

# SOYBEAN INOCULATION TRIAL

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**A field experiment was conducted** at the North Dakota State University Carrington Research Extension Center to evaluate the response of soybean to commercial and experimental inoculants and to compare this response to varying levels of soil nitrogen (N).

The trial was sown to Roundup Ready soybean cultivar 'RG200RR' (Maturity Group 0.0) on 29 May at the rate of 200,000 live seeds / acre in 7" rows. A soil sample the previous fall tested 37 lbs.  $\text{NO}_3^-$ -N / acre, with adequate phosphorus. In addition to an absolute control (no inoculum, no N fertilizer), N fertilizer treatments were included to study total N levels (soil test + fertilizer) of 50, 75, and 150 lbs. N / acre without inoculation. Additional inoculant treatments of interest were also included. Plots measured 10' x 25' and were arranged in a randomized complete block design with four replicates. Weeds were controlled with herbicides and hand weeding. No other pesticides were applied.

Although soybean had been grown previously in nearby fields, the plot area did not have a known history of soybean, as evidenced by the sparse nodulation in the control treatment (Table 1). Visual nodulation scores indicated that 20 of the 38 inoculation treatments were significantly better than the control. No statistically significant differences among treatments were detected in days to physiological maturity, height, or lodging (Table 2).

Despite the lack of significant differences in grain yield, all inoculation and N fertilizer treatments resulted in numerically higher yields, with some yield increases greater than 30 percent (Table 3). Starter levels of N fertilizer (50 and 75 lbs. total N / acre) numerically increased yield over the control, but only 150 lbs. N / acre approached the yield of the best inoculant treatments. Future research will include starter N in combination with inoculation. Seed oil concentration tended to decrease with increased yield, while highly significant positive correlations existed among seed N concentration, grain yield, and grain N yield (Tables 3 and 4). The positive yield response to all inoculation / N fertilizer treatments and the positive correlation between grain yield and seed N concentration are indications that N was a limiting factor to soybean production at this site.

Averaged across all treatments within a category, all inoculant formulations numerically improved nodulation, grain yield, seed protein concentration, and grain N yield over the uninoculated (including the N fertilizer) treatments (Table 5). Grain yield and quality characteristics were similar among inoculant formulations, but visual nodulation scores tended to be better with seed-applied inoculants than with granular products applied in-furrow. Future trials will include a combination of seed-applied and granular inoculants.

**Table 1. Soybean inoculation treatment effects on plant development, NDSU Carrington, 2003.**

Treatment	Formulation	Manufacturer	Nodulation
			(1-9) <sup>1</sup>
Control	x	x	6.8
N Fertilizer (to 50 lbs total N / acre)	x	x	7.5
N Fertilizer (to 75 lbs total N / acre)	x	x	8.1
N Fertilizer (to 150 lbs total N / acre)	x	x	8.4
HiStick 2	Peat	Becker Underwood	5.0
HiStick Exp A	Peat	Becker Underwood	5.8
HiStick 2 + ExpB	Peat	Becker Underwood	5.1
HiStick 2 + ExpC	Peat	Becker Underwood	3.6
MicroFix	Peat	Becker Underwood	5.6
SoySterile	Peat	Becker Underwood	4.8
HiStick N/T	Peat	Becker Underwood	5.5
HiStick L N/T	Liquid	Becker Underwood	4.8
HiStick L N/T + ExpD	Liquid	Becker Underwood	4.8
HiStick L N/T + ExpE	Liquid	Becker Underwood	4.4
HiStick L N/T + Exp A Phosphate Solubilizer	Liquid	Becker Underwood	4.9
HiStick L N/T + Exp B Phosphate Solubilizer	Liquid	Becker Underwood	5.0
HiStick L N/T + Exp B1 Phosphate Solubilizer	Liquid	Becker Underwood	5.1
HiStick L	Liquid	Becker Underwood	4.9
BU Exp H	Liquid	Becker Underwood	4.8
Nod +	Liquid	Becker Underwood	5.5
BU Exp J	Liquid	Becker Underwood	4.5
Exp Nod + Concentrate	Liquid	Becker Underwood	4.7
Nod + Extender	Pre-inoculation	Becker Underwood	5.5
Nodulator	Granular	Becker Underwood	6.5
Nodulator Exp A	Granular	Becker Underwood	6.5
NodulatorExp B	Granular	Becker Underwood	6.3
RhizoFlo Exp A	Granular	Becker Underwood	5.8
RhizoFlo	Granular	Becker Underwood	7.0
RhizoFlo Exp B	Granular	Becker Underwood	5.9
CellTech SCI PreInoc	Pre-inoculation	Nitragin	6.3
Soil Implant	Granular	Becker Underwood	5.5
NRow	Granular	INTX Microbials	6.3
NTake	Liquid	INTX Microbials	5.7
ProLiquid	Liquid	Advance Inoculant	5.5
TagTeam	Peat	Philom Bios	5.3
CellTech SCI	Liquid	Nitragin	5.1
CellTech SCI Exp1 (Optimize)	Liquid	Nitragin	4.2
CellTech SCI Exp2	Liquid	Nitragin	4.5
NitraStik-S	Peat	Nitragin	5.9
ApronMaxx	x	x	6.9
CellTech SCI + ApronMaxx	Liquid	Nitragin	4.8
RizoLiq + ApronMaxx	Liquid	Rizobacter Argentina	4.7
RizoLiq + ApronMaxx 20May	Pre-inoculation	Rizobacter Argentina	5.0
Mean			5.6
C.V. (%)			17.0
LSD (0.05)			1.33
LSD (0.01)			1.75
<sup>1</sup> 1 = profuse, 9 = no nodules			

**Table 2. Soybean inoculation treatment effects on yield parameters, NDSU Carrington, 2003.**

Treatment	Physiological	Height (cm)	Plant
	Maturity DAP <sup>1</sup>		Lodging (1-9) <sup>2</sup>
Control	110	74	1.0
N Fertilizer (to 50 lbs total N / acre)	111	77	1.5
N Fertilizer (to 75 lbs total N / acre)	112	82	1.3
N Fertilizer (to 150 lbs total N / acre)	110	86	1.3
HiStick 2	109	74	1.3
HiStick Exp A	110	76	1.3
HiStick 2 + ExpB	109	75	1.0
HiStick 2 + ExpC	109	78	1.5
MicroFix	108	79	1.0
SoySterile	108	78	1.0
HiStick N/T	108	74	1.0
HiStick L N/T	107	72	1.0
HiStick L N/T + ExpD	108	75	1.0
HiStick L N/T + ExpE	109	69	1.0
HiStick L N/T + Exp A Phosphate Solubilizer	108	77	1.0
HiStick L N/T + Exp B Phosphate Solubilizer	108	77	1.0
HiStick L N/T + Exp B1 Phosphate Solubilizer	107	79	1.0
HiStick L	111	81	1.3
BU Exp H	109	76	1.3
Nod +	109	71	1.0
BU Exp J	110	75	1.5
Exp Nod + Concentrate	111	74	1.0
Nod + Extender	110	78	1.5
Nodulator	111	78	1.0
Nodulator Exp A	111	76	1.0
NodulatorExp B	111	75	1.0
RhizoFlo Exp A	110	72	1.0
RhizoFlo	110	71	1.0
RhizoFlo Exp B	110	77	1.0
CellTech SCI PreInoc	109	74	1.3
Soil Implant	110	75	1.5
NRow	109	71	1.0
NTake	108	73	1.0
ProLiquid	112	72	1.3
TagTeam	111	71	1.5
CellTech SCI	110	73	1.0
CellTech SCI Exp1 (Optimize)	110	70	1.3
CellTech SCI Exp2	109	72	1.0
NitraStik-S	108	80	1.0
ApronMaxx	110	70	1.0
CellTech SCI + ApronMaxx	110	69	1.0
RizoLiq + ApronMaxx	109	77	1.0
RizoLiq + ApronMaxx 20May	109	64	1.0
Mean	109	75	1.1
C.V. (%)	2.3	10.9	26.9
LSD (0.05)	NS	NS	NS
LSD (0.01)	NS	NS	NS
<sup>1</sup> days after planting	<sup>2</sup> 1 = erect, 9 = prostrate		

**Table 3. Soybean inoculation treatment effects on yield parameters, NDSU Carrington, 2003.**

	Grain	Test	Seed	Seed	Seed	Grain
Treatment	Yield	Weight	Weight	Oil <sup>1</sup>	Protein <sup>1</sup>	N Yield
	(bushel/acre)	(lb/bu)	(g/250)	(%)	(%)	(lb/acre)
Control	30.5	58.3	30.3	19.3	31.5	576
N Fertilizer (to 50 lbs total N / acre)	36.1	58.2	30.5	19.3	31.7	686
N Fertilizer (to 75 lbs total N / acre)	35.8	58.0	30.6	19.5	31.1	668
N Fertilizer (to 150 lbs total N / acre)	40.6	58.1	32.1	18.9	33.2	807
HiStick 2	40.2	58.3	33.5	18.2	35.6	858
HiStick Exp A	40.0	58.2	33.8	18.4	35.6	854
HiStick 2 + ExpB	36.7	58.3	33.8	18.3	35.5	782
HiStick 2 + ExpC	41.4	58.4	34.4	18.2	35.9	890
MicroFix	36.7	58.4	33.0	18.2	35.8	789
SoySterile	34.9	58.2	31.4	18.7	34.2	714
HiStick N/T	36.9	58.2	33.7	18.6	35.2	778
HiStick L N/T	40.9	58.3	33.0	18.4	35.3	866
HiStick L N/T + ExpD	40.7	58.2	32.7	18.3	35.5	865
HiStick L N/T + ExpE	40.5	58.4	33.0	18.3	35.5	862
HiStick L N/T + Exp A Phosphate Solubilizer	38.7	58.3	33.1	18.5	35.7	829
HiStick L N/T + Exp B Phosphate Solubilizer	38.5	58.2	32.2	18.5	34.8	803
HiStick L N/T + Exp B1 Phosphate Solubilizer	37.0	58.3	33.2	18.4	35.4	785
HiStick L	41.7	58.2	34.2	18.2	36.3	906
BU Exp H	41.3	58.2	33.2	18.0	36.5	904
Nod +	41.4	58.1	34.0	18.4	35.4	880
BU Exp J	37.4	58.2	33.5	18.2	36.1	808
Exp Nod + Concentrate	41.6	58.0	34.7	18.3	36.0	899
Nod + Extender	40.5	58.4	32.8	18.2	35.6	866
Nodulator	40.1	58.1	31.7	18.8	33.8	812
Nodulator Exp A	39.8	58.1	32.7	18.8	33.8	809
NodulatorExp B	41.1	58.0	32.6	18.4	34.9	860
RhizoFlo Exp A	36.0	58.3	32.6	18.6	34.4	742
RhizoFlo	40.5	58.3	32.3	18.5	35.4	858
RhizoFlo Exp B	38.0	58.5	32.9	18.2	35.9	819
CellTech SCI PreInoc	39.3	58.3	32.7	18.1	36.2	855
Soil Implant	40.3	58.0	34.2	18.1	36.4	879
NRow	39.8	58.3	32.8	18.0	36.0	859
NTake	39.1	58.1	32.7	18.5	34.9	820
ProLiquid	37.8	58.1	33.7	18.1	35.8	812
TagTeam	38.9	58.0	32.2	18.5	34.8	813
CellTech SCI	39.8	58.4	33.5	18.0	36.4	870
CellTech SCI Exp1 (Optimize)	40.6	58.1	33.7	18.1	36.4	887
CellTech SCI Exp2	34.3	58.1	33.2	18.0	36.6	751
NitraStik-S	35.5	58.2	32.3	18.6	34.5	735
ApronMaxx	30.1	58.0	29.7	19.5	31.3	566
CellTech SCI + ApronMaxx	38.2	58.1	34.7	18.2	36.2	829
RizoLiq + ApronMaxx	39.8	58.3	32.2	18.4	35.2	841
RizoLiq + ApronMaxx 20May	36.2	58.0	32.1	19.0	33.5	728
Mean	38.4	58.2	32.8	18.5	35.0	807
C.V. (%)	12.3	0.5	3.8	1.5	2.3	12.4
LSD (0.05)	NS	NS	1.52	0.4	1.2	141
LSD (0.01)	NS	NS	2.01	0.5	1.5	187

**Table 4. Correlation coefficients among parameters in the soybean inoculation trial, NDSU Carrington, 2003.**

		Physiological		Plant	Grain	Test	Seed	Seed	Seed	Grain
Parameter	Nodulation	Maturity	Height	Lodging	Yield	Weight	Weight	Oil	Protein	N Yield
Nodulation	1	0.1870	0.1763	0.0798	-0.0575	-0.1730	-0.3431	0.4302	-0.5169	-0.1980
P-value		0.0165	0.0239	0.3096	0.4671	0.0277	<0.0001	<0.0001	<0.0001	0.0115
Phys. Maturity	0.18697	1.0000	-0.0788	0.2281	0.0332	-0.2728	0.2722	-0.1448	0.0170	0.0335
P-value	0.0165		0.3162	0.0033	0.6747	0.0004	0.0005	0.0661	0.8299	0.6726
Height	0.17633	-0.0788	1.0000	0.2786	0.3520	0.0639	-0.0901	0.0960	-0.0609	0.2874
P-value	0.0239	0.3162		0.0003	<0.0001	0.4193	0.2542	0.2241	0.4412	0.0002
Lodging	0.07982	0.2281	0.2786	1.0000	0.1864	-0.0661	0.1405	-0.1330	0.1209	0.2043
P-value	0.3096	0.0033	0.0003		0.0176	0.4030	0.0746	0.0916	0.1254	0.0091
Grain Yield	-0.05753	0.0332	0.3520	0.1864	1.0000	-0.1260	0.2879	-0.1961	0.3025	0.9647
P-value	0.4671	0.6747	<0.0001	0.0176		0.1103	0.0002	0.0124	<0.0001	<0.0001
Test Weight	-0.17297	-0.2728	0.0639	-0.0661	-0.1260	1.0000	0.0383	-0.2329	0.2138	-0.0551
P-value	0.0277	0.0004	0.4193	0.4030	0.1103		0.6287	0.0029	0.0063	0.4866
Seed Weight	-0.34311	0.2722	-0.0901	0.1405	0.2879	0.0383	1.0000	-0.7177	0.7363	0.4547
P-value	<0.0001	0.0005	0.2542	0.0746	0.0002	0.6287		<0.0001	<0.0001	<0.0001
Seed Oil	0.43018	-0.1448	0.0960	-0.1330	-0.1961	-0.2329	-0.7177	1.0000	-0.9415	-0.4291
P-value	<0.0001	0.0661	0.2241	0.0916	0.0124	0.0029	<0.0001		<0.0001	<0.0001
Seed Protein	-0.51688	0.0170	-0.0609	0.1209	0.3025	0.2138	0.7363	-0.9415	1.0000	0.5384
P-value	<0.0001	0.8299	0.4412	0.1254	<0.0001	0.0063	<0.0001	<0.0001		<0.0001
Grain N Yield	-0.19801	0.0335	0.2874	0.2043	0.9647	-0.0551	0.4547	-0.4291	0.5384	1.0000
P-value	0.0115	0.6726	0.0002	0.0091	<0.0001	0.4866	<0.0001	<0.0001	<0.0001	

**Table 5. Effect of inoculant formulation on soybean performance, NDSU Carrington, 2003.**

		Physiological		Plant	Grain	Test	Seed	Seed	Seed	Grain	
Formulation	n <sup>1</sup>	Nodulation	Maturity	Height	Lodging	Yield	Weight	Weight	Oil <sup>5</sup>	Protein <sup>5</sup>	N Yield
		(1-9) <sup>2</sup>	(DAP) <sup>3</sup>	(cm)	(1-9) <sup>4</sup>	(bushel/acre)	(lb/bu)	(g/250)	(%)	(%)	(lb/acre)
Granular	31	6.2	110	74.4	1.1	39.4	58.2	32.7	18.5	35.0	828
Liquid	67	4.9	109	73.9	1.1	39.3	58.2	33.4	18.3	35.8	844
Peat	35	5.2	109	76.1	1.2	38.0	58.3	33.2	18.4	35.2	804
Preinoculated	11	5.6	109	72.6	1.3	38.9	58.3	32.6	18.4	35.3	824
Uninoculated	20	7.5	110	77.7	1.2	34.6	58.1	30.6	19.3	31.7	662

<sup>1</sup>number of observations in a mean; <sup>2</sup>1 = profuse, 9 = no nodules; <sup>3</sup>days after planting  
<sup>4</sup>1 = erect, 9 = prostrate; <sup>5</sup>13% moisture