SEED INOCULATION AND NITROGEN FERTILIZER TRIALS WITH SOYBEANS

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INTRODUCTION

Currently there is a lot of interest in soybean seed inoculation. There are some new products on the market that are creating renewed interest in seed inoculation even on fields that have a history of soybean production. Some of the new inoculants have claims for higher potency, new and better strains of *Rhizobium*, higher numbers of *Rhizobium* per gram of material, sterilized peat media, seed sticker additions and etc. Many companies are beginning to pay more attention to storage and handling of these materials to increase effectiveness. There is also evidence that these materials may be slightly better than the old inoculants even when used in old soybean fields. Urbana Laboratories have an exclusive license to produce and sell a patented *Bradyrhizobium japonicum* strain. In 1993, university trials in the Midwest showed a positive response in 11 of 16 field trials. Yield increases ranged from 1-5 bushels with this new strain of inoculum when tested on traditional soybean ground.

Michigan State University does not recommend nitrogen (N) fertilizers on soybeans and yet it is recognized that some farmers in the state are having problems of inadequate N fixation due to poor nodulation or inactive nodules. There are some indications that the poor nodulation occurs on high pH soils (pH's greater than 7.2). In light of this information we conducted six soybean seed inoculation and N management trials in the last five years.

MATERIALS AND METHODS

Information regarding the trial locations and cultural practices for the field experiments are shown in Table 1. Three of the four trials conducted in 1990 and 1991 were conducted as replicated strip trials. In these trials the treatments extending the entire length of the field and were replicated four times. Treatments in the 1990 Sanilac county trial were strips 200 ft. long replicated four times. For this trial four N rates and two application dates were evaluated with both inoculated and non-inoculated soybeans. The N source for all of the trials was ammonium nitrate (34-0-0). In Huron county, two N rates, 0 and 40 lb/A,

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were tested. The 40 lb N was applied at emergence and at early bloom in two separate treatments. Yields in the strip trials were measured using the farmer's combine and a weigh wagon. The Sanilac county trial was harvested with a small plot combine.

The 1993 and 1994 trials were conducted in small plot research plots on the Michigan State University Research Farm at East Lansing. Plots were four rows wide and 50 feet long. The two center rows were harvested for yield and grain moisture.

Leaf N content was measured on upper fulled developed leaves sampled from each treatment in mid-August.

RESULTS AND DISCUSSION

1990 Sanilac County Inoculation and N Management Trial

Data for this trial are shown in Table 2. The inoculated treatment produced significantly higher yield and lower moisture content compared to non-inoculated. However, N rates and dates of N application did not produce significant differences in yield or grain moisture. Statistical analysis indicated that the interaction effect between inoculation and N rate on soybean yield was not significant. Leaf N between inoculated and non-inoculated treatments was not significantly different. Leaf N increased with increasing N rates, but was not influenced by the date of application. The leaf N concentration in all treatments were within the sufficiency range for soybeans (4.25-5.50 percent).

1990 Huron County Inoculation and N Management Trial

Data for this trial are shown in Table 3. As in Sanilac county, the inoculated seed produced significantly higher soybean yields compared to non-inoculated. The yield response to N fertilizer in the inoculated plots was not consitent. The interaction effect between inoculation and N rate was significant. This was due to a yield decrease in the inoculated plots with N and a yield increase in non-inoculated plots with N. In field observations, plant vigor appeared to be better in the early N application (June 7) than late application (July 10) with or without seed inoculation. However, yields in the late N application with inoculation was higher compared to late N application without inoculation. Poor soil structure at this location was not conducive to rapid early soybean growth and resulted in poor plant stands. This may account for the lower grain yield compared to the Sanilac county. The inoculated

seed treatment had significantly higher leaf N compared to non-inoculated. The leaf N increased with N application for both application dates, but the June application resulted in a significantly higher N content than July application. The leaf N concentration was below the critical value of 4.25 percent for soybeans in those treatments where the seed was not inoculated and no N was applied.

1991 Saginaw County Seed Inoculation and N Management Trial

The data for this trial is shown in Table 4. All treatments produced excellent soybean yields. Seed inoculation did not significantly increase soybean yields compared to non-inoculation. Nitrogen application at emergence significantly reduced yields compared to no N or N application at early bloom. It is hypothesized that N application at emergence may have delayed the *Rhizobium* nodulation and N fixation. A detectable N shortage in this treatment, however, was not evident from the leaf N data. The moisture content of the grain was not significantly affected by either seed inoculation or N rates.

The lack of a significant yield response to seed inoculation at this location was unexpected, because this field had never been planted to soybeans. Somehow the N fixing *Rhizobium* were already present in the field and infection occurred soon after emergence. It is our conjecture that the *Rhizobium* bacteria may have entered the field through floods and/or wind borne soil particles.

1991 Bay County Seed Inoculation and N Management Trial

The data for this trial is shown in Table 5. The results indicated that neither the seed inoculation nor the N application treatments had any significant effects on grain yield, moisture content, and leaf N. The leaf N content in the two 1991 N trials were very similar although somewhat below the generally accepted critical value of 4.25 percent for soybeans. The samples may have been taken too late in the growing season.

This site had a history of soybeans prior to 1991, therefore it is very likely that this field contained adequate N fixing bacteria prior to establishing the experiment.

1993 Seed inoculation trial

The data for this trial are shown in Table 6. Grain yield and moisture of leaf N were not significantly affected by seed inoculation ($P \geq 0.05$). At a lower level of significance the 2x rate of Hi-Stick showed a significant decrease in yield. Other states have reporting similar findings with the 2x rate of this product. The non-inoculated and Hi-Stick (1x) rate produced the highest yield.

1994 Seed inoculation trial

The data for this trial are shown in Table 7. The inoculation treatments did not significantly affect yield or grain moisture, however there were some significant effects on leaf N content. Hi-Stick (1x) had the lowest N content while the non-inoculated plots had the highest N content. All values, however, were well above the critical level of 4.25 percent.

SUMMARY

These data suggest that soybean seed inoculation with *Rhizobium* is most beneficial when soybeans are planted to new soybean ground. When native soil *Rhizobium* inoculum is present, soybeans did not significantly respond to seed treatment with *Rhizobium*. The use of N fertilizer on soybeans is not needed when soybeans are adequately inoculated either with seed treatment or native soil inoculum. When soybeans are not adequately inoculated they benefited from the added N fertilizer but the highest yields obtained were still lower than when soybeans were properly inoculated.

We have evaluated Hi-Stick, Nitragin and Sow-Fast for the last two years at Michigan State University. Our trials have been on land that has had a recent history of soybean production (2 or 3 years away from the previous soybean crop). These trials are continuing in 1995. We are evaluating Hi-Stick, Sow-Fast and Urbana Laboratory inoculum in both conventional tillage and no-tillage systems. We are also looking at humus and liquid carriers for the inoculants.

Table 1. Agronomic characteristics of the soybean test locations.

Year	1990	1990	1991	1991	1993	1994
Location	Sanilac Co.	Huron Co.	Saginaw Co.	Bay Co.	MSU	MSU
Soil Type	Parkhill clay loam	Shebeon/ Kilmanagh loam	Tappen loam	Tappen loam	Capac loam	Capac loam
Soil pH	6.4	6.7	7.3	6.9	7.4	6.1
Previous Crop	corn	drybeans	corn	corn	corn	corn
Soybean Variety	Elgin 87	Countrymark FFR 241	Calahan	BSR 101	Pioneer 9273	Resnik
Planting Date	May 28	May 14	May 21	May 23	May 14	May 12
Harvest Date	Oct. 24	Oct. 26	Sept. 28	Sept. 27	Oct 25	Oct. 24

Table 2. **Effect of seed inoculation and nitrogen fertilizer on soybean yield, grain moisture and leaf N content (Sanilac county, 1990).**

Treatments			Yield*	Moisture*	Leaf N*
Inoculation	N(lb/A)	Date	bu/A	%	%
+	0	-	46.7^{ab}	14.8^{ab}	4.91^{e}
+	40	May 31	45.2^{ab}	14.6^{ab}	5.23^{bcd}
+	80	May 31	46.5^{ab}	14.5^{ab}	5.40^{ab}
+	120	May 31	47.6^{a}	14.5^{ab}	5.55^{a}
+	40	Jul 10	46.8^{ab}	14.6^{ab}	5.18^{bcde}
+	80	Jul 10	46.9^{ab}	14.4^{b}	5.05^{cde}
-	0	-	43.6^{b}	14.7^{ab}	4.93^{e}
-	40	May 31	43.6^{b}	14.9^{ab}	4.97^{de}
-	80	May 31	46.0^{ab}	14.8^{ab}	5.01^{de}
-	120	May 31	44.1^{ab}	14.7^{ab}	5.31^{abc}
-	40	Jul 10	45.2^{ab}	14.7^{ab}	5.13^{bcde}
-	80	Jul 10	45.4^{ab}	15.0^{a}	5.52^{a}
			Overall Treatment Means		
		Inoculated	46.6^{a}	14.6^{b}	5.22
		Non-inoculated	44.7^{b}	14.8^{a}	5.14
	0	-	45.1	14.7	4.92^{c}
	40	May 31	44.4	14.7	5.10^{b}
	80	May 31	46.3	14.7	5.21^{b}
	120	May 31	45.9	14.6	5.43^{a}
	40	Jul 10	46.0	14.7	5.16^{b}
	80	Jul 10	46.2	14.7	5.23^{ab}

* Means followed by different letters are significantly different as determined by the Duncan's Multiple Range test ($P \geq 0.05$)

Table 3. Effect of seed inoculation and nitrogen fertilizer on soybean yield, grain moisture and leaf N content (Huron county, 1990).

Treatments			Yield*	Moisture*	Leaf N*
Inoculation	N(lbs/A)	Date	bu/A	%	%
+	0	-	35.3[a]	12.4	3.93[c]
+	80	Jun 7	30.1[b]	12.5	4.75[a]
+	80	Jul 10	37.0[a]	12.7	4.45[b]
-	0	-	21.1[d]	12.6	3.60[d]
-	80	Jun 7	29.7[b]	12.4	4.61[ab]
-	80	Jul 10	24.8[c]	12.4	4.08[c]
			Overall Treatment Means		
		Inoculated	34.2[a]	12.5	4.38[a]
		Non-inoculated	25.2[b]	12.6	4.10[b]
	0	-	28.2	12.5	3.77[c]
	80	Jun 7	29.9	12.5	4.68[a]
	80	Jul 10	30.9	12.6	4.26[b]

* Means followed by different letters are significantly different as determined by the Duncan's Multiple Range test ($P \geq 0.05$).

Table 4. Effects of seed inoculation and nitrogen fertilizer on soybean yield, grain moisture, and leaf N content (Saginaw county, 1991).

Treatment			Yield*	Moisture*	Leaf N*
Inoculation	N(lb/A)	Date	bu/A	%	%
+	0	-	53.3[ab]	12.5	3.0 [ab]
+	40	Jun 6	51.9 [cd]	12.4	3.1 [a]
+	40	Jul 2	53.2[abc]	12.6	3.1 [a]
-	0	-	52.2 [bcd]	12.5	2.9 [b]
-	40	Jun 6	51.7 [d]	12.5	3.0 [ab]
-	40	Jul 2	53.7[a]	12.4	3.1 [a]
			Overall Treatment Means		
		Inoculated	52.8	12.5	3.1
		Non-inoculated	52.5	12.5	3.0
	0	-	52.8[a]	12.5	3.0
	40	Jun 6	51.8 [b]	12.5	3.1
	40	Jul 2	53.4[a]	12.5	3.1

* Means followed by different letters are significantly different as determined by the Duncan's Multiple Range test ($P \geq 0.05$).

Table 5. **Effects of seed inoculation and nitrogen fertilizer on soybean yield, grain moisture, and leaf nitrogen (Bay county, 1991).**

Treatment			Yield*	Moisture*	Leaf N*
Inoculation	N(lbs/A)	and time	bu/A	%	%
+	0	-	52.7	14.0	2.9
+	40	Jun 6	52.1	14.1	3.0
+	40	Jul 2	51.9	13.9	3.0
-	0	-	51.2	13.8	2.9
-	40	Jun 6	51.8	14.0	2.9
-	40	Jul 2	52.4	14.4	2.9
			----Overall Treatment Means------		
		Inoculated	52.2	14.0	3.0
		Non-inoculated	51.8	14.1	2.9
	0	-	51.9	13.9	2.9
	40	Jun 6	51.9	14.0	2.9
	40	Jul 2	52.1	14.2	3.0

* Means were not statistically different at $P \geq 0.05$.
Grain yield was adjusted to 13% moisture.

Table 6. **Effect of seed inoculation on soybean yield, grain moisture and leaf N content (MSU Research Farm 1993).**

Treatment	Grain Yield* bu/A	Moisture* %	Leaf N* %
Hi-Stick (1x)	59.8	12.1	5.34
Hi-Stick (2x)	57.4	12.1	5.47
Nitragin (1x)	58.6	12.2	5.41
Nitragin (2x)	59.6	12.2	5.42
Check	61.0	12.1	5.40

* Means were not statistically different at $P \geq 0.05$.
Grain yield was adjusted to 13% moisture.

Table 7. Effect of seed inoculation on soybean yield, grain moisture and leaf N content (MSU Research Farm 1994).

Treatment	Grain Yield bu/A	Moisture %	Leaf N %
Hi-Stick (1x)	47.3	15.3	6.00[c]
Hi-Stick (2x)	42.4	15.5	6.42[ab]
Sow-Fast (1x)	44.7	15.3	6.26[b]
Sow-Fast (2x)	41.1	15.7	6.43[a]
Check	44.4	15.5	6.34[ab]

* Means were not statistically different at $P \geq 0.05$.
Grain yield was adjusted to 13% moisture.

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