**TITLE:** Cotton Row Spacing and Plant Population Affect Weed Seed Production

**DISCIPLINE:** Weed Science

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**ABBREVIATIONS:** CPWC (critical period of weed control), UNR (ultra-narrow row)

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# ABSTRACT

**Weed control is one of the limitations to profitable cropping systems. The objectives of this research were to determine if weed growth and weed seed production were reduced by cotton row spacing and cotton plant population density. Ultra-narrow row (UNR) cotton grown in 25-cm rows reduced sicklepod [*Senna obtusifolia* (L.) H.S. Irwin & Barneby] plant biomass and seed production by 80% compared to conventional row spacing (91 cm). There was an inverse hyberbolic correlation between cotton yield and sicklepod seed production, with the highest yield and least sicklepod seed production in UNR cotton. In the second study, cotton was seeded at four rates: 49,000; 99,000; 118,000; and 148,000 plants ha$^{-1}$. There were inverse linear relationships between cotton plant population density and sicklepod plant biomass, sicklepod seed production, and smallflower morningglory [*Jacquemontia tamnifolia* (L.) Griseb] seed production. At the maximum cotton density, the predicted sicklepod biomass, sicklepod seed production, and smallflower morningglory seed production were reduced 70%, 72%, and 82%, respectively, relative to the lowest cotton density. Increased cotton seeding rates (in both conventional row patterns and UNR) reduced weed seed production. However, under the current economic scenarios, cotton seed price likely prohibits the application of this information as a means to reduce weed populations.**

## Key Words

Crop density, crop row spacing, *Jacquemontia tamnifolia*, *Senna obtusifolia*, sicklepod, smallflower morningglory, soil seedbank, weed fecundity.

Weeds have an estimated annual economic impact on US agricultural production of $15 billion (Bridges, 1994). Growers spend in excess of $1 billion annually to control weeds (Bridges, 1992), yet weeds still persist. Buhler (2002) defines weed control as actions that eliminate an existing population. While a desirable short-term objective is to control potential and emerged weeds, successful weed management systems must reduce weed populations. Weed management emphasizes preventing weed reproduction, reducing weed emergence after crop planting, and minimizing weed interference with crop yield (Buhler, 1996, 2002; Cardina et al., 1999; Zimdahl, 1991). Effective weed management systems will consist of multiple control tactics and will integrate knowledge of the weed's biology (Buhler, 2002). One of the challenges for effective integrated weed management will be to develop cropping systems that minimize the opportunity for weed growth and reproduction (Cardina et al., 1999).

Previous studies have demonstrated that weed growth and weed seed production can be minimized with cultural practices in dry bean (*Phaseolus vulgaris* L.) (Blackshaw et al., 1999), field pea (*Pisum sativum* L.) (Lemerle et al., 2006), safflower (*Carthamus tinctorius* L) (Blackshaw, 1993), wheat (*Triticum aestivum* L.) (Wilson et al., 1995), and corn (*Zea mays* L.) (Teasdale, 1998). Doubling of wheat densities reduced annual ryegrass (*Lolium rigidum* Gaud.) weed biomass by 50%, and weed biomass was correlated with weed seed production (Lemerle et al., 2004). This strategy has been promoted to growers in Australia as an effective component of cropping systems, especially those that include herbicide-resistant weeds, in which there are limited control tactics (Lemerle et al., 2004).

Studies have shown that autumn additions to the soil seedbank were related to seedling recruitment in the following spring (Crawley, 1992; Jensen, 1998; Webster et al., 2003). Hartzler and Roth (1993) found that weed management efficacy was related to the level of control in the previous season. Giant foxtail (*Setaria faberi* Herrm.) control was 59% in the year following 100% weed control, but only 15% in treatments where giant foxtail was not controlled the previous season (Hartzler and Roth, 1993). Therefore, management systems that limit additions to the soil seedbank could have immediate impact on weed control programs. By their nature, soil seedbanks will buffer against localized eradication of a species, but consistent efficacious management can reduce weed populations over time. Mortensen et al. (2000) indicated that smaller weed populations in the soil seedbank require less intensive weed control than higher soil seedbank populations. A combination of conventional weed management with various cultural practices that maximize crop competitiveness and minimize weed seed production could achieve this goal. The objectives of this research were to determine if weed growth and seed production were reduced by cotton row spacing and cotton plant population density.

## MATERIALS AND METHODS

Field studies were conducted between 1999 and 2001 at the USDA-ARS Jones Farm near Chula, Georgia, USA (N31°30.855´, W83°32.611´). The soil type was a Tifton loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiudults) with pH of 6.1 to 6.5 and organic matter 0.8 to 1.0%. The experimental area was prepared using a combination in-row subsoiler with bed shaper prior to planting. The UNR treatment in the row spacing study required a flat seed bed, therefore these areas were disked prior to planting. In 1999, 'Suregrow 585R' was planted May 4 in the row spacing study and May 6 in the cotton density study. In 2000, 'Suregrow 125R' was planted May 5 in the row spacing study and 'Deltapine DP 458R' was planted in the cotton density study on May 1. In 2001, Deltapine DP 458R was planted May 8 in both studies. In the row spacing study, cotton was planted in both conventional rows that were spaced 91 cm apart and in 25-cm rows for the UNR system.  Both row patterns were planted at a rate of 10 cotton seed $m^{-1}$ of row; or 110,000 and 392,000 seed $ha^{-1}$ in the 91- and 25-cm rows; respectively.  In the cotton density study, cotton was planted at four rates: 49,000; 99,000; 118,000; and 148,000 plants $ha^{-1}$ in rows spaced 91 cm apart.  In the conventional row spacing treatments and the cotton density study, plots were four rows wide and 7.6 m long.  In the UNR treatments, plots were 10 rows wide and 7.6 m long.  All treatments were replicated four times in a randomized complete block design.

Following planting, the entire experimental area was treated with pendimethalin (Prowl, BASF Corporation, Research Triangle Park, NC) at 930 g ai $ha^{-1}$, and 0.76 cm of irrigation was applied the same day.  These fields had naturalized populations of sicklepod in each year, while the field used for the cotton density study in 1999 also had smallflower morningglory.  At the 3- to 4-leaf stage of cotton, five sicklepod or five smallflower morningglory within 10 cm of the crop row were covered with inverted cups to protect them from the application of glyphosate (Roundup ULTRA, Monsanto Co., St. Louis, MO) at 0.95 kg ae $ha^{-1}$ that was used to remove all undesired weeds.  Grass weeds that emerged subsequently were treated with clethodim (Select, Valent Agricultural Products, Walnut Creek, CA) at 0.28 kg ai $ha^{-1}$ and crop oil concentrate at 1.0% (v $v^{-1}$); broadleaf weeds were hand-removed or hoed.  Herbicides were applied using a tractor-mounted $CO_2$-pressurized sprayer equipped with flat-fan nozzles calibrated to deliver 140 L $ha^{-1}$ at 160 kPa.

Weeds were removed prior to harvest; plant biomass was measured and number of seeds produced quantified for each weed.  Plots were machine-harvested; plots with conventional row spacing were harvested with a spindle picker, while a stripper-harvester was used in UNR plots.

Lint yield in the conventional row spacing treatments was estimated using standard lint gin-out of 40.5% of seed cotton yield. Due to increased foreign matter contamination associated with UNR, lint yield for these treatments was estimated using 28.0% of seed cotton yield. Data were analyzed using ANOVA with years as random effects. In both studies, due to lack of treatment by year interactions, data were combined across years. Treatment means were separated using the $F$-test from ANOVA in the row spacing study. In the cotton density study, regression was used to evaluate the effect of cotton density on both weed biomass and weed seed production. Correlations between cotton yield and weed seed production were evaluated.

## RESULTS AND DISCUSSION

**Row Spacing.** Cotton row spacing had a significant effect on the cotton-sicklepod interaction. The average sicklepod biomass in the conventional row spacing was 0.244 kg plant$^{-1}$, while the narrow-row spacing significantly reduced ($F$ = 47.64, $P$ < 0.0001) sicklepod plant biomass by 80% (0.046 kg plant$^{-1}$) (Table 1). Compared to weed growth in soybean [*Glycine max* (L.) Merr.] rows spaced 91 cm apart, weed biomass was reduced 47 to 67% in rows spaced 46 cm apart and 76 to 90% in rows with 23-cm row spacing (Yelverton and Coble, 1991). Relative to peanut (*Arachis hypogaea* L.) rows spaced 81 cm apart, sicklepod biomass was reduced 20 to 31% and 36 to 43% when peanut rows were narrowed to 41 and 20 cm, respectively (Buchanan and Hauser, 1980).

As was seen with sicklepod biomass, sicklepod seed production was reduced 80% ($F$ = 11.53, $P$ = 0.0079) in narrow-row cotton (494 seed plant$^{-1}$) compared to conventional row spacing (2,407 seed plant$^{-1}$) (Table 1). Previous studies have not evaluated cotton row spacing effects on weed seed production. Differences in velvetleaf (*Abutilon theophrasti* Medicus) seed production could not be detected when corn was planted at the same population density per hectare in two row spacing patterns (38 and 76 cm) (Teasdale, 1998).

Cotton lint yield in the narrow-row spacing was approximately 60% greater ($F = 46.93$, $P < 0.0001$) than that in the conventional row spacing (Table 1). Other studies have found great variability in cotton yield in UNR compared to conventional row spacing (Boquet, 2005; Jost and Cothren, 2000; Vories and Glover, 2006). Rogers et al. (1976) determined that the critical period of weed control (CPWC) in cotton, the time during which cotton must be kept free of weeds in order to avoid a yield loss, was affected by row spacing. Under high weed densities (100 broadleaf and grass weeds $m^{-2}$), the CPWC was reduced to a 4-wk period in cotton with 53-cm rows, while the CPWC was 6 to 12 wk in cotton rows spaced 106 cm apart (Rogers et al., 1976).

There was an inverse hyperbolic correlation between sicklepod seed production per plant and cotton yield (Figure 1). The highest cotton yields and lowest sicklepod seed production were observed with UNR. While conventional row spacing provided a large range of cotton yields and sicklepod seed production, the lowest yields and highest sicklepod seed production occurred in the conventional row spacing.

The effects of row spacing on weed-crop interactions in the current study and that by Rogers et al. (1976) were complicated by crop density, as the in-row cotton seeding rates were similar among row spacings. In the current study, the UNR treatments had 3.6 times more plants per ha than the conventional row spacing. This increased crop density likely improved the ability of the crop to compete with sicklepod earlier in the growing season compared with the conventional row spacing. High cotton population densities will encourage production of uniform branching which improves harvest efficiency and reduces bark and trash contamination of the lint (Culpepper and York, 2000; Vories and Glover, 2006). However, the increased cotton plant population represents a major input cost, as transgenic cotton seed is among the greatest expenses in producing the crop (Shurley and Ziehl, 2007). Based on 2007 prices, transgenic cotton seed in UNR and conventional row spacing treatments would cost \$643 $ha^{-1}$ and \$180 $ha^{-1}$, respectively (Shurley and Ziehl, 2007). Larson et al. (2003) determined that a cotton density of 156,000 plants $ha^{-1}$ maximized profits in UNR cotton, a seeding rate that is 60% less than that used in the current study.

**Crop Density.** Cotton planting density influenced sicklepod and smallflower morningglory growth and reproduction. There was an inverse linear relationship between cotton plant density and sicklepod biomass ($R^2 = 0.34$, $P = 0.0021$); higher cotton densities were more suppressive of sicklepod growth than were lower cotton densities. The predicted reduction of sicklepod biomass by cotton at 148,000 plants $ha^{-1}$ was 70% compared to that in cotton at 49,000 plants $ha^{-1}$ (Figure 2). A previous study demonstrated that cotton planted at high populations more effectively reduced sicklepod and pigweed (*Amaranthus* spp.) growth (Street et al., 1981). Compared to cotton planted at 47,000 plants $ha^{-1}$, cotton seeded at 94,000 and 187,000 plants $ha^{-1}$ reduced sicklepod biomass 16 to 26% and 28 to 43%, respectively (Street et al., 1981). Relative to cotton seeded at 47,000 plants $ha^{-1}$, cotton planted at 94,000 plants $ha^{-1}$ reduced pigweed biomass 23% in one year, but no differences were detected in the other two years. Pigweed biomass was reduced 19 to 56% by cotton at 187,000 plants $ha^{-1}$ relative to cotton at 47,000 plants $ha^{-1}$ (Street et al., 1981).

There were inverse linear relationships between cotton population density and seed production for both sicklepod and smallflower morningglory (Figures 3 and 4). The predicted sicklepod seed production at the lowest cotton density was 3,860 seeds per plant, while the highest cotton density reduced predicted seed production by 72% (1,060 seeds per plant) (Figure 3). At the lowest cotton population density, predicted smallflower morningglory seed production was 6,900 seeds per plant, while the highest cotton density reduced this estimation 82% to 1,190 seeds per plant (Figure 4). Doubling of corn population density reduced velvetleaf seed production by 99% when the weed emerged with the crop, but prevented velvetleaf seed production when it emerged at the three-leaf corn stage (Teasdale, 1998).

Inverse linear correlations existed between cotton yield and seed production of both sicklepod ($R = 0.55$, $P = 0.0005$, Figure 5) and smallflower morningglory ($R = 0.85$, $P < 0.0001$, Figure 6). In general, the more of the limited resources that are utilized by the crop, evidenced through greater crop yield, the less are available to the competing weed, which is confirmed through less seed production. This correlation demonstrates that poor weed control can penalize growers in multiple ways: first, greater weed seed production indicates less crop yield in the current season and second, greater weed seed production ensures survival of this species to compete in successive growing seasons.

Increased cotton seeding rates (in both conventional row patterns and UNR) can reduce weed seed production. Therefore, it is possible that weed management systems can reduce weed seedbank populations over time. While the current study only evaluated weeds that emerged with the crop, seed production from later emerging weeds may be reduced even more due to the relative competitiveness of the cotton canopy in suppressing weed establishment and growth. There is, however, a cost associated with the benefit from increased cotton seeding rates. The cost of cotton seed likely prohibits increased seeding densities as a means reducing weed populations. The current recommendation is to minimize cotton seeding rate, which allows more cotton production per plant and less cotton seed cost per hectare (Bednarz et al., 2000; Brown et al., 2007; Siebert et al., 2006). However, cropping systems with low crop densities will likely have a greater dependence upon herbicides as the crop canopy will not be as competitive for growth-limiting resources compared with higher crop densities. Weeds that tolerate (Culpepper et al., 2004; Mueller et al., 2005; Webster et al., 2005) or are resistant (Culpepper et al., 2006; Perez-Jones et al., 2005; Trainer et al., 2005) to the most commonly used herbicides will become a greater challenge. Alternative weed management systems that combine the remaining herbicide tools with cultural practices that increase crop competitiveness and reduce the ability of weeds to reproduce will likely become a consideration for growers in the future.

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Table 1. The influence of cotton row width on sicklepod plant biomass, sicklepod seed production, and cotton yield.

| Row spacing[a] | Sicklepod biomass ($g\ plant^{-1}$) | Sicklepod seed production ($\#\ plant^{-1}$) | Cotton lint yield ($kg\ ha^{-1}$) |
|---|---|---|---|
| Conventional | 0.244 | 2407 | 996 |
| Ultra-narrow row | 0.046 | 494 | 1636 |
| *F*-test | 47.64 | 11.53 | 46.93 |
| *P*-value | <0.0001 | 0.0079 | <0.0001 |

[a] Conventional cotton row spacing was 91 cm. Ultra-narrow row spacing was 25 cm.

Figure 1. The correlation between cotton yield and sicklepod seed production.

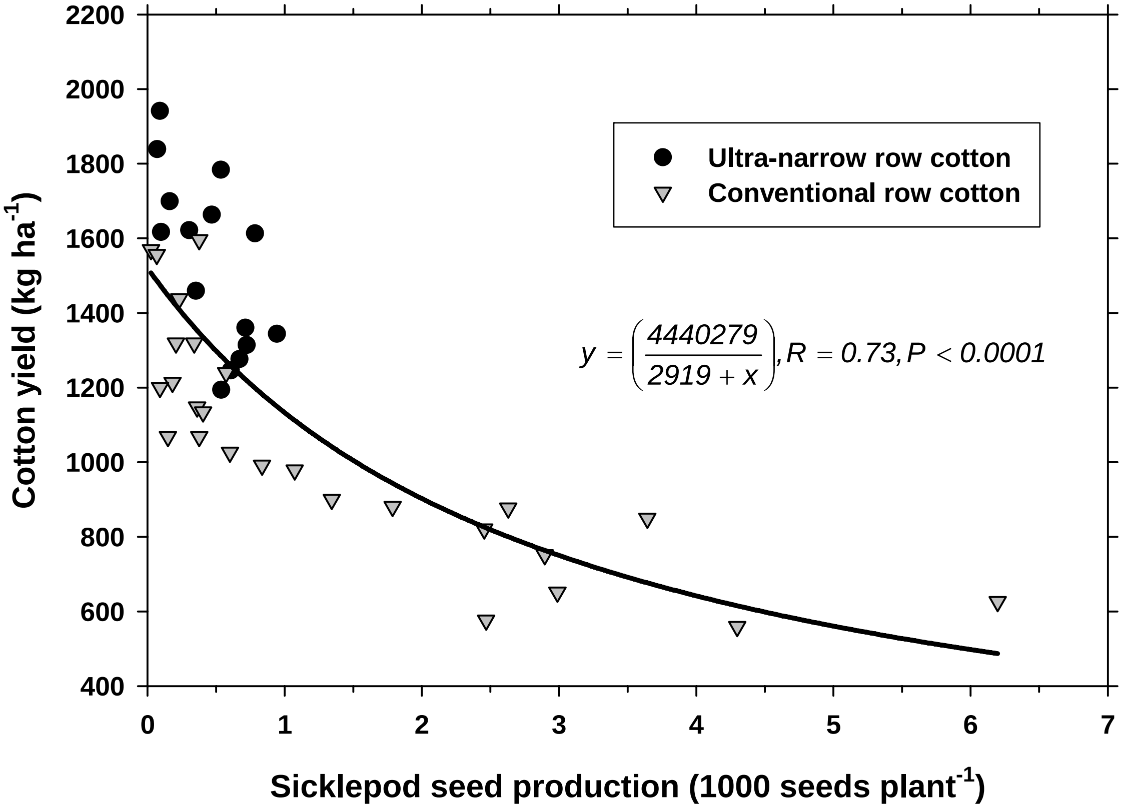

Figure 2. The relationship between sicklepod plant biomass and cotton population density.

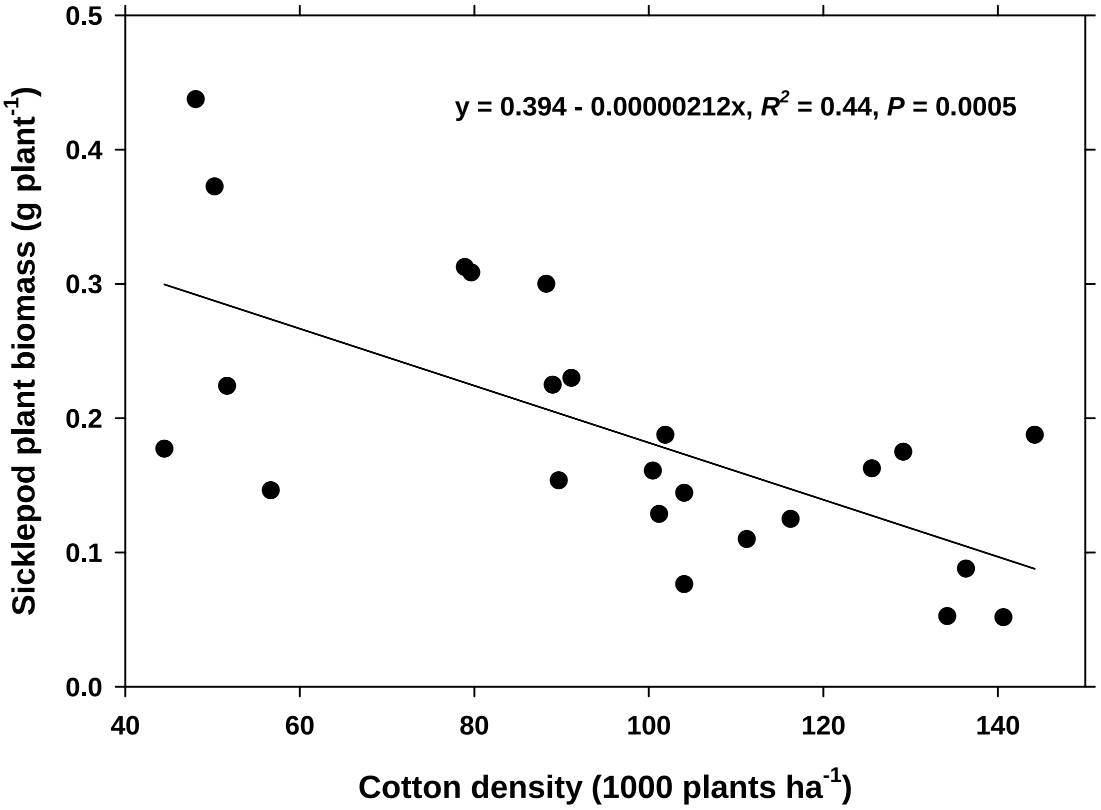

Figure 3. The relationship between sicklepod seed production and cotton plant density.

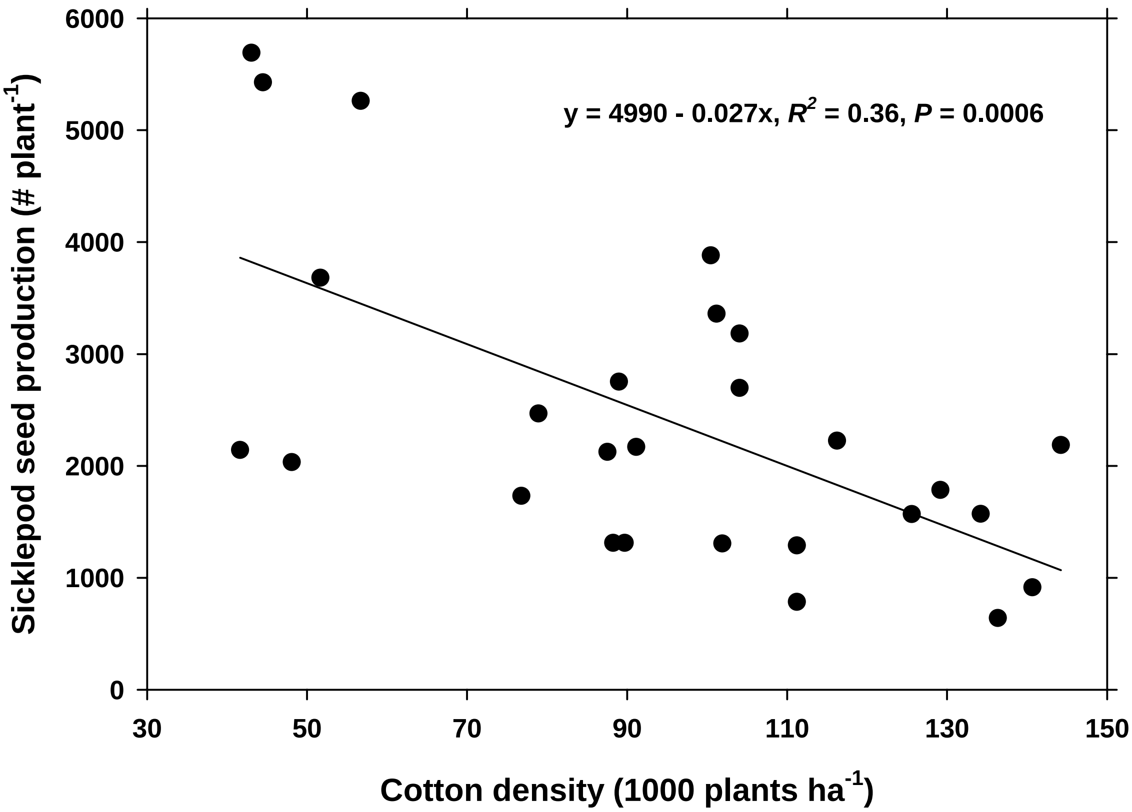

Figure 4. The relationship between smallflower morningglory seed production and cotton population density.

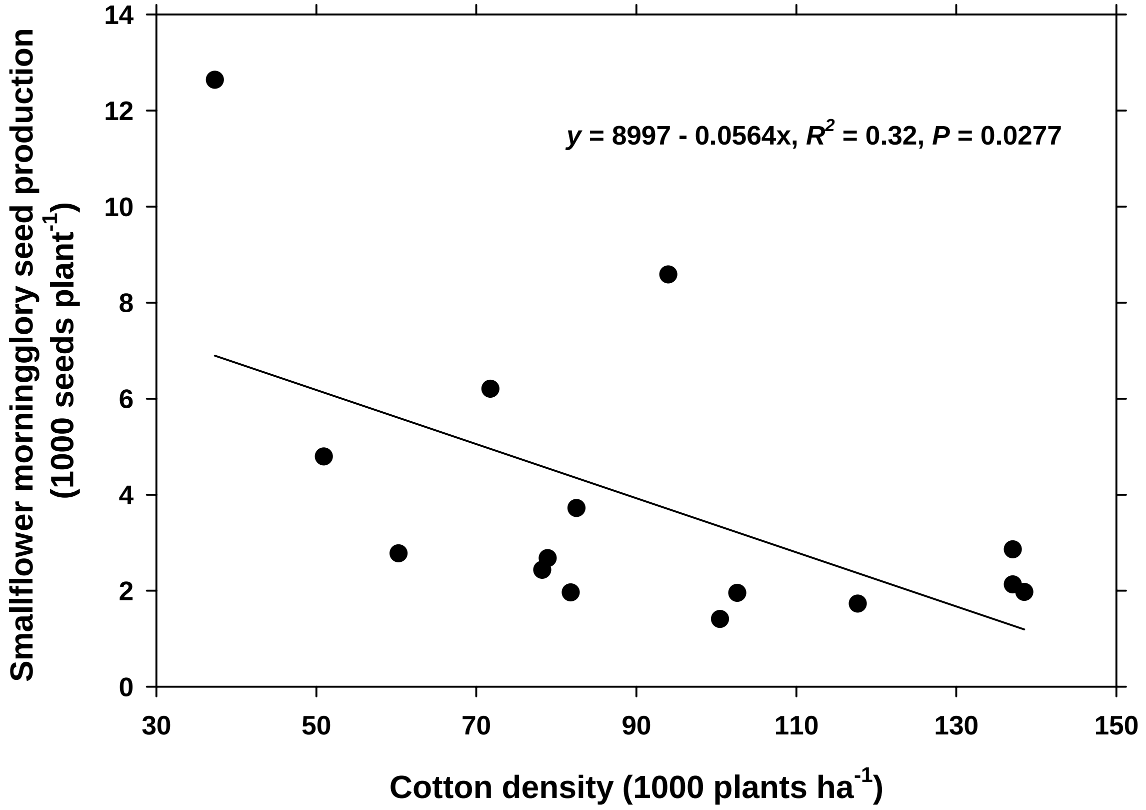

Figure 5. The correlation between cotton yield and sicklepod seed production.

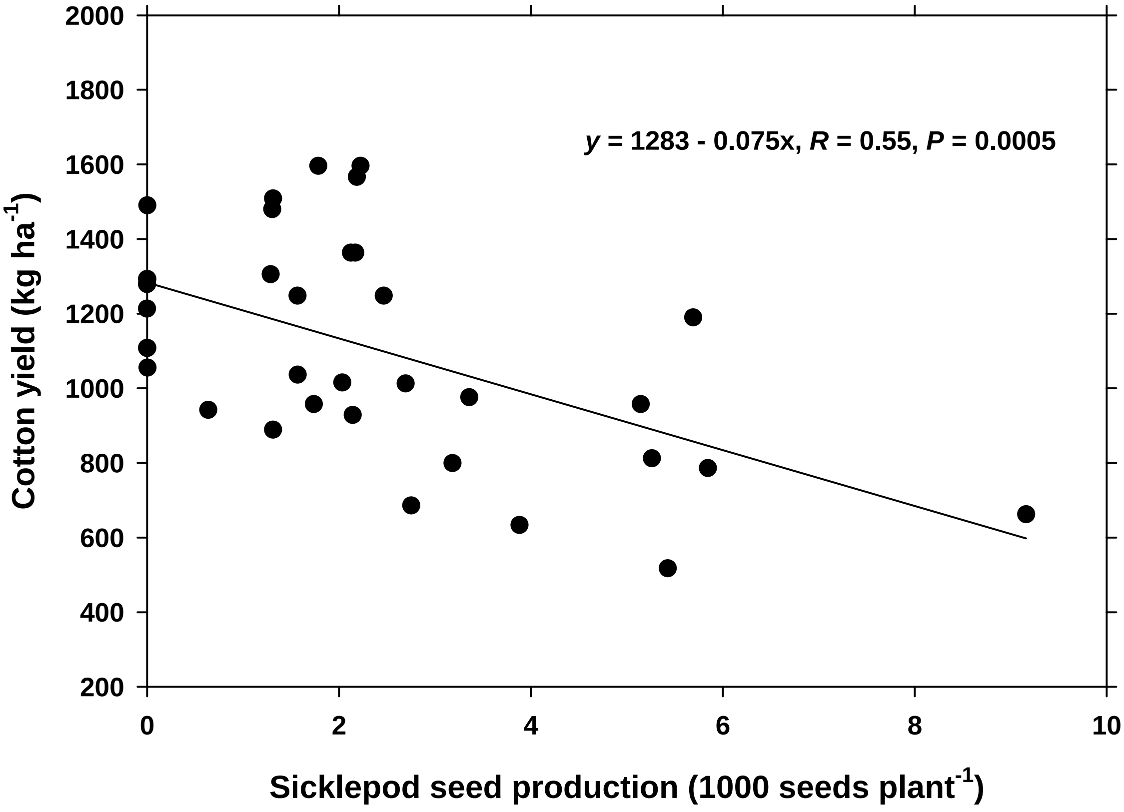

**Figure 6.** The correlation between cotton yield and smallflower morningglory seed production.