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PLANT POPULATION EFFECTS on TWIN LINE COTTON PRODUCTION

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Abstract

Three experiments at the University of Arizona Maricopa and Marana Agricultural Centers in 2002 and 2003 measured effect of plant populations on the yield of cotton planted in the twin seed-line per bed configuration. In 2002 at the Maricopa Ag. Center, the plant populations were 52800, 69200, 82800 and 96200 plants per acre (PPA) for Stoneville 4892BR and 54800, 70800, 90500 and 104500 PPA for AG3601, respectively. The two lowest plant populations which were in the range of common commercial plant densities resulted in the greatest lint yields for both varieties (an average of 1708 and 1287 lb lint/A for ST4892BR and AG3601, respectively) but there was a significant linear decrease in yield with increasing plant population. In 2003, the cotton variety Delta Pine 449BR was planted and the population densities were 22000, 29000, 36000, 46000, 51000, 61000, and 64,000 PPA at the Marana Ag. Center and 24000, 34000, 41000, 56000, 63000, 71000, and 86,000 PPA at the Maricopa Ag. Center. Cotton yield did not vary significantly as a function of population density at Maricopa and averaged 1526 lb lint/A. At Marana there was a slight trend of increasing yield with increasing plant densities with the three highest plant populations averaging 1385 lb lint/A. In the experiments with ST4892BR and AG3601 at Maricopa in 2002 and with DP449BR in 2003 there was a linear decrease in fiber micronaire with increasing density but this effect of density on micronaire was not observed possibly because plant populations Marana were lower than in the other experiments.

Introduction

The double seed-line per bed or twin-line planting configuration was developed as a result of ultra narrow row (UNR) cotton production research conducted in 1999 and 2000 that compared the yield and production costs of a 10 inch UNR system on the flat (no beds) with a conventional 40 inch row system on beds (Husman et al., 2001; Husman et al., 2000; McCloskey et al., 2000). The UNR system produced 3 to 9 percent more lint while reducing variable costs by 5 to 12 percent. While these results were encouraging, there was little commercial interest in adopting the UNR system due to consistent challenges related to stand establishment, weed control, plant height control, and dessication for stripper harvest. In addition, the perceived quality stigma associated with stripper cotton and potential additional discounts this posed resulted in unacceptable risks for Arizona producers. The twin-line system is a less radical departure from conventional production than UNR systems and may be of more commercial interest if twin-line system yields are consistently greater than that of the conventional single seed-line per bed system. A major advantage of the twin-line system is that the crop is harvested with a conventional spindle picker, equipment producers currently own. In addition, stand establishment, weed control, and plant height management are similar in conventional and twin-line systems again increasing the potential that producers may adopt the system.

Three experiments comparing single and twin-line production systems in terms of yield and production costs were conducted in Arizona in 2001(Husman et al., 2002). Research was continued in 2002 at multiple test locations to evaluate yield, fiber quality, and compare costs between the twin-line and single-line production systems (Husman et al., 2003a). In general, yields were comparable in both the single- and twin-line configurations at all locations. At some farms the twin-line system yielded more than the conventional single-line system, at others the single-line system yielded more than the twin-line system, but at most farms there was no significant difference in yield between the two systems. There were also no differences in production costs between the single- and twin-line systems.

In response to the inconsistent results obtained in the twin-line versus single-line comparison research and in response to grower questions, two studies were initiated in 2002; the first evaluated two phenologically different varieties at four plant populations, and the second evaluated six popular commercially available Upland cotton varieties in the twin-line configuration (Husman et al., 2003b). The plant population study found that as plant population decreased, yield increased in a linear fashion but did not appear to peak or to decline at the lowest population. Therefore, plant population experiments designed to evaluate yield response over a greater range of plant populations were conducted at two locations in 2003.

Materials and Methods

Experiments conducted in 2002 and 2003 at the University of Arizona Maricopa Agricultural Center and at the University of Arizona Marana Agricultural Center in 2003 were designed to measure cotton yield response to various plant populations in the twin-line production system. The 2002 experiment at MAC consisted of four target plant populations of 60, 80, 100, and 120,000

ppa and two varieties, Stoneville 4892BR and AG3601. The varieties were chosen based on their distinctly different growth characteristics. Stoneville 4892BR has a branching bush type characteristic with multiple fruiting sites per fruiting branch while AG3601 has a columnar cluster type growth characteristic. Plots were 6 rows wide with 40 inch rows by 550 feet long and the experiment was replicated 4 times using a randomized complete block split-plot design. The experiment was dry planted on April 3, irrigated up on April 5, and harvested on October 24, 2002.

In 2003, the experiments consisted of seven target plant populations of 23, 34, 44, 56, 70, 83, and 98,000 ppa using the variety DP449BR. Plots were 6 rows wide with 40 inch rows by 790 feet long at the Maricopa site and 8 rows wide with 40 inch rows by 580 feet long at the Marana site. The Maricopa experiment was replicated twice while the Marana experiment was replicated 4 times and the plots in both experiments were arranged using a randomized complete block design. The Maricopa experiment was dry planted on April 9, irrigated on April 16 to germinate the seed, and harvested on November 10, 2003. The Marana experiment was dry planted on April 10, irrigated on April 15 to germinate the seed, and harvested on October 29, 2003.

Prior to planting, the beds were shaped to facilitate planting the twin-line configuration. The experiments were planted using a 6 row (12 planter units) Monosem twin-line vacuum planter with planter units spaced 7.25 inches apart. At Marana, the two pairs of outside planter units were locked up so that the planter in this configuration was essentially a 4-row planter. Seeding rate changes were made to achieve the targeted plant populations by changing the driver and driven sprockets according to the planter operations manual. Plots were harvested by picking the center four rows of each plot with a 4 row Case-IH 2155 at the Maricopa experiments and a 2 row John Deere 9930 at Marana. The seed cotton from each plot was weighed using a boll buggy equipped with load cells and a weighing system. Sub-samples of approximately 6 to 8 pounds of seed-cotton were taken from each plot and ginned for lint turnout. A sub-sample of fiber was then submitted to the USDA Cotton Classing Office, Phoenix, Az. for HVI classing.

Percent ground cover measurements were made by selecting three subplots in each plot, one area near each end of a plot and one area in the middle of the plot. These areas were then flagged (one flag on each side of the furrow) so that repeated measurements were made in the same locations for the rest of the season. Percent groundcover measurements were made by analyzing digital images. An Olympus Camedia C3030 3 megapixel digital camera mounted 2 m above the ground on a pole was used to take pictures in three subplots per plot in all treatments in the Maricopa and Marana experiments. A software package (SigmaScan from SPSS Science Software) was used to digitally analyze and calculate the ratio of green image pixels to non-green pixels which was used to calculate percent ground cover. Later in the season as the plants developed, a Licor LAI-2000 Canopy Analyzer was used to measure the leaf area index (LAI) in three subplots per plot similar to the percent ground cover measurements.

Results and Discussion

The average final plant populations at Maricopa in 2002 were 53000, 69000, 83000, and 96000 ppa for the ST4892BR variety and 55000, 71000, 90000, and 104000 PPA for the AG3601 variety (Table 1). The highest and statistically similar lint yields were obtained at the lowest populations of each variety (Table 1). There was a significant trend of decreasing lint yield with increasing density or plant population for both the ST4892BR and AG3601 varieties (Figure 1). The average final populations of DP 449BR in the 2003 experiments were 24000, 34000, 41000, 56000, 63000, 71000, and 86000 ppa at Maricopa (Table 2) and 22000, 29000, 36000, 46000, 51000, 61000, and 64000 ppa at the Marana site (Table 3). Final populations were below target populations particularly at the greater densities at the Marana site were possibly due to planting at a fast ground speed that caused non-uniform seed drop. As stated earlier, the 2003 experiments were designed to measure yield response to a wide range of plant populations since the 2002 experiment found that yield decreased with increasing population density over the population range of 55,000 to 104,000 PPA. However, there were no significant yield differences or a trend in yield differences with population density at Maricopa in 2003 even though plant populations ranged from 24,000 to 86,000 PPA (Table 2; Figure 2). In contrast, there was a small but statistically significant linear trend of increasing yield with increasing population density at Marana in 2003 (Table 3, Figure 2). Plant spacing in the seed lines was more variable at the Marana location than at Maricopa. Thus, there were larger canopy gaps at the low densities in Marana and this may have accounted for the discrepancy in yield response to population density between the two locations. The results from all of the experiments indicate that the greatest yield in the twin-line cotton production system occurred at cotton population densities of 50,000 to 60,000 plants/acre similar to the yield response of conventional single-line per bed cotton production systems to population density.

Fiber micronaire was affected by plant populations with micronaire decreasing with increasing plant population in the experiments at Maricopa in 2002 and 2003 when plant populations included densities substantially above 60,000 plants/acre (Table 1 and 2). This results are consistent with the measurement of lower fiber micronaire at the high plant densities used in the ultra-narrow row cotton experiments conducted in Arizona (Husman et al., 2001) and in the first year of twin-line experiments conducted in 2001 when the plant populations in the twin-line plots were double those in the conventional single-line plots (Husman et al., 2002). The highest plant population obtained at Marana in 2003 was about 64,000 plant/acre and the range of densities was probably

not sufficient to measure and effect of plant densities on fiber micronaire (Table 3). The results from Marana in 2003 and the inconsistent relationship of micronaire with plant densities in the 2002 twin-line versus single-line comparison studies (Husman et al., 2003a), suggest that other factors such as environmental conditions, length of season and boll load can obscure the relationship between plant density and fiber micronaire especially if plant densities are below about 80,000 plants/acre.

There were small increases in percent groundcover with increasing population density up to about 60,000 to 70,000 plants/acre after which the response reached a plateau at Maricopa in 2003 (Figure 3). Similarly at Marana in 2003, percent groundcover increased with increasing population density up to the maximum densities achieved in the experiment, about 65,000 plants/acre (Figure 4). This result was expected simply because the greater the density, the greater the leaf area and the greater percent groundcover up to the point at which leaves from adjacent plants overlapped. Later in the season, leaf area index (LAI) was measured with a LiCor LAI-2000 since the cotton plants had multiple layers of leaves in the canopy. Similar to percent groundcover, LAI increased with increasing plant density up to about 60,000 to 70,000 plants/acre where a plateau was reached at Maricopa in 2003 (Figure 5). At Marana in 2003, LAI was only weakly related to plant density and appeared to reach a maximum at about 50,000 plants/acre (Figure 5). Given the variable response of yield to plant population density, it did not appear that there was much of a relationship between percent groundcover or LAI and yield. This was probably due to the ability of plants to detect the presence of neighboring plants and specifically the ability of cotton plants to compensate for a wide range of densities and environmental conditions in terms of boll production and yield.

Conclusions

The plant population experiment results in 2002 were consistent across two varieties with distinctly different growth characteristics. ST4892BR is a branching bush type plant with multiple fruiting sites per branch while AG3601 exhibits an upright, columnar tight cluster fruiting pattern. Plant populations which resulted in the greatest yield were 53,000 to 71,000 plants per acre. The plant population experiment results in 2003 were inconsistent across the 2 locations. At Maricopa, there were no statistical differences in yield with a population range of 24,000 to 86,000 ppa. At the Marana site, the highest yields were measured at the higher plant populations and decreased when population declined below approximately 50,000 ppa. However, plant spacing was less uniform at the Marana site, possibly accounting for the yield decrease at the lower populations. Based upon the 3 experiments in 2002 and 2003, it is suggested that a twin line plant population of 50,000 to 60,000 ppa should be targeted. However, the 2003 Maricopa results suggest that if the stand is uniformly spaced, plant boll production can compensate for a wide range of population densities possibly from approximately 25,000 to 85,000 ppa resulting constant yield. These results and conclusions are not necessarily surprising since they are similar to results obtained in population studies in conventional single line production systems.

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Table 1. Yield and fiber quality of ST 4892BR and AG 3601 planted at various densities in a twin-line per bed planting configuration on 40 inch rows at the Maricopa Agricultural Center in 2002. Regression analysis showed that both yield (see Figure 1) and fiber micronaire decreased as density increased. The regression equation for the micronaire (mic) of AG3601 was mic = 4.987 - 0.0000113(density) with P = 0.0039 and R^2 = 0.5399. The regression equation for the micronaire of ST4892BR was mic = 5.723 - 0.0000774(density) with P = 0.039 and R^2 = 0.2966. There was no statistically significant relationship between density and staple, strength or uniformity for either variety.

Variety	Density x 10^{-3} (plants/A)	Lint (lb/A)	Micronaire	Staple	Strength	Uniformity
ST4892BR	52.8	1743	5.3	37	29.7	83
ST4892BR	69.2	1672	5.2	36	28.5	83
ST4892BR	82.8	1583	5.1	36	30.0	83
ST4892BR	96.2	1533	5.0	36	28.4	82
AG3601	54.8	1299	4.4	38	32.3	81
AG3601	70.8	1275	4.2	38	33.5	82
AG3601	90.5	1131	3.9	38	33.7	82
AG3601	104.5	1079	3.9	38	33.9	82

Table 2. Yield and fiber quality of DP 449BR planted at various population densities at the Maricopa Agricultural Center in 2003. Regression analysis showed that fiber micronaire decreased as density increased. The regression equation for the micronaire (mic) was mic = 5.328 - 0.00000455(density) with P = 0.0152 and R^2 = 0.3498. Lint yield, staple and strength did not vary as a function of population density.

Density x 10^{-3} (plants/A)	Lint Yield (lb/A)	Micronaire	Staple	Strength
24	1510 a	5.15	34.0 a	30.7 a
34	1564 a	5.20	34.5 a	29.8 a
41	1566 a	5.30	34.0 a	29.2 a
56	1512 a	5.05	34.0 a	29.0 a
63	1491 a	4.90	34.5 a	31.2 a
71	1526 a	5.00	34.0 a	28.9 a
86	1513 a	5.00	34.5 a	30.1 a
P	0.8600		0.9795	0.2615
CV	4.22	2.08	2.78	3.32

Values are means (SAS PROC GLM (ANOVA); means within a column followed by the same letter are not significantly different at the P=0.05 level according to the LSD mean separation test.

Table 3. Yield and fiber quality of DP 449BR planted at various population densities at the Marana Agricultural Center in 2003. Regression analysis indicated that lint yield increased with increasing density; lb lint/A = 1262 + 0.00192(density) with P = 0.0016 and R^2 = 0.3062. There were no relationships between density and the fiber quality parameters of micronaire, staple or strength.

Target Density x 10^{-3} (plants/A)	Actual Density x 10^{-3} (plants/A)	Lint Yield (lb/A)	Micronaire	Staple	Strength
23	22	1285	5.13 a	35.3 a	29.9 a
34	29	1337	5.03 a	35.3 a	29.0 a
44	36	1325	5.10 a	35.3 a	29.3 a
56	46	1321	5.00 a	35.8 a	29.6 a
70	51	1391	5.00 a	35.0 a	29.3 a
83	61	1370	4.88 a	35.3 a	29.5 a
98	64	1394	5.08 a	35.3 a	29.4 a
P			0.1755	0.9425	0.8681
CV			2.53	2.44	3.32

Values are means (SAS PROC GLM (ANOVA); means within a column followed by the same letter are not significantly different at the P=0.05 level according to the LSD mean separation test.

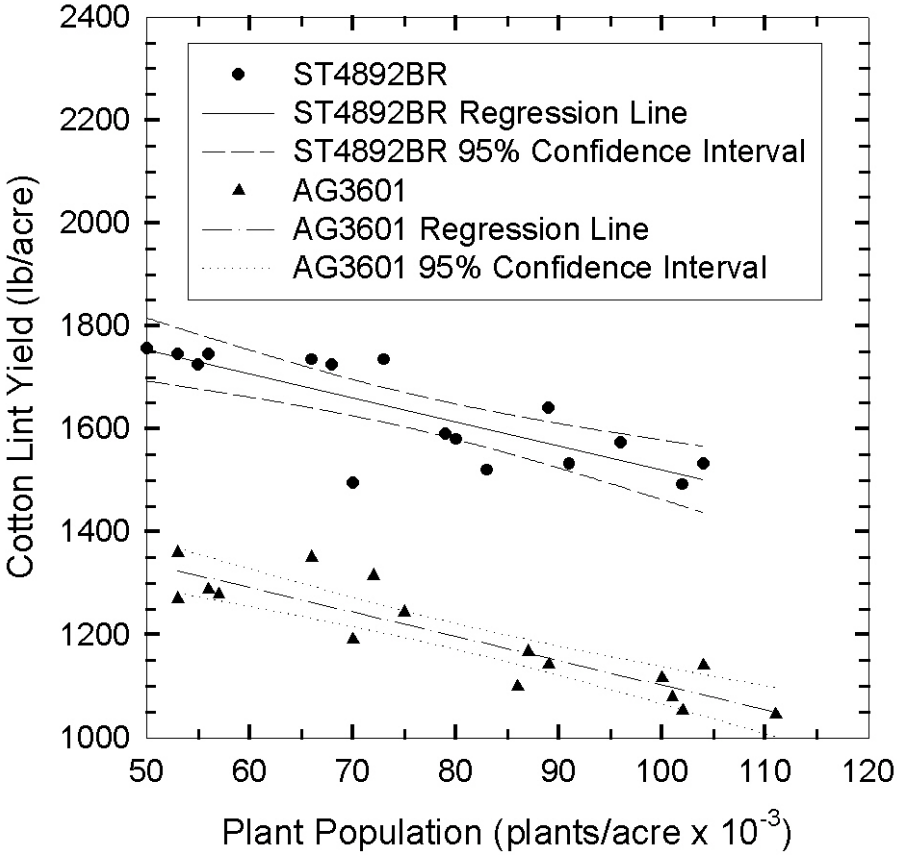

Figure 1. Relationship of lint yield with increasing density for two varieties, ST4892BR and AG3601, in the twin-line cotton production system at the Maricopa Agricultural Center experiment in 2002. The regression equation for ST4892BR was Yield = 1987 - (0.00467 * Density) with P = 0.0002 and R^2 = 0.6335. The regression equation for AG3601 was Yield = 1576 - (0.00474 * Density) with P<0.0001 and R^2 = 0.8016.

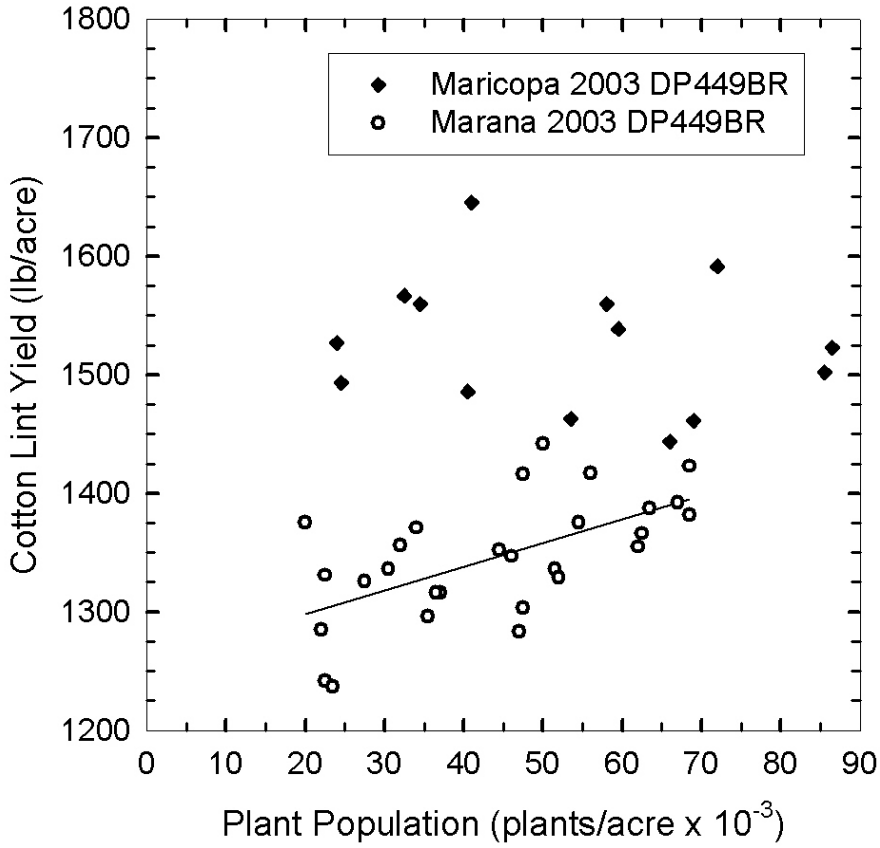

Figure 2. Relationship of lint yield produced by DP449BR with increasing plant density in the twin-line cotton production system for experiments conducted at the Maraicopa Agricultural Center and Marana Agricultural Center in 2003. The regression equation for lint yield at Marana was lb/A = 1262 + 0.00192(density) with P=0.0016 and R^2 = 0.3062. The regression equation for lint yield at Maricopa was not statistically significant.

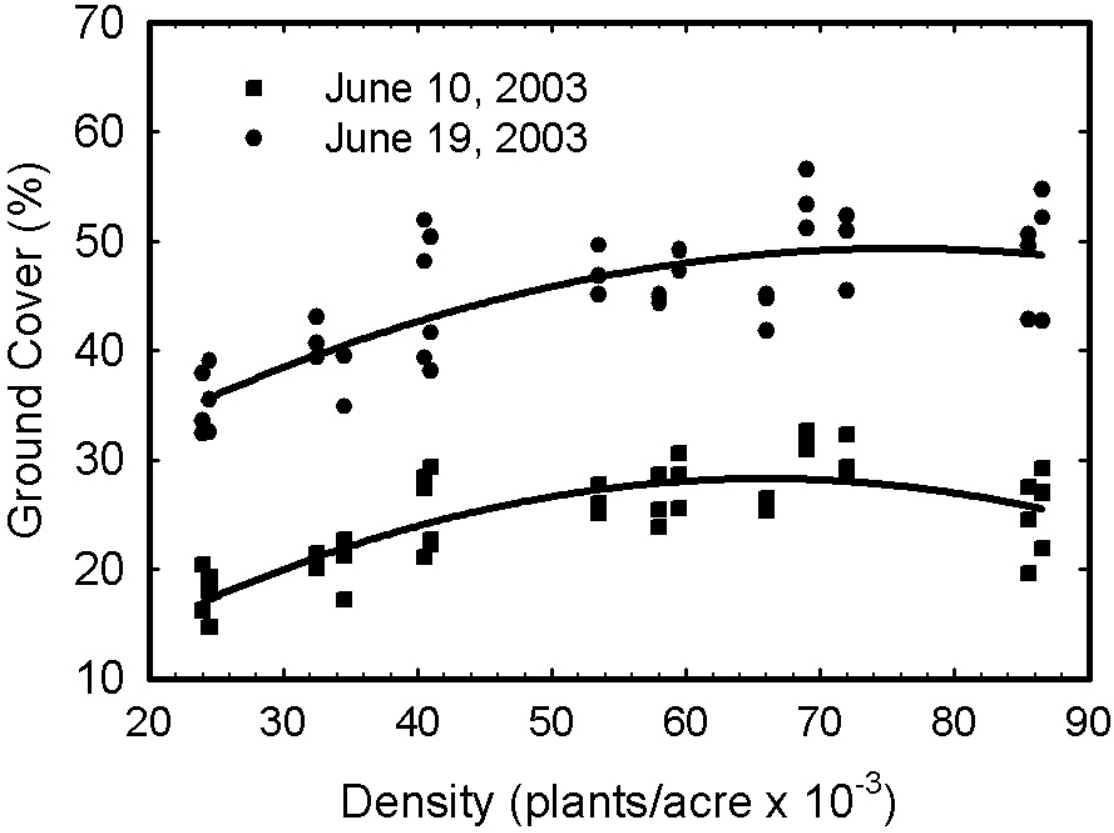

Figure 3. Relationship of percent groundcover and population densities at Maricopa early in the 2003 season. Multiple regression curves using the independent variables of density and the square of density were used to describe percent ground cover. The significance and coefficient of determination for each measurement were: for 10 June 2003, $P<0.0001$ and $R^2=0.668$ and for 19 June 2003, $P<0.0001$ and $R^2=0.580$.

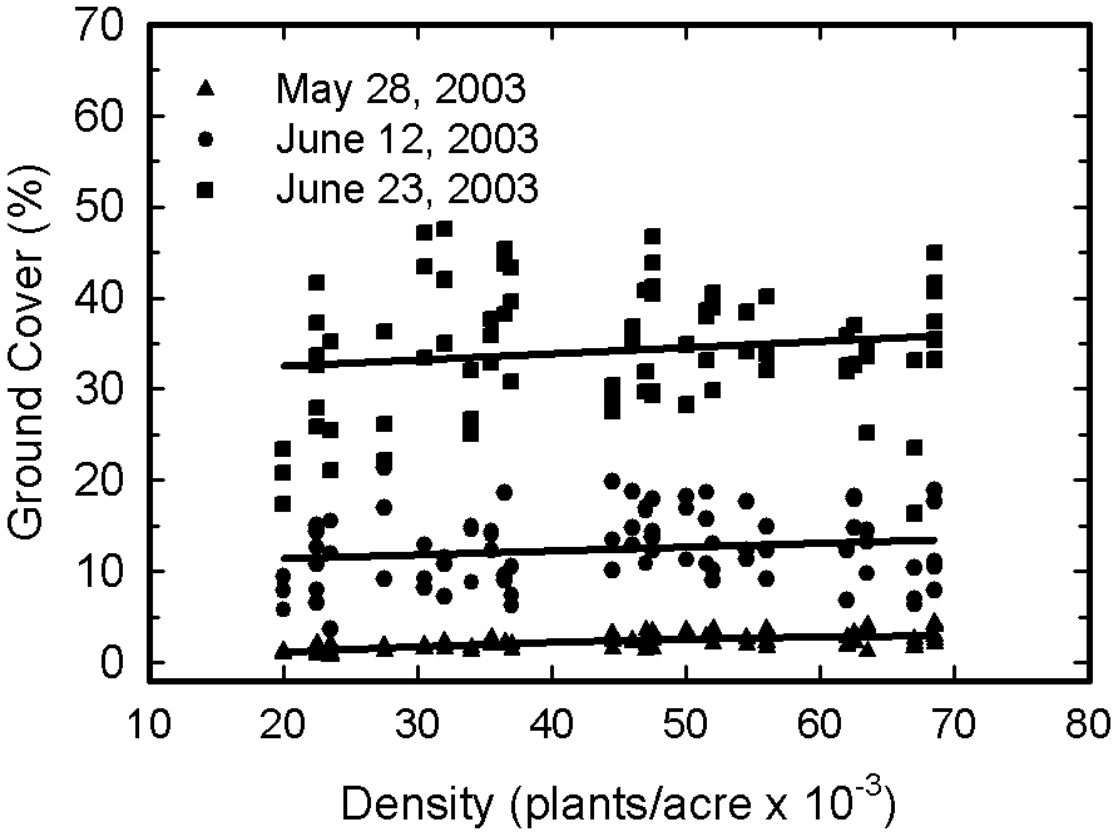

Figure 4. Relationship of percent groundcover and population densities at Marana early in the 2003 season. Multiple regression curves using the independent variables of density and the square of density were used to describe percent groundcover. The significance and coefficient of determination for each measurement were: for 28 May 2003, $P<0.0001$ and $R^2=0.413$; for 12 June 2003, $P<0.0125$ and $R^2=0.0834$; and for 23 June 2003, $P=0.0067$ and $R^2=0.098$.

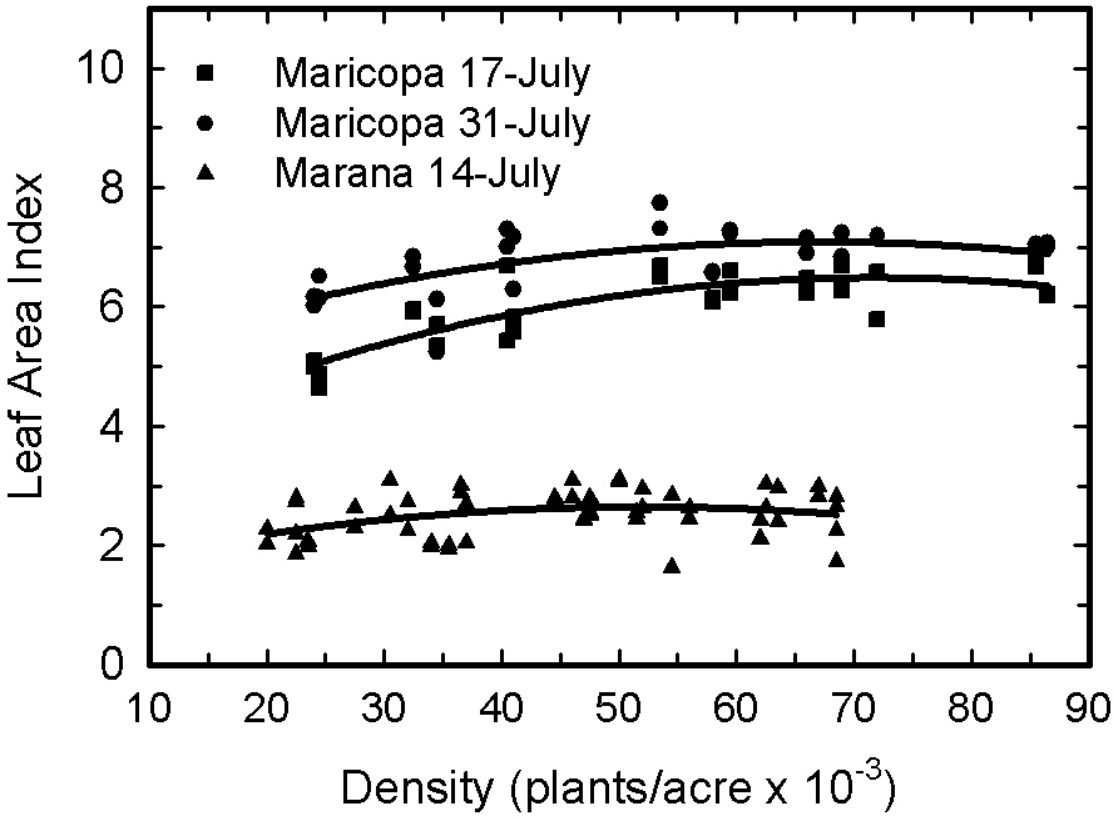

Figure 5. Relationship of leaf area index (LAI) and cotton population densities at Maricopa and Marana at mid-season in 2003. Multiple regression curves using the independent variables of density and the square of density were used to describe leaf area index. The significance and coefficient of determination for each measurement were: for Marana, P=0.0375 and R^2=0.0864; for Maricopa on July 17, P<0.0001 and R^2=0.679; and for Maricopa on July 31, P=0.0027 and R^2=0.326.