did not affect earliness in Texas although yields were increased. Workers in Georgia reported no increased earliness due to the narrow-row configuration (1, 14).

Ray (24) noted that conflicting results may not be surprising. Increasing plant density, which is often associated with narrow-row planting, delays maturity by raising the node of the first fruiting branch. However, the greater number of fruiting positions from more plants in narrow-row patterns increases earliness. He concluded that which of the two factors is dominant will depend upon cultivar, climatic factors, plant density, row spacing, and other production practices.

We previously reported that the first boll was raised one node for each 11 plants/m^2 increase in density (7). Assuming each rise in node number delays the onset of boll production by 3 days, increasing plant density from 7.4 to 22.2 plants/m^2 should delay fruiting by 4 days. In our study, the additional fruiting positions from the high plant density more than compensated for this delay. For example by 19 June, when flowering for about 3% of the total seedcotton yield had occurred, the number of bolls/m^2 initiated that later matured from plants grown in double rows on 76-cm beds was 3.5, 5.1, and 5.4 for plant densities of 7.4, 14.8, and 22.2 plants/m^2. On 102-cm beds similar values were 2.8, 3.8, and 3.9 bolls/m^2.

In and of itself, greater fruit production early in the season does not necessary mean a reduction in the growing season. As illustrated in Fig. 4, narrow-row cotton can reach an equivalent yield to that of conventionally planted cotton at an earlier date. But this may not mean that the crop will be ready to harvest earlier.

High boll production early in the season from double rows resulted in low petiole NO_3 levels during June. Nitrate-nitrogen on 15 June 1970, averaged over other treatments, was 11,440 ppm with two rows per bed and 13,535 ppm with one row per bed. On 30 June 1970, similar values were 8,281 and 10,500 ppm. This trend held early in 1971 with NO_3-N values of

Table 2. Effect of plant density and harvest date on boll period. Data are averaged over other treatments.

	Year		
	1970	1971	1972
Plant density		days	
7.4 plants/m²	49.1	50.8	53.9
14.8 plants/m²	50.2	51.0	55.1
22.2 plants/m²	50.9	51.4	55.6
L.S.D.$_{0.05}$	0.3	0.6	1.1
Harvest date			
18 Aug.	–	–	53.7
25 Aug.	49.6	–	53.8
1 Sept.	48.6	49.7	54.4
8 Sept.	52.0	–	53.3
15 Sept.	–	51.4	53.4
22 Sept.	–	52.0	53.6
29 Sept.	–	–	56.1
6 Oct.	–	–	56.1
13 Oct.	–	–	58.0
20 Oct.	–	–	56.2
L.S.D.$_{0.05}$	0.5	0.5	1.6

11,673 and 11,977 ppm on 22 June and 11,580 and 13,156 ppm on 2 July for two and one rows per bed, respectively. At later sampling dates in 1971, nitrate levels did not continue to be lower in cotton on two rows per bed. The values were 7,299 and 5,103 ppm on 20 July and 5,898 and 5,097 on 12 August for two and one rows per bed, respectively. Low petiole nitrate levels in double row cotton during June probably resulted from high nitrogen mobilization into the large number of developing bolls.

Low nitrate levels early in the season of narrow-row cotton could be partially responsible for the earliness reported by some workers. The result would be a slowing of vegetative growth needed to support new fruiting sites later in the season. We did not take vegetative tissue weights, but plant height was significantly reduced by narrow rows. Averaged over other treatments, mature plant height was 102 and 98 cm for one and two rows per bed, respectively. It is evident that timing of N fertilizer requirements of narrow-row cotton will differ from conventionally planted cotton with narrow-row cotton requiring a higher proportion of the total N early in the season.

Boll and Fiber Properties

Increasing plant density significantly lengthened the boll period in each of the 3 years (Table 2). The effect was small, ranging from 0.6 days in 1971 to 1.8 days in 1970. We cannot determine whether the primary effect of high plant density is to slow physiological development of bolls or if the major effect is on the rate of drying and opening as bolls reach physiological maturity. It may be that both processes are affected. High plant density results in a large amount of transpiring leaf area in the central portion of the plant canopy where most bolls develop (7). It would be logical to expect higher humidity in the microenvironment of high-density plantings and slow drying and opening of bolls. In addition, plants grown in crowded conditions may experience physiological stresses that slow the rate of boll development.

Bolls that opened late in the season had a longer boll period than bolls that opened earlier (Table 2). This is primarily a temperature effect as noted by others (13, 16, 20, 21, 28). Mutsaers (21) concludes that for a wide range of environmental conditions, boll period can be described by a negative exponential relationship involving only temperature. He reports the Q_{10} to be about 2.5.

Table 3. Effect of plant density on selected boll and fiber properties. Data are averaged over other treatments and years.

Plant density	Boll size	Lint index	Seed index	Fiber strength	Fiber fineness
Plants/m²	g	g/100 seed		mN/tex	Micronaire index
7.4	5.19	6.26	10.8	211	5.07
14.8	5.10	6.12	10.7	208	4.88
22.2	5.00	6.06	10.6	206	4.82
L.S.D.$_{0.05}$	0.09	0.10	0.1	3	0.09

The reason for the longer boll period in 1972 than in 1970 or 1971 cannot be explained by temperature. Temperatures at Sky Harbor International Airport (5 kg from the experimental site) in 1972 were generally equal to or higher than those during the previous 2 years. We suspect that physiological stresses associated with the heavy boll load in 1972 may have slowed the rate of development of these bolls. However, an explanation for the abrupt change in boll period starting on 22 Sept. 1972 in not apparent.

Boll size, lint index, seed index, fiber strength, and fiber fineness from the yield plots were all significantly reduced by increase in plant density, although the average effects were less than 5% (Table 3). Other treatments had no significant influence on these boll and fiber properties. The one exception was a rows per bed effect on seed index. Seed from one row per bed were larger than those from two rows per bed with 3-year averages of 10.8 and 10.6 g/100 seed. The small seed from double rows probably reflects greater intraplant competition among developing seed as a result of the large boll set with double rows per bed. Percent lint, seed per boll, and 50% span-length were not significantly influenced by the treatments.

Seasonal changes in boll and fiber properties from the tagged plots were similar to those reported by others (3, 26) and are not reported. Maximum values normally occurred near midseason at the time of greatest flowering and boll set. Seedcotton yield assigned to each boll-set period was significantly, positively correlated to all boll and fiber properties except fiber strength. Boll size changes in response to treatments and flowering date were about equally influenced by lint index, seed index, and seed per boll with pooled correlation coefficients averaged for the years of 0.61, 0.66, and 0.63, respectively. Changes in boll size were also associated with changes in fiber fineness ($r = 0.64$), to a lesser extent with 50% span-length ($r = 0.32$), but not with fiber strength ($r = -0.04$). Lint index was related to seed index ($r = 0.75$), fiber fineness ($r = 0.75$), to a lesser extent with 50% span-length ($r = 0.22$), but not with fiber strength ($r = -0.06$). Fiber 50% span-length was only weakly related to fiber strength ($r = 0.18$) and fiber fineness ($r = 0.24$). Changes in fiber strength and fiber fineness were not related ($r = -0.40$).

There were very few consistently significant interactions of flower period × treatment on boll and fiber properties in the tagged plots during the 3 years. The one exception is shown in Fig. 5. Lint index was depressed by high plant density early in each fruiting cycle. This same interaction was significant during 2 of the 3 years for percent lint and fiber strength, and during 1 year for boll size, seed index, and fiber fineness. These relations suggest that fiber development is more sensitive to interplant competition early in the season than seed development even though the ontogeny of development of the two is similar (2). Supporting evidence is seen in data from the yield plots where bolls were sampled to represent average seasonal fruiting. Increasing plant density from 7.4 to 22.2 plants/m^2 decreased lint index by 3.2% and seed index by only 1.9% (Table 3).

CONCLUSIONS

Our experiment was designed to study the influence of row spacings independent from plant density. The results show that while seedcotton yield is primarily influenced by row spacing (rows per bed), plant density has the primary influence on boll and fiber properties. While narrow rows increased seedcotton yields up to 11% (Table 1), the effect of plant density on boll and fiber properties was less than 5% (Table 3). Although increasing plant density of narrow-row cotton above that used in conventionally planted cotton may have little effect on yield, it may aid harvesting with finger-stripper harvestors (7). If this plant density adjustment is deemed necessary, our data show that there should be little concern about adverse effects on boll and fiber properties.

It is apparent that the yield advantage of narrow-row production develops early in the fruiting cycle. Thus, the system will show the greatest yield increase over conventionally planted cotton when fruiting seasons are short. Where shortening of the production season is desired, the system offers great potential for maintaining yields. As originally conceived, satisfactory narrow-row production was thought to require a high plant density. Our results show that there is no yield advantage to using higher than normal plant densities. We should point out, however, that the cotton cultivar we used was not developed to be used in narrow-row plantings. New cultivars that have been developed for narrow rows may require higher plant densities. Although the finger-type stripper is used in many areas to harvest narrow-row cotton, a suitable means of harvesting high quality fiber remains a major limitation to expanded production of this cultural system.

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