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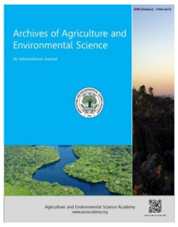

ORIGINAL RESEARCH ARTICLE

Effects of boron foliar fertilization on irrigated soybean (*Glycine max* L. Merr.) in the Mississippi River Valley Delta of the midsouth, USA

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ABSTRACT

Boron (B) deficiencies have been observed in some irrigated soybean fields in the lower Mississippi River Valley on silt loam soils of pH $\geq$7.0 and irrigated with water having high calcium (Ca) and magnesium (Mg). Boron fertilization effects on irrigated soybean grown using the Early Soybean Production System (ESPS) in the Midsouth have yet to be determined. Three commercial cultivars available for use in the ESPS were selected and foliar fertilized with a B solution at GS's R3 and/or R5 at concentrations of 280 g B ha^{-1}, 560 g B ha^{-1}, or a split application at both R3 and R5 of 280 g B ha^{-1}. Established stands were greater in 2016 than 2015 (262,378 vs. 180,804 plants ha^{-1}) resulting in respective mean yields of 4239.7 vs. 3794.7 kg ha^{-1}, but no significant interactions with years were noted. Yields of AG4632 were unaffected by B fertilization. Boron fertilization of P47T36 at R5 generally improved yields (>4000.0 kg ha^{-1}) over the control (3668.6 kg ha^{-1}) and applications at R3 (<3900.0 kg ha^{-1}). The 560 g B ha^{-1} treatment at R3 for P50T64 produced less seed (3742.5 kg ha^{-1}) than all other treatments while no other differences were noted. Some differences were noted in 100 seed weights but they were neither large nor consistent. It is doubtful that economic benefits to soybean in the Mississippi Delta would result unless a B deficiency was positively identified early in a growing season or in previous seasons. It is concluded from this experiment, that foliar fertilization of soybean with B, as a general production practice, is not recommended.

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INTRODUCTION

Boron (B) is an essential micronutrient in soybean (*Glycine max* L. Merr.) with roles in nitrogen (N) fixation (Bolaños *et al.,* 1996), tissue development, reproduction, and photosynthate translocation (Davidson, 2014). Its principle role is in cell wall development and as a result deficiency symptoms often first appear in apicies with subsequent stunting and rosetting of the plants. Lee and Aronoff (1967), showed that, biochemically, B combines with 6-phosphglucanate in the pentose phosphate pathway to form a 6-phosphglucanate-borate complex that cannot be further metabolized and thus inhibits the pathway. In a B deficiency this pathway becomes prominent and excess synthesis of phenolic acids occur.

The normal content of B in a soybean is considered to be between 20.0 to 100.0 mg B kg^{-1} dry matter with 16.0 to 20.0 mg B kg^{-1} considered to be the transition zone between deficiency and adequacy (Ohlroggee, 1960). Bruns (2017) recently reported that with irrigation, a soybean yield of 3322 kg seed ha^{-1} in the lower Mississippi River Valley would remove about 153.9 g B ha^{-1} and that about 465.0 µg B plant^{-1} would be returned to the soil in the crop residue. Boron deficiencies in soybean are not as frequent in clay soils as coarse well drained sandy soils where plants can frequently have a positive response to B fertility rates of 3.4 to 5.7 kg B ha^{-1} (Tisdale *et al.,* 1975). Schon and Blevins (1990) showed multiple applications totaling 1.12 kg B ha^{-1} to soybean throughout reproductive growth increased branch and pods per branch. Reinbott and Blevins (1995) later report an average increase in soybean seed yields of 8.0% by multiple foliar applications totaling 1.12 kg B ha^{-1} and 2.56 kg Mg ha^{-1}. Martens and Westermann (1991) and later Sutradhar *et al.* (2016) though reported only small yield responses in soybean to B fertilization. These supported earlier observations by both Touchton and Boswell (1995) and Woodruff (1979) who reported mixed results from foliar fertilization with B of soybean grown on sandy-loam soils.

Boron deficiencies have been shown to occur in parts of the lower Mississippi River Valley. Silt loam soils of pH ≥7.0 and irrigated with water high in calcium (Ca) and magnesium (Mg) bicarbonate are prone to B deficiencies (Slaton *et al.,* 2013). Ross *et al.* (2006) reported yield increases ranging from 4 to 130% above unfertilized alkaline soils in Northeast Arkansas. Bellaloui *et al.* (2013) demonstrated foliar B-fertilization of soybean increased B accumulation in leaves and seed and altered seed protein and fatty acid content. Given soybean's economic importance to the Midsouth USA, research into factors with potential yield benefits is of keen interest. Boron fertilization's potential to improve seed yields on irrigated soybean grown using the Early Soybean Production System, now commonly practiced in the lower Mississippi River Delta, have yet to be determined. The objective of this study was to determine if foliar fertilization of irrigated soybean with B affected yield and seed weight.

MATERIALS AND METHODS

Trade names are used in this publication are solely for the purpose of providing specific information. Mention of a trade name, propriety product, or specific equipment does not constitute a guarantee or warranty by the USDA-ARS and does not imply approval of the named product to exclusion of other similar products. The author declares there is no conflict of interests regarding the publication of this article.

The experiment was conducted on a Dundee silty clay (fine -silty, mixed, active, thermic Typic Endoaqualfs) pH= 7.0 and B≤0.8 mg kg^{-1} located 2 km north of Elizabeth, MS and during 2015 and 2016 on a field previously planted to soybean. Site preparation included disking and forming 0.5 m high ridges, spaced 1.0 m apart. In late winter 67.2 kg K ha^{-1} as murate potash was applied pre-planting. No other fertilizer was applied. Rows were later harrowed to form a seed bed approximately 0.4 m across each ridge. Seedings were done 22 April, 2015 and 25 April 2016 using a John Deere model 7100 vacuum planter (Moline, IL).

The experimental design used was a split plot of a randomized complete block replicated three times and data analyzed using statistical procedures outline by McIntosh (1983) for combining experiments. Whole plots were 8 single-rows seeded at a rate of 300,105 seeds ha^{-1} and consisted of one of three cultivars assigned at random within replications; Asgrow brand[1] AG4632 (Monsanto Co., St. Louis, MO), Pioneer brand[1] P47T36 and P50T64 (DuPont Pioneer Co., Johnston, IA). Sub-plots were six different randomly assigned applications of SOLUBOR[1] (Southern Agricultural Insecticides, Inc., Palmetto, FL) applied at growth stage R3 and/or R5 (Ritchie *et al.,* 1994). Treatments were applied as a foliar spray and consisted of; an untreated control, 280 B g ha^{-1} applied at R_3, 560 g B ha^{-1} applied at R_3, 280 g B ha^{-1} applied at R5, 560 g B ha^{-1} applied at R5, and 280 B g ha^{-1} applied at R_3 and again at R_5. Boron treatments were applied to the center four rows of each sub-plot at a spray rate of 37.8 L ha^{-1}. These same four rows were later non-destructively sampled for stand establishment, then later harvested for yield using a plot combine with a weighing system, and sampled for seed weight determinations.

The experiment received 396.0 mm total rainfall in 2015 and 543.5 mm in 2016. Furrow irrigation of 25.4 mm per A was applied 18 June, 16 July, 23 July, 3 August and 12 August 2015 and 28 June 2016. Data were analyzed using the PROC MIXED procedures of the Statistical Analysis System (SAS Institute, 2012) with cultivar × replication (year) and replication (year) as random effects.

RESULTS AND DISCUSSION

Established plant stands were less (P≤0.10) in 2015 than 2016 (180,804 vs. 262,378 plants ha^{-1}) which resulted in a lower mean yield in 2015 than 2016 (3594.7 vs. 4239.7 kg ha^{-1}, respectively). No significant interactions involving year x cultivars or year x treatment were noted for seed yield. Yields for P50T46 were significantly (P≤0.10) greater than P47T36 in the untreated control (Table 1).

Table 1. Seed yields of three irrigated soybean cultivars treated with foliar applications of boron fertilizer at two rates (280 B g ha^{-1} and 560 kg B ha^{-1}) and two growth stages (R_3 and R_5).

Cultivar	Yield (kg ha^{-1})					
	Control	280 @ R3	560 @ R3	280 @ R5	560 @ R5	280 @ R3 +280 @ R5
AG4632	3883.5	3897.0	3950.8	3917.2	3957.5	3883.6
P47T36	3668.6	3897.0	3729.0	4044.8	4347.2	4259.8
P50T64	4011.2	3802.4	3742.5	3836.5	3883.6	3876.9

Means of three replications and two years (2015 and 2016). LSD $_{0.10}$=248.6 for means within a row or a column.

Table 2. Seed weights of three irrigated soybean cultivars treated with foliar applications of boron fertilizer at two rates (280 B g ha^{-1} and 560 g B ha^{-1}) and two growth stages (R_3 and R_5).

Cultivar	100 seed wt. (g)					
	Control	280 @ R3	560 @ R3	280 @ R5	560 @ R5	280 @ R3 + 280 @ R5
AG4632	14.5	14.7	14.6	15.6	14.7	14.7
P47T36	14.1	14.3	14.5	14.3	14.3	14.9
P50T64	15.3	15.3	14.7	15.6	14.5	14.8

Means of three replications and two years (2015 and 2016). LSD $_{0.10}$=0.4 for means within a row or a column.

However, seed yields in the 560 g B ha^{-1} treatment at R_5 and the split application treatment were significantly greater for P47T36 than either P50T64 or AG4632. No other yield differences among cultivars were observed across the remaining B fertility treatments. For the cultivar P50T64 seed yield was significantly ($P \leq 0.10$) less at 560 g B ha^{-1} at R3 compared to all other treatments except 560 g B ha^{-1} at R5. No other treatment differences were noted for this cultivar. The seed yield of AG4632 was unaffected by B fertility. The fact that the soil at the experimental site was silty clay may have contributed to a lack of consistent responses to B fertility as was stated by Tisdale *et al.* (1975). These yield data do not support observations by Ross *et al.* (2006) and Slaton *et al.* (2006) on soils in the lower Mississippi River Valley of Arkansas.

Across cultivars, the 100 seed weights for P50T64 were greatest for the control and 280 g B ha^{-1} treatments at both growth stages than for both 560 g B ha^{-1} treatments and the split application (Table 2). Other significant differences in 100 seed weights among B fertility treatments was observed with the cultivar AG4632 at 280 g B ha^{-1} applied at R5 having a greater weight than all other treatments. For P47T36 the split application of 280 g B ha^{-1} at R_3 and again at R_5 had greater seed weights than all other treatments except 560 g B ha^{-1} at R_3. No other significant differences in 100 seed weights were observed. These results neither dispute nor support the findings of Reinbott and Blevins (1995) and later Bellaloui *et al.* (2013) who observed increases in 100 seed weights of foliar fertilized soybean.

Conclusions

It is concluded from this experiment, that foliar fertilization of soybean with B, as a general production practice, is not recommended especially on heavier clay or silty-clay soils. Given the general lack of a consistent yield response to B foliar fertilization though as seen in this experiment, such treatments are doubtful to be economically beneficial to soybean in the lower Mississippi River Valley unless B deficiency symptoms were positively identified early in a growing season or in previous seasons at a particular site. Further research would be needed to determine if some consistency in cultivar differences in the response to B fertilization exist and if so, would it be economically beneficial to take advantage of such a difference.

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