Micronutrient Content of Irrigated Soybean Grown in the Midsouth

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Abstract

Micronutrients are essential to soybean (*Glycine max* L. Merr.) growth but required in minute quantities. Concentrations and tissue contents of Fe, B, Zn, Mn and Cu were determined for two MG IV and one MG V irrigated cultivars grown in twin-rows in the Mississippi Delta on a Dundee silty clay (fine-silty, mixed, active, thermic Typic Endoaqualfs) and a Bosket fine sandy loam site (fine-loamy, mixed, active, thermic Mollic Hapludalfs), near Stoneville, MS in 2011 and 2012. Plants were sampled at growth stages V3, R2, R4, R6 and R8, their tissues separated, dried, weighed and ground for later nutrient concentration assays. Total nutrient contents were calculated from these data. No cultivar, site or year differences in concentrations or contents of the nutrients were observed. Iron had the greatest concentration and plant content of all elements at all growth stages, followed by B, Zn, Mn and Cu. Due to the elements being immobile, maximum concentrations and contents in leaves were acquired at R4 and declined as leaves senesced. In stems both concentrations and contents remained constant, or increased during this time, while seed containing pods rapidly increased until (R8). These data show a 3328 kg ha^{-1} seed yield will remove about 325.0 g Fe ha^{-1}, 153.9 g B ha^{-1}, 175.6 g ha^{-1}, 100.0 g Mn ha^{-1} and 52.5 g Cu ha^{-1}.

Introduction

Micronutrients or "trace elements" in crop production are, as the two terms imply, essential elements to the successful completion of a crop's life cycle but only needed in minute amounts. The quantities of such ions contained in the soil and utilized by a plant are often measured in grams or milligrams per hectare, are seldom at inadequate levels, and can be toxic if in excess, be it naturally or by failed attempts at supplemental fertilization. Research into micronutrients over the past 50 y has been encouraged largely by the successes in yield increases resulting from supplemental fertilization with the macro-nutrients N, P, and K. The extensive use of supplemental N fertilizers especially after WWII on non-legume species such as corn (*Zea mays* L.) and small grains saw a near doubling in seed yields and resulted in research to explore the possibility of similar increases by added micronutrients.

In soybean one of the more comprehensive reports on nutrient uptake and composition until recently, was written by Ohlrogge (1960) who extensively reviewed the literature on soybean nutrient uptake and requirements written in the previous four decades. Information on B, Zn, Fe, Mn, and Cu concentrations found in this research are discussed but information about deficiency symptoms or evidence of toxic levels are lacking. Bender et al. (2015) recently published an extensive study of biomass production and nutrient uptake of two MG 2.8 and one Mg 3.4 soybean cultivars grown on glacial formed soils near 40° N and 42° N latitude. The concentrations of measured micro-nutrients in the seed from their study showed B, Zn, Mn, Fe, and Cu to be (31.9, 40.2, 26.3, 70.7, and 11.3 µg g^{-1} respectively).

Materials and Methods

The experiment was conducted during the 2011 and 2012 growing seasons at two sites. One site was a Bosket fine sandy loam site, located on the Mississippi State University Delta Branch Research and Extension Center. Soil tests prior to initiating the experiment showed this site to have a pH=6.8, OM= 18.3 g kg^{-1}, P=54.0 $kgha^{-1}$, and K=53.7 $kgha^{-1}$. The second site was a Dundee silty clay located on private property leased by the Crop Production Systems Research Unit of the USDA-ARS. Soil tests at this site showed a pH=6.7, OM= 22.8 gkg^{-1}, P=38.0 $kgha^{-1}$, and K=64.9 $kgha^{-1}$. A pre-plant annual application of 0-33-66, N-P-K was applied both years of the experiment. The experimental design employed in the study was a randomized complete block replicated three times. Experimental units were one of three soybean cultivars, Asgrow[1] (Monsanto; St Louis, MO) AG4303 (MG 4.3), Pioneer[1] (DuPont; Johnston, IA) 94B73 (MG 4.8), and Asgrow AG5503 (MG 5.5). Plots were eight 12 m rows seeded in a twin- row configuration planted with a Monosem[1] NG3 (Monosem; Edwardsville, KS). Each row of a twin-row unit was spaced 25 cm apart and centered on 102 cm between units. A seeding rate of 30 seed m^{-2} occurred on 14 April 2011 at both locations, 23 April 2012 on the Dundee soil and 25 April, 2012 on the Bosket soil. The previous crop at both sites in 2011 was corn (*Zea mays* L.) and soybean in 2012.

Beginning at growth stage V3 (three trifolates unfolded) and continuing at R2 (full flowering), R4 (full pod), R6 (full seed), and R8 (full maturity), three randomly selected plants from each plot were harvested from either row 2 or row 7. Sampling was done on individual cultivars as they reached the described growth stage (Ritchie et al., 1994) and as weather would permit. Total leaf area per plant was determined using a LiCor[1] LI-3100C leaf area meter. At V3, R2, R4, and R6. Leaves, stems, and pods from each plot were placed in separate paper bags, oven dried at 70° C for at least 76 h, weighed, and then ground to pass a 2.0 mm screen. A minimum 2.5 g sample of ground tissue was placed a 5 ml plastic sample bottle and sealed for later analysis. Individual samples were analyzed by Waters Agricultural Laboratories, Inc.[1] (Camilla, GA). An open vessel wet digestion method described by Miller (1998) was used to determine the micro nutrient elements in this experiment.

The four center rows of each plot were harvested at maturity (R8), for yield determination. Data for the micronutrients along with their total contents in the leaf, stem, pod, seed, and residue (dead stem and pod tissue at harvest) were analyzed using ANOVA procedures of SAS 9.4 (Statistical Analysis System SAS Institute, Cary, NC). Due to a lack of statistical significance between site and/or year interactions in the initial data analyses, both sites and years were combined and treated as an individual random environmental effect in the final analysis.

[1]Disclaimer

Trade names are used solely for the purpose of providing specific information. Mentions of a trade name, propriety product, or specific equipment does not imply approval of the named product to exclusion of other similar products.

Table 1. Micronutrient Concentration (µg g^{-1} dwt) of Irrigated Soybean at Five Different Growth Stages Grown in the Lower Mississippi River Valley. †

Tissue	Element	V3	R2	R4	R6	R8	$lsd_{0.05}$=
Leaves	Fe	305.06	552.92	222.73	174.72		34.40
	B	110.57	92.83	83.70	141.76		7.39
	Zn	58.05	61.00	66.72	58.97		3.30
	Mn	55.56	65.88	56.68	55.42		5.40
	Cu	11.50	12.86	12.17	8.31		0.22
Stems	Fe	203.46	146.59	64.46	54.83		42.10
	B	54.58	49.23	34.52	36.69		5.89
	Zn	35.22	31.80	16.65	13.60		1.23
	Mn	22.94	20.05	15.84	14.26		1.68
	Cu	10.65	10.70	7.61	5.52		3.60
Pods	Fe			107.43	95.56	*	
	B			61.33	52.58	*	
	Zn			51.53	44.28	*	
	Mn			34.28	29.93	*	
	Cu			12.04	11.81	ns	
Seed	Fe					97.65	
	B					46.25	
	Zn					52.77	
	Mn					30.17	
	Cu					15.78	
Residue	Fe					77.21	
	B					47.79	
	Zn					18.54	
	Mn					16.02	
	Cu					5.53	

†Means of three cultivars (AG4303, 94B73, and AG5503), two years (2011 and 2012), two sites (Tunica clay and Bosket fine sandy loam), three replications, and three plants.

Table 2. Micronutrient Content (µg $plant^{-1}$) of Irrigated Soybean at Five Different Growth Stages Grown in the Lower Mississippi River Valley. †

Tissue	Element	V3	R2	R4	R6	R8	$lsd_{0.05}$=
Leaves	Fe	445.23	1558.50	1930.54	445.23		184.56
	B	163.94	247.51	744.72	787.66		68.40
	Zn	87.60	167.52	569.45	346.62		32.37
	Mn	80.65	182.30	489.20	303.51		36.79
	Cu	17.25	35.30	103.81	50.49		5.34
Stems	Fe	278.96	372.20	590.53	784.51		93.92
	B	64.23	122.77	313.10	512.97		23.38
	Zn	42.80	81.69	138.38	198.83		12.08
	Mn	28.48	51.24	141.14	200.34		13.13
	Cu	12.93	27.33	68.12	78.94		4.85
Pods	Fe			572.68	2012.91	*	
	B			275.70	1062.14	*	
	Zn			229.09	894.44	*	
	Mn			154.13	558.60	*	
	Cu			61.15	547.72	*	
Seed	Fe					2317.07	
	B					1074.8	
	Zn					1229	
	Mn					703.44	
	Cu					371.43	
Residue	Fe					742.99	
	B					424.66	
	Zn					151.63	
	Mn					174.31	
	Cu					50.58	

†Means of three cultivars (AG4303, 94B73, and AG5503), two years (2011 and 2012), two sites (Tunica clay and Bosket fine sandy loam), three replications, and three plants.

Table 3: Whole Plant Micronutrient Content (µg $plant^{-1}$) of Irrigated Soybean at Five Different Growth Stages, and Grown in Twin-Rows in the Lower Mississippi River Valley.†

Element	V3	R2	R4	R6	R8	$lsd_{0.05}$=
Fe	724.19	1930.70	3093.75	3242.65	3060.06	1364.56
B	228.17	370.28	1333.52	2362.77	1499.46	1110.67
Zn	130.40	249.21	936.92	1439.89	1380.63	778.03
Mn	109.13	233.54	784.47	1062.45	877.75	528.91
Cu	30.18	62.63	233.08	677.15	422.01	340.37

†Means of three cultivars (AG4303, 94B73, and AG5503), two years (2011 and 2012), two sites (Tunica clay and Bosket fine sandy loam), three replications, and three plants.

Results and Discussion

Based on these data and a grand average yield of 3328 kg ha^{-1} seed from this study (48 bu A^{-1}), soybean in the lower Mississippi River Valley will remove 325.0 g Fe ha^{-1}, 153.9 g B ha^{-1}, 175.6 g Zn ha^{-1}, 100.0 g Mn ha^{-1}, and 52.5 g Cu ha^{-1}. These values are somewhat greater than those acquired by Bender et.al. (2015), with non-irrigated MG 2.8 and MG 3.4 cultivars grown at 40° and 42° north latitude. Other comparisons of these data with previous research include the range of micronutrient composition in soybean leaves grown in Indiana as reported by Small and Ohlrogge (1973). At growth stage R4 they reported Fe ranged from 189 to 312 µg g^{-1}, B 49 to 53 µg g^{-1}, Zn 49 t0 53 µg g^{-1}, Mn 73 to75 µg g^{-1} and Cu 13 to 14 µg g^{-1}. With the exception of B, which in this experiment was 87.3 µg g^{-1}, the remaining micronutrients of the leaves at R4 are within or close to being within range of Small and Ohlrogge's (1973) reported data. These data do not appear to provide a definitive answer to how much of any one or a set of micronutrients are required by soybean. It appears that a number of items likely influence the concentrations and contents of soybean, including the location of where the crop is grown, cultivar, irrigation, soil pH, and the availability of other nutrients, especially P in the form of phytate. In this experiment neither a deficiency nor toxic level of any of the micronutrients was observed and therefore were within an acceptable level for soybean growth.

References

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