Fertilizer Management of Soybean in Northwestern and Northcentral North Dakota

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ABSTRACT

Soybean (*Glycine max* L.) is a new cash crop for northcentral and northwestern North Dakota (ND) producers. Soils and climate in these new soybean areas differ from current fertilizer guidelines. North central and northwestern ND is more undulating, arid, cooler, and has differing soil pH. A three year study to evaluate soybean best management practices was initiated in the spring of 2016 and will be concluded in 2018. Each year had two sites and twelve treatments. One site was acidic (pH < 6.2) and the other was alkaline (pH > 7.2). Both site treatments were: untreated check, inoculated with rhizobia (*Bradyrhizobium japonicum* L.), broadcast urea (50 lbs ac^{-1}), broadcast MAP (100 lbs ac^{-1}), In-furrow 10-34-0 (3 gal ac^{-1}), in- furrow 6-24-6 (3 gal ac^{-1}), foliar 9-18-9 (3 gal ac^{-1}) at V5 and R2, and foliar 9-18-9 (3 gal ac^{-1}) with sulfate (1 lb ac^{-1}) at V5 and R2. The acidic site had two treatments of sugarbeet (*Beta vulgaris* L.) waste lime (2 tons ac^{-1} and 4 tons ac^{-1}). The alkaline site received treatments of iron ortho-ortho-EDDHA (3 gal ac^{-1}) (Soygreen®), and naked ortho-ortho-EDDHA (3 gal ac^{-1}) (Levesol®). Fertilizer treatments did not affect soybean yield, oil, or protein content at individual environments or when the four environments were combined for statistical analysis.
The presented data reflects the 2016 and 2017 growing season.

INTRODUCTION

North Dakota has historically been a leading spring wheat (*Triticum aestivum* L.) producer (NASS, 2018a). Spring wheat acres have decreased from 8,314,229 ac in 1997 (NASS, 2018a) to 5,352,282 ac in 2017 (NASS, 2018b). Many of those acres have changed to soybean (Glycine Max *L.*) as that crop has increased from 1,144,389 in 1997 (NASS, 2018a) to 7,103,029 ac grown in 2017 (NASS, 2018b). The change in acres has mostly occurred in northcentral and northwestern North Dakota.

Current North Dakota soybean fertility recommendations have been developed from data collected in the eastern third of North Dakota (Franzen, 2018). Eastern North Dakota receives more rainfall than western North Dakota. The annual normal total precipitation in Fargo is 22.6 in (46.897°N, 96.812°W) while Crosby (48.807152°N, 103.311735°W) receives 15.18 in (NDAWN, 2018a). Southern North Dakota is warmer than northern North Dakota. The average annual air temperature in Crosby is 39.0°F whereas Fargo is 42.0 °F (NDAWN, 2018b). Soybean seed breeders and agronomists recommend growers use Group 0 maturity soybeans in Fargo, whereas 00 and 000 maturity group soybeans are recommended in Crosby (Kandel, 2010).

Soil parent materials north and east of the Missouri river in North Dakota are of glacial origin. The Red River Valley consists of lacustrine sediments as a result of thousands of years of sedimentation from ancient glacial Lake Agassiz. Landscapes have more soil variability in western North Dakota compared to eastern North Dakota (Bluemle, 2000). Due to different soil types and climate, research is needed to guide soybean producers in their fertilization strategies with data collected from the more arid and cooler northwest/northcentral regions of North Dakota.

MATERIALS AND METHODS

Experimental sites were screened and selected using soil test results in the spring prior to planting. Six soil cores were collected at the 0-6 inch and 6-24 inch depth using a hand push probe of 1-inch diameter to characterize each site. The cores were composited and sent to the North Dakota State University Soil Testing Laboratory, Fargo, ND for analysis (Table 1). All soil tests were conducted using approved and standard practices (North Central Regional Research Publication, 2015). All Columbus site soils types were a fine-loamy mixed superactive frigid Typic Argiustoll (Williams loam). The Minot 2016 soil type was a fine-loamy mixed superactive frigid Pachic Argiudoll (Aastad). The 2017 Riverdale soil type was a fine-silty mixed superactive frigid Pachic Haplustoll (Wilton) (USDA-NRCS, 2018).

Table 1. Site location and soil test results of research plots.

Site	Year	Location	N		P	K	Zn	Fe	E.C.	pH
			0-6 in depth	6-24 in depth	---------------0-6 in depth---------------					
		latitude, -longitude--	- lbs ac^{-1}-		---------ppm--------				-mmhos/cm-	
Columbus 1	2016	48.795444°N, 102.853044°W	26.6	65.0	6	224	0.29	11	0.35	7.6
Minot 1	2016	48.179167°N , 101.316367°W	6.9	26.6	8	316	0.29	48	0.47	6.2
Columbus 2	2017	48.8891°N , 102.8701°W	23.6	38.4	5	276	0.48	7	0.2	7.2
Riverdale	2017	47.5018° N, 101.2781°W	26.6	35.4	7	223	0.69	56	0.31	5.8

Soybean cultivars were chosen based on maturity and iron deficiency chlorosis rating (IDC) (Kandel et al., 2017; Kandel et al., 2016; Kandel et al., 2015). Soybeans planted at the Columbus sites were IDC tolerant (Table 2).

Table 2. Soybean variety and cropping practices of the respective research site.

Site	Seed Company	Soybean Cultivar	Planting	V5 Fertilizer Application	R2 Fertilizer Application	Harvest
			------------------------Date------------------------			
Columbus 1	NorthStar Genetics	NS0081NR2	5/30/2016	7/8/2016	7/27/2016	9/23/2016
Minot 1	Proseed	20-30	5/29/2016	7/8/2016	7/28/2016	9/25/2016
Columbus 2	Legend	009R20	5/22/2017	7/6/2017	8/4/2017	9/29/2017
Riverdale	Hefty	H009R3	5/24/2017	7/8/2017	8/5/2017	10/1/2017

The experimental design was a randomized complete block with twelve treatments and replicated four times. The fertilizer treatments were: check, inoculation (*Bradyrhizobium japonicum* L.), hand applied urea (46-0-0) (50 lbs ac^{-1}), hand applied monammonium phosphate (11-52-0) (100 lbs ac^{-1}), hand applied waste sugarbeet (*Beta Vulgaris* L.) lime (2 and 4 tons ac^{-1}). The urea was treated with N-(n-butyl)-thiophosphoric triamide (Agrotain Advance 1.0®) to reduce ammonia volatization (Koch Agronomic Services, 2018). Waste sugarbeet lime treatments were applied only at the Minot and Riverdale sites because of the acidic soil pH (Table 1).

Ammonium polyphosphate (10-34-0), orthophosphate-polyphosphate (6-24-6), Fe ortho-ortho-EDDHA (Soygreen®, West Central Inc, 2018a), and naked ortho-ortho-EDDHA (Levesol®, West Central Inc., 2018b) fertilizers were applied as a liquid in furrow at 3 gal ac^{-1}. The ortho-ortho-EDDHA treatments with and without Fe were applied only at the Columbus sites because of its alkaline soil pH (Table 1).

Foliar treatments were applied with a hand boom sprayer at the V5 and R2 growth stage (Fehr and Caviness, 1977). The foliar treatments were a mixture of anhydrous ammonia-phosphoric acid-potassium hydroxide based liquid fertilizer (9-18-9) and 9-18-9 with ammonium sulfate (1lb ac^{-1}) applied at a rate of (3 gal ac^{-1}).

Experimental units were 10 ft wide and 30 ft long Plots were managed using best management practices as described by Kandel (2010). Soybeans were seeded at a rate of 150,000 pure live seed per acre with a single disk opener cone plot planter. The planter row spacing was 7.5 in. Pesticide treatments were based on present weed species at each location and applied according to their respective label and recommendations (Zollinger et al., 2016; 2017). Soybeans were harvested using a small plot combine.

Soybeans were cleaned by a vacuum-type seed cleaner before yields, protein, and oil content were determined. Oil and protein content were measured using a DA 7200 NIR analyzer (Perten Instruments Incorporated, 2017).

Analysis of variance was performed using the PROC GLM procedure of SAS software version 9.4 (SAS Institute Incorporated, 2012). Environments were considered homogenous when the variance across sites were less than a factor of 10 (Tabachnick and Fidell, 2001). Environments were treated as a random effect.

RESULTS AND DISCUSSION

Fertilizer treatments did not affect soybean yield, oil content, or protein content at individual environments (Table 3).

Table 3. Mean yield, protein, and oil of soybeans across all environments.

Treatment	Yield -(bu/ac)-	-Protein %-	-Oil %-
Inoculation	33.30	33.49	14.97
Beet Lime 4 tons ac^{-1}	32.87	34.83	14.68
Urea 50 lbs ac^{-1}	31.95	33.88	14.82
*10-34-0	31.72	33.63	15.14
Beet Lime 2 tons ac^{-1}	31.54	34.65	14.82
11-52-0 50 lbs ac^{-1}	31.15	33.74	15.02

Check	30.01	33.77	15.06
*6-24-6	29.90	33.42	15.09
**Foliar 3-18-18 @V5 with AMS	29.86	33.49	15.06
**Foliar 3-18-18 @R2 with AMS	29.27	33.65	14.96
†Foliar 3-18-18 @V5	29.11	33.96	14.95
†Foliar 3-18-18 @R2	29.05	33.63	15.02
*Levesol	28.50	32.68	15.14
*Soygreen	24.48	32.37	15.38
LSD (0.10)	NS	NS	NS

*Fertilizers where applied in-furrow at 3 gal ac^{-1}.

**Fertilizers where applied with hand sprayer at respective growth stage at 3 gal ac^{-1} with 4 lbs ac^{-1} AMS.

†Fertilizers where applied with hand sprayer at respective growth stage at 3 gal ac^{-1}.

Table 4. Mean and range of yield, oil content, and protein content of each environment. No statistical significance was observed at individual sites.

Environment	Parameter	-Yield (bu ac^{-1})-	-Oil %-	-Protein %-
Minot 2016	Mean	37.2	14.83	34.45
	Range	30.30 - 47.39	14.55 - 15.24	33.91 - 34.93
Columbus 2016	Mean	30.5	33.63	14.75
	Range	26.66 - 32.73	33.18 - 34.01	14.35 - 14.88
Riverdale 2017	Mean	27.6	34.88	14.66
	Range	26.27 - 29.60	34.62 - 35.19	14.39 - 14.90
Columbus 2017	Mean	25.7	31.69	15.82
	Range	22.30 - 27.65	30.97 - 32.19	15.56 - 16.09

Nitrogen applications did not affect soybean yield. Soil nitrate-N values (0-24 in depth) ranged from 33.5 to 91.5 lb ac^{-1} nitrate-N (Table 1). Higher values of soil nitrate can hinder rhizobia nodulation (Weber, 1966), and can result in greater iron deficiency chlorosis (Bloom et al., 2011). Iron deficiency chlorosis and lack of rhizobia bacteria nodules were not observed during the field season at any site. Although N application did not decrease yield, neither did it increase yield. Weber (1966) observed that it took 150 lbs N ac^{-1} to equal the yields of properly nodulated soybeans.

A yield response was expected from the phosphorus applications as all P soil tests (Table 1) were in the low to medium fertility level using the Olsen phosphorus test procedure (Franzen, 2013).Regional research indicates that broadcast P application are superior to banded applications (Buah et al., 2000; Edwards, 2017; Rehm, 1986). In these studies, neither banded nor broadcast P affected soybean yields.

Foliar fertilizers applied at the V5 and R2 growth stage (Fehr and Caviness, 1977) did not affect yield. Timely rains during the R1 to R6 growth stages are very important for good soybean yields during pod development and fill (Klocke, 1989), and in this study, these growth stages occurred during the month of August (NDAWN, 2018a). Nearby NDAWN weather stations recorded 0.76 to 1.20 in of rainfall during August, which likely depressed soybean yields.

The 2017 growing season was characterized with drought (Hoell, 2018). The NDAWN Bowbells weather station (near Columbus sites) and Garrison weather station (near Riverdale) recorded only 9.33 and 5.92 in of growing season precipitation respectively. Rainfall during the 2016 growing season was roughly twice that received in 2017. The Bowbells NDAWN weather station received 18.79 and Minot recorded 16.55 of rainfall in 2016 (NDAWN, 2018a). Rainfall is believed to be the biggest factor affecting yields at all testing sites.