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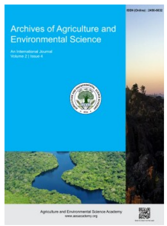

ORIGINAL RESEARCH ARTICLE

A lack of response of irrigated soybean (*Glycine max* L. Merr.) in rotation with cotton (*Gossypium hirsutum* L.) in the Mississippi Delta, USA

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ABSTRACT

The effects of cotton (*Gossypium hirsutum* L.): soybean [*Glycine max* (L.) Merr.] rotations on the respective crops are limited. This manuscript discusses the response of irrigated soybean in crop rotation with cotton. An irrigated soybean: cotton rotation experiment was conducted from the year 2012 through 2015 near Elizabeth, MS. The crop rotation sequences were included continuous soybean (SSSS), continuous cotton (CCCC), cotton followed by soybean (SCSC), soybean followed by cotton (CSCS), soybean followed by two year of cotton (SCCS), and cotton followed by two year of soybean (CSSC). The rotations were grown under two production systems conventional and transgenetic with respect to weed control. During this study, a weed control treatment of (pendimethalin pre-emergence vs. glyphosate post-emergence) as included on the soybean plots was used. The soybean yields across rotations within a year were not significantly different. The means yields differed among years (3655.1, 3023.6, 3500.6 and 2600.3 Kg ha^{-1} for the year 2012, 2013, 2014 and 2015, respectively) and appear related to difference in rainfall/irrigation amounts. The results revealed that the weights of 100 seed samples averaged 13.9g in the year 2015 which differed from the previous years (16.2, 15.6, and 16.2g; 2012, 2013 and 2014, respectively). Therefore, the rotations of cotton with soybean appear to have neither a beneficial or negative effect on soybean yield.

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INTRODUCTION

Crop rotations of many kinds have been practice worldwide for centuries and numerous scientific articles are available about rotations of various crop species (Bruns, 2012). However, for many years prior to the mid-1990's, continuous cotton production was a normal practice for much of the Cotton Belt of the United States because, even in rotation with other crops, the financial return per hectare would not match that of a monoculture of cotton and soybean (Hake *et al*., 1991; Ashworth *et al*., 2017). By the late 1990's changes in farm commodity support programs in the United States made the production of other crops besides cotton financially feasible. In the year 2001 several experiments on crop rotations with cotton begin to be published showing benefits from such practices. Wesley *et al.* (2001) compared deep soil tillage of heavy clay soils in autumn to conventional tillage in the Mississippi Delta. The rotation sequences with cotton and soybean increased yields of both crops when grown in combination with deep tillage. Guidy *et al.* (2001) reported data from a 10 year crop rotation study that a cotton-cotton-soybean rotation yielded economic returns above direct costs of $122.73 (U.S.) and $327.03 (U.S.) over continuous cotton and soybean respectively. Bryson *et al.* (2003) found a reduction in populations of the weed, purple nutsedge (*Cyperus rotundus*), in rotations of transgenic cotton and soybean. Using cotton, maize (*Zea mays* L.) and soybean in various rotation schemes, Ashworth *et al.* (2016) reported increasing crop diversity with these two crops in one or two years of a four year cycle with cotton stabilized cotton seed yield in the long-term. Pettigrew *et al.* (2016) recently reported from this experiment lint yield increases of cotton following soybean were likely a result of increased soil-N fixed by the previous soybean crop and/or altered microbial populations favorable to cotton. Potential rotations of these two species exist due to annual changes in markets for these commodities. Therefore the present investigation was conducted to study the response of irrigated soybean (*Glycine max* L. Merr.) in rotation with cotton (*Gossypium hirsutum* L.) in the Mississippi Delta, USA.

MATERIALS AND METHODS

The soybean: cotton rotation experiment was conducted from the year 2012 through 2015 on a Dundee silty loam (fine-silty, mixed active, thermic Typic Ochraqualf) site 1.0 km north of Elizabeth, MS and leased by the Crop Production Systems Research Unit of the USDA-ARS at Stoneville, MS as described by Pettigrew *et al.* (2016). Rotation sequences were; continuous soybean (SSSS), continuous cotton (CCCC), cotton followed by soybean (SCSC), soybean followed by cotton (CSCS), soybean followed by two year of cotton (SCCS), and cotton followed by two year of soybean (CSSC). The rotations were grown under two production systems conventional and transgenetic with respect to weed control. Both herbicide treatments were applied according to label recommendations along with cultivation at plant growth stage R_1 (Hanway and Thompson, 1967).
Seven d prior to crop planting the entire experimental area was sprayed with 1.1 Kg a.i. ha^{-1} of paraquat for early vegetation control. For both transgenic and conventional soybean management systems both *S*-metolachlor and pendimethalin at 1.1 Kg a.i. ha^{-1} each were applied pre-emergence. In the transgenic management system 0.9 Kgs a.i. ha^{-1} of glyphosate was applied approximately 28 d post emergence and again at R_1. For the conventional management system 1.1 Kg a.i. ha^{-1} *S*-metolachlor plus 0.27 Kg ai ha^{-1} fomesafen were applied 28 d post emergence followed by chlorimuron at 151 g a.i. ha^{-1} applied at R_1.
Field preparation began with disking and forming 51cm high ridges, spaced 102 cm apart. In late winter 67.2 Kg K ha^{-1} as murate potash was applied with no other fertilizer application later. Rows were harrowed to form a seed bed approximately 12" across each ridge. The cultivar used, was Dekalb brand DKR 4744 R2/S (Monsanto, St. Louis, MO). Though it was a glyphosate resistant cultivar, it was used in both the transgenic and conventional management systems. The seeding rate for soybean was 121,500 seeds A^{-1} in twin-row spaced 25.0 cm apart with 102 cm between row pairs. An experimental unit was eight row pairs 21 m long. Seeding dates for both crops were 24 April, 30 April, 5 May and 30 April for the years 2012, 2013, 2014 and 2015, respectively. Two furrow irrigations of 25.0 mm $^{-1}$ were applied in 2012, three in 2013, two in 2014 and four in 2015. Irrigation applications in this experiment were made primarily to meet water management requirements for cotton. The Paraquat was applied as a desiccant at 1.1 Kg a.i. ha^{-1} 14 days prior to harvest. Four center row pairs were machine harvested with a Kincaid 8X-P (Kincaid Equipment Mfg. Haven, KS) combine equipped with a Harvest Master weighing system (Juniper Systems, Logan, UT), sampled and seed weights accumulated. Data were analyzed using PROC MIXED of the SAS system (Cary, NC).

RESULTS AND DISCUSSION

The results of irrigated soybean seed yields in four rotation schemes with cotton in the Mississippi Delta over four years are given in Table 1. The results indicated that the herbicide treatments were found to have no impact on seed yields nor seed weights and therefore were combined in the analysis of rotation sequences. The statistical analysis of data on the seed yields in the years 2012 > 2014 > 2013 > 2015 were noted insignificantly ($P \leq 0.05$) different among different years (Table 1). Additionally, the statistical analysis also indicated that within years, yields across rotation schemes were not significantly different. The mean yield differences between years are most likely related to the amount of available water each year by both rainfall and irrigation (Table 2). Cotton is known to benefit from some drought stress between irrigations and that excessive irrigation can result in more vegetative grow, shading of the lower canopy thus causing boll drop and reduced yields (Munk and Farah, 2017). Numerous research articles demonstrate that soybean yields decline with drought stress, especially during reproductive growth. Mean weights of 100 seed samples were similar to observations on seed yield. Moreover, no statistically significant differences were observed between rotation sequences within a given year.

Table 1. Irrigated soybean seed yields in four rotation schemes with cotton in the Mississippi Delta over four years.

Rotation	Yield† (kg ha^{-1})			
Scheme	2012	2013	2014	2015
SSSS	3621.5	2976.5	3574.5	3714.5
SCSC	3735.8		3467	
SCCS	3621.5			2515.9
CSCS		3016.8		2566.7
CSSC		3084	3467	
MEAN‡	3655.1	3023.6	3500.6	2600.3

†Means of 12 replications; ‡Means of 12 replications and 3 rotation schemes, $LSD_{0.05}$=100.8.

Table 2. Total available water to a cotton: soybean rotation experiment near Elizabeth, MS during May to August.

Source	mm ha^{-1}			
	2012	2013	2014	2015
Rainfall†	386.1	191.8	351.8	164.3
Irrigation	50.8	76.2	50.8	101.6
TOTAL	436.9	268.0	402.6	265.9

†Mississippi State University Extension Service (MSUES). 2016. Delta Agricultural Weather Center. Mississippi State University, Mississippi State, MS. (Source: http://www.deltaweather.msstate.edu accessed on 28 February, 2017).

However, the mean 100 seed weights were 16.2, 15.6, 16.2 and 13.9 g for the year 2012, 2013, 2014 and 2015, respectively with the only significant (*P≤0.05*) difference being the observed mean for 2015 being less than the three previous years. Again, the less available moisture in 2015 compared to the previous years' undoubtedly resulted in lower seed weight due to possible moisture stress that occurred. These data demonstrate that neither a benefit nor detrimental effect of rotating soybean with cotton will occur with respect to seed yield or seed weight in soybean regardless of the rotation scheme used in producing these two crops. As previously reported, cotton does appear to receive a yield benefit following soybean (Pettigrew *et al.*, 2016) and though there does not appear to be any negative effect of cotton preceding soybean neither is there evidence of soybean yield increases following cotton based on data from this study. The potential increase in income with greater cotton lint yields combined with the lack of negative effects on soybean seed yields should justify the employment of rotations in producing these two crops.

Conclusion

The present investigation concluded that Soybean yields across rotations within a year were not significantly different. Means yields differed among years (3655.1, 3023.6, 3500.6, and 2600.3 Kg ha^{-1} for the years 2012, 2013, 2014 and 2015, respectively) and appear related to difference in rainfall/ irrigation amounts. Weights of 100 seed samples averaged 13.9 g in 2015 which differed from the previous years (16.2, 15.6, and 16.2g; 2012, 2013 and 2014, respectively). Thus, the rotations of cotton with soybean appear to have neither a beneficial or negative effect on the soybean yield. Wilhelm and Wortmann (2004) also reported the similar changes in the crop yield of corn and soybean due to the crop rotations.

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