

## Boron Fertilization of Rice with Soil and Foliar Applications

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### Abstract

Soil sampling and testing for B is currently not a common practice for farmers producing rice (*Oryza sativa* L.) in the southeastern United States. Field research in Missouri showed that rice yields were greatest when soil B levels were 0.25 to 0.35 ppm by the hot water extraction method. In 2000, rice receiving soil-applied B produced significantly greater yields than rice with foliar-applied B and rice with no B applied. In 1999 and 2001, there was no significant difference between yields obtained with foliar or soil B applications.

### Introduction

Yield increases from boron fertilization in soybean (*Glycine max*) and cotton (*Gossypium hirsutum*) have been reported in field tests in Missouri, Georgia, Tennessee, and Arkansas (1,7,12,13). The authors are not aware of any rice research reports from B fertilization field tests in the southeastern United States. The lack of interest in B fertilization in rice may be partly due to work by Marsh (11), which showed that the boron requirements for dicotyledon plants were greater than monocotyledon plants. The functions of B in rice plants are to promote cell growth and development of the panicle (5). Loomis and Durst (10) found that 90% of the boron in plants is localized in the cell walls. Symptoms of B-deficiency in rice are sometimes difficult to visually detect in the field (8). Boron deficiency symptoms in rice begin with a whitish discoloration and twisting of new leaves (9,18). Severe deficiency symptoms from rice include thinner stems, shorter and fewer tillers, and failure to produce viable seeds. Boron deficient stems and leaves were found to be brittle while boron sufficient leaves and stems are flaccid.

Tracy et al. (17) found that most irrigation wells (Fig. 1) in the Missouri rice producing counties contain high pH water buffered with calcium carbonate. Boron was not measured in the irrigation water samples. The high pH probably has a negative effect on soil boron availability to rice plants flooded with this water. Boron primarily occurs in the soil as  $H_3BO_3$ . Available B is derived from decomposition of organic matter and release from clay minerals. The  $H_3BO_3$  form of B is highly mobile in the soil (14). Liming decreases boron availability in soils because higher pH levels favor the  $B(OH)_4^-$  form. In this form, clay minerals as well as Al and Fe oxides adsorb B (3).



Fig. 1. Irrigation wells used for rice production in Southeast Missouri and Northeast Arkansas often contain high levels of calcium carbonate which reduces soil B availability to rice plants.

No specific boron soil test recommendations for rice are in place for Arkansas, Mississippi, or Missouri. The current University of Missouri soil test recommendations for all row crops is to apply B at 0.5 lb/acre when less than 0.25 ppm hot-water extractable B is found in the top 6 inches of soil. Boron is very water-soluble and is mobile in soil-water solutions (8). In Southeast Missouri, hot water extractable B in rice soils generally range between 0.1 and 0.5 ppm.

Farmers prefer to minimize their trips across a field to apply chemicals. In drill-seeded rice, B can be applied as a dry material with P and K fertilizers before planting or with urea before establishing a permanent flood. Many cotton farmers in the southeastern United States routinely foliar apply B on cotton in a tank mix with insecticides. If weed control is not reduced in an herbicide/B tank-mix, soluble B could be foliar-applied when rice farmers spray postemergence herbicides for grasses and weeds. Research is needed to determine whether tank mixing B with herbicides has a negative impact on weed control.

In 1999, a study was initiated to evaluate boron fertilization on rice in the upper Mississippi River Delta region. The objectives of the experiments were to (i) compare the effect of soil and foliar boron applications at different rates on rice grain yields and (ii) evaluate weed control from herbicides mixed with soluble boron.

### **Boron Soil and Foliar Fertilization**

Two experiments were conducted on fields at the Missouri Rice Research Farm (36°N, 90°W) in Dunklin County, Missouri. Both experiments were designed as randomized complete blocks with four replications. A boron fertilizer rate experiment using soil and foliar application methods was conducted in 1999, 2000, and 2001. An experiment studying the effects of mixing soluble boron with postemergence herbicides was conducted in 2001 and 2002.

### **Site Descriptions**

Both experiments were conducted on Crowley silt loam soils (fine, montmorillonitic, thermic Typic Albaqualf). The soils are derived from fluvatile sediments and have a silt loam A horizon, which overlies a thick, silty clay loam argillic horizon (6). Experiments were moved each year to new fields to maintain established soybean/rice rotations. In the B application/rate experiment, the average soil water pH of the surface horizon in the test rice fields was 6.2; average organic matter content was 1.4%; and soil boron content was 0.19 ppm hot-water extractable B. In the herbicide/B interaction experiment, the average soil water pH of the fields was 6.0; organic matter was 1.7%; and the soil boron content averaged 0.21 ppm hot-water extractable B. This field was infested with barnyardgrass (*Echinochloa crus-galli*) and hemp sesbania (*Sesbania exaltata*).

There was no record of boron fertilizer ever being applied on any of the test fields. Fields were conventionally tilled each year. In early May of each year, 'Kaybonnet' rice was drill-seeded at a rate of 75 lb/acre.

### Boron Rate Experiment

Rice response to five rates of boron was evaluated with two application methods. Boron rates were 0, 0.25, 0.50, 0.75, and 1.00 lb/acre. Two application methods, soil and foliar spray, were evaluated for each boron rate. Soil applications were made just prior to planting. Foliar sprays were made at V4 (early tiller) growth stage (4). To achieve uniform B spreading, soil applications were made by mixing fine granular sodium borate ( $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$ ) 20% B (Solubor, U.S. Borax, Valencia, CA) with 2.5 gal of water and evenly applied to the appropriate plots using a hand watering bucket (Fig. 2). Foliar applications were made using a backpack  $\text{CO}_2$  pressurized sprayer (Fig. 3). Sodium borate was mixed with water and the sprayer was calibrated to apply 20 gal/acre. Immediately before flooding, soil samples were collected from each plot, which had received soil boron applications at planting. These soil samples represent a 0- to 6-inch depth. Boron content was then determined by the hot water soluble method (2) at the University of Missouri Delta Regional Soils Testing Lab, Portageville, MO. Each plot was rated for boron deficiencies and toxicity symptoms at V4 (first tiller) and again at R0 (panicle initiation).



Fig. 2. Soil B treatments were applied on plots by dissolving granular sodium borate in water and uniformly distributing the solution with a watering bucket.



Fig. 3. A backpack  $\text{CO}_2$  sprayer was used to apply foliar treatments.

### Boron with Herbicide Experiment

Soluble boron was mixed with a propanil + molinate (Arrosolo) herbicide premix to determine whether B interferes with postemergence grass control in rice. Barnyardgrass control from a pre-mix of propanil and molinate (2.25 lb propanil a.i. per acre + 2.25 lb molinate a.i. per acre) was evaluated with and without B fertilizer. The field was first treated with a blanket application of propanil + molinate as part of a normal weed control program when barnyardgrass had two to three leaves. Boron treatments were applied with a second application of propanil + molinate and were applied two to four days before the establishment of permanent flood when rice was at the V4 stage of growth. Barnyardgrass had regerminated and was in the two- to three-leaf stage at the time of pre-flood applications of herbicide and boron. Barnyardgrass was the only weed present. Treatments were applied with a back-pack  $\text{CO}_2$  pressurized sprayer calibrated to apply 20 gal/acre. Fine granular sodium borate was mixed with the herbicide + B treatment at a rate of 0.50 lb of B per acre. An untreated check was included in the experiment.

The statistical analyses of yield and barnyardgrass control were performed using Mixed Model procedures of the Statistical Analysis System (15). The Mixed Model procedure provides Type III F values, but does not provide mean square values for each element within the analysis or the error terms. Mean separation was evaluated through a series of pair-wise contrasts among all treatments (16). Probability levels greater than 0.05 were categorized as non-significant. Regression analysis was used to quantify the effects of pre-plant soil boron applications on soil test boron levels and determine the optimum B fertilizer rates for rice yields.

### Soil versus Foliar Boron

A strong linear correlation ( $R^2 = 0.97$ ) was found between hot-water extractable B at V4 rice growth stage and soil fertilizer boron application made one month earlier, prior to planting (Fig. 4). This showed that soil tests were effective in detecting boron from fertilizer applications.

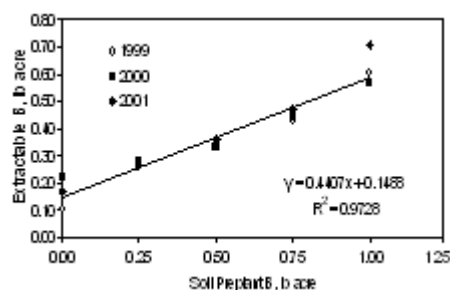


Fig. 4. Effect of soil boron fertilizer applied before planting on extractable B at V4 growth stage.

Significant interactions were found across years for fertilizer application methods (soil versus foliar) and fertilizer rates (Table 1). This suggests weather had an effect on rice response to boron. In 2000, rice receiving soil-applied boron produced significantly greater yields than rice with foliar-applied B (Table 2). Since the soil-applied treatments were made at planting as compared foliar treatments made at the V4 growth stage, soil applied B may have helped early vegetative growth and promoted tillering. In 1999 and 2001, there were no significant differences between yields obtained with foliar or soil boron applications. The foliar applications were made when the rice plants were small (V4 stage) and most of the spray was deposited on the soil rather than the rice plants. Thus, most of the foliar spray served as a soil treatment. The floodwaters then moved this boron into the soil.

Table 1. Analysis of variance for method of application and rate of boron fertilizer in 1999, 2000, and 2001.

Effect	Significance
Year	n.s.
Method	n.s.
Year*Method	†
Rate	††
Year*Rate	††
Method*Rate	n.s.
Year*Method*Rate	n.s.

n.s. = Non-significance.

† Indicates significance at  $P = 0.05$ .

†† Indicates significance at  $P = 0.01$ .

Table 2. Effect of method of boron fertilizer application on rice yields in 1999, 2000, and 2001 averaged across boron rates.

Year	Method of application	Rice yield†† (bu/acre)
1999	Soil	149.2 a
	Foliar	150.8 a
	Check†	145.5 a
2000	Soil	163.7 a
	Foliar	153.5 b
	Check	137.3 c
2001	Soil	145.7 a
	Foliar	146.7 a
	Check	137.8 a

† Check treatments received no soil or foliar boron applications.

†† Yield values in the same year followed by the same letter were not significantly different at  $P = 0.05$ .

### Boron Fertilizer Rates

Averaged across application methods in each year, rice yields from the untreated check (no applied B) were numerically lower than all other treatments (Table 3). No significant differences were found in yields among treatments in 1999. However, significant differences were found in 2000 and 2001. In 2000, rice yields from all B treatment rates were significantly greater than the untreated check. The 0.50-lb/acre B rate produced the greatest yields. In 2001, the 1.0-lb/acre B rate produced the highest yields.

Table 3. Effect of rate of boron fertilizer application on rice yields in 1999, 2000, and 2001 averaged across methods of application.

Year	Rate of boron (lb/acre)	Rice yield † (bu/acre)
1999	0	145.5 a
	0.25	150.9 a
	0.50	148.3 a
	0.75	155.8 a
	1.00	149.6 a
2000	0	137.3 d
	0.25	159.5 bc
	0.50	175.0 a
	0.75	159.5 bc
	1.00	161.8 b
2001	0	137.8 b
	0.25	149.3 ab
	0.50	144.5 ab
	0.75	148.1 ab
	1.00	151.3 a

† Yield values in the same year followed by the same letter were not significantly different at  $P = 0.05$ .

### Boron with Herbicide

Adding sodium borate to propanil + molinate increased the pH of the spray solution from 7.4 (without B) to pH 8.2 (with B). Boron had no adverse effects on barnyardgrass control or crop response to propanil + molinate. (Table 4). Further research is needed to determine how adding B might affect the activity of other rice herbicides.

Table 4. Effect of applying soluble boron with propanil + molinate herbicide at V4 rice growth stage on barnyardgrass (*Echinochloa crus-galli*) control and rice yields averaged across 2001 and 2002.

Treatment	Barnyardgrass † control (%)	Rice injury (%)	Rice yield (bu/acre)
Untreated check	0 b	0 a	51 b
Propanil + molinate	74 a	0 a	82 a
Propanil + molinate + boron	82 a	0 a	89 a

† Barnyard grass control, rice injury, and yield values followed by the same letter were not significantly different at  $P = 0.05$ .

### Summary

Most cotton growers in the Upper Delta region are aware of the need for boron fertilization in cotton. However, applying boron is not a common practice of rice producers. Our results indicate that the optimum preplant B rate in rice for Missouri soils was between 0.25 and 0.5 lb/acre (Fig. 5), which corresponded with a critical level for hot water extractable boron between 0.25 and 0.35 ppm hot water extractable boron (Fig. 4). Currently, the University of Missouri recommendation for other row crops is to apply boron when the soil test B levels are found to be less than 0.25 ppm by the hot water extraction method.

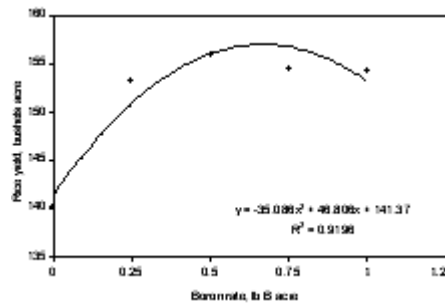


Fig. 5. Regression analysis response curve from average rice yields receiving five rates of B fertilizer in 1999, 2000, and 2001.

Rice yields increased with 0.5 to 1.0 lb added boron fertilizer per acre. In two out of three years, boron applications increased rice yields by more than 10 bu/acre. The cost of one pound of boron is currently less than three dollars. For rice farmers, this would be more than a 10 to 1 return on their input cost. In fields with low soil test B, we recommend that rice farmers soil apply B before planting or as a foliar spray with postemergence herbicides. In addition, B may be mixed with the herbicide propanil + molinate resulting in cost- and time-savings to growers, as opposed to separate boron and herbicide applications.

Many rice farmers in the Upper Delta have soil conditions conducive for a B response but they lack information that would advise them of the need. We randomly selected and tested fifty soil samples for B from rice grower fields at the University of Missouri Delta Regional Soil Testing Lab. More than half of the samples tested below 0.25 ppm B by hot water extraction (*data not shown*). The majority of these low B soils were silt loam soils. This indicates that boron deficiency in rice might be more widespread on the lighter texture, rice soils found west of Crowley's Ridge.

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