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NF539 Yield Suppressions of Glyphosate-Resistant (Roundup Ready) Soybeans

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Yield Suppressions of Glyphosate-Resistant (Roundup Ready) Soybeans

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Glyphosate is a popular postemergence herbicide. Glyphosate-resistant soybean technology is gaining acceptance in Nebraska and U.S. cropping systems. However, potential yield suppression from either genetic differences among varieties, the glyphosate-resistant gene/gene insertion process, or glyphosate is a concern. The first of these could contribute to a yield lag; the latter two could contribute to a yield drag.

Lag Versus Drag

Yield lag is the potential yield suppression due to the age of the variety in which the gene is inserted.

Yield drag is the potential yield suppression due to glyphosate or the insertion of the gene itself.

Yield suppression (if it exists) = Yield drag (due to herbicide or glyphosate-resistant gene) + Yield lag (due to the variety containing the glyphosate-resistant gene)

Data from University soybean variety performance trials in Nebraska and other states suggest a yield suppression may exist. *Figure 1* shows data from the 1998 variety trials at Lancaster County. Conventional varieties (nonglyphosate-resistant) were included in either the early-maturing or late-maturing performance trials. All but the lowest yielding conventional varieties yielded more than the glyphosate-resistant varieties. No one else has reported the effects of glyphosate on a diverse group of commercially available glyphosate-resistant soybean varieties or whether the glyphosate-resistant gene/gene insertion process suppresses soybean yield.

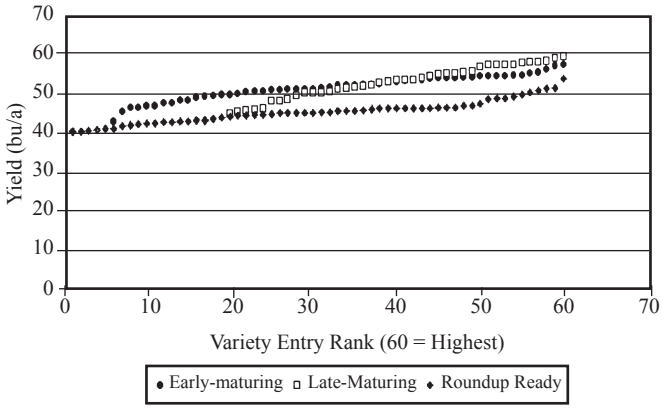

Figure 1. 'Early-maturing' and 'late-maturing' performance trials compared conventional varieties in Lancaster County, Nebraska, in 1998. Data from university soybean variety performance trials in Nebraska and other states suggest a yield suppression may exist.

Research Goals

We designed experiments to test for both elements of yield drag: the effect of glyphosate herbicide application and the effect of the glyphosate-resistant gene. Since we could not distinguish between yield drag associated with the glyphosate-resistant gene or effects of its insertion, reference to this gene in the following could mean either or both of these possibilities. Two experiments were conducted at each of four Nebraska locations for two years with the intent to:

- investigate the glyphosate herbicide effect on 12-13 varieties; and
- look at the effect of the glyphosate-resistant (glyphosate-resistant) gene on five pairs of glyphosate-resistant, nonglyphosate-resistant sister cultivars (eight other cultivars were included as checks).

We used four locations:

- NU Northeast Research and Extension Center Haskell Agricultural Laboratory, Concord;
- NU Agronomy Farm, Lincoln;
- NU South Central Research and Extension Center, Clay Center; and
- NU West Central Research and Extension Center, North Platte.

Study One: Glyphosate Herbicide Effect

Thirteen glyphosate-resistant varieties *(Table I)* were grown to determine the effect of glyphosate, ammonium sulfate (AMS), and water application (herbicide effect). Direct comparisons were made within the same glyphosate-resistant variety planted in side-by-side plots with one plot sprayed with glyphosate with 2 percent AMS and the other plot sprayed only with 2 percent AMS in the first year. In the second year a water-only treatment also was included. All plots were maintained weed-free by using hand weeding and preemergence application of metolachlor and metribuzin. Crop growth and development were monitored. Both glyphosate applications were at standard rates (32 oz/acre of Roundup Ultra) and timing for soybean production (21 and 42 days after soybean emergence).

Table I. Glyphosate-resistant varieties included in the glyphosate herbicide effect study. These were all either Maturity Group II or III varieties adapted to the locations.

Golden Harvest H1280RR	Northrup King S23F5
Golden Harvest H1357RR	NU Pride Excel 8355
Pioneer 92B25	Dyna Grow 187
Pioneer 92B51	Asgrow A3601STS/RR
Asgrow AG2702	NC+ 32RR
Asgrow AG3002	Stine 3203-4 (1999 only)
Northrup King S28V8	

Did glyphosate adversely affect growth and development of glyphosate-resistant soybeans? No. Flowering date was affected by neither glyphosate nor AMS *(Table II)*. However, plant height at physiological maturity in 1999 was reduced by 0.3 to 0.4 inches with glyphosate *(Table II)*. This finding was consistent across all locations but was not significant in the two-year analysis. Physiological maturity of most of the varieties was likewise not generally affected by the spray treatments.

Did glyphosate affect grain yield of glyphosate-resistant soybeans? No. Grain yield of glyphosate-resistant varieties was neither affected by glyphosate at any location nor affected when averaged across locations *(Figure 2)*. Two-year average grain yield of varieties treated with glyphosate, AMS, and water was 55.7 bushels per acre; this was not different than 56.5 bushels per acre with AMS and water treatment.

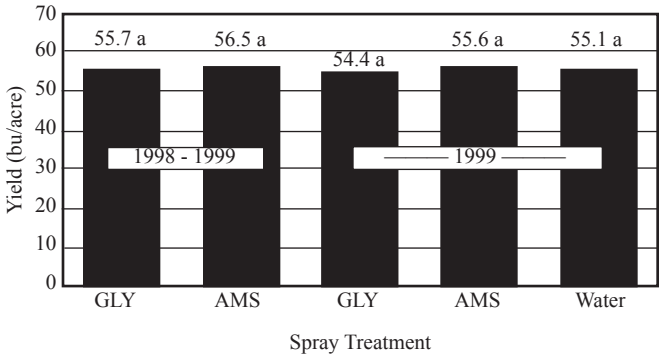

Figure 2. Comparisons of glyphosate-resistant soybeans with: 1) glyphosate, AMS, and water (GLY); 2) AMS and water (AMS); and 3) water. Treatment yields within the same year groupings were similar (P ≤ 0.05).

Study Two: Glyphosate Resistant Gene Effect

In the second study, five backcross-derived pairs of glyphosate-resistant and nonglyphosate-resistant soybean sister lines were compared along with three high-yield, nonherbicide-resistant varieties and five other herbicide-resistant varieties *(Table III)*. Weeds were controlled with metolachlor and metribuzin combined with hand weeding. This study allowed us to compare glyphosate-resistant varieties and their nonglyphosate-resistant sister lines to monitor yield drag and also to obtain a measure of yield lag by comparing glyphosate-resistant to conventional varieties. Glyphosate was not applied to the soybeans in this study.

Table II. Spray treatment effects on plant characteristics. University of Nebraska, 1998-1999.

Spray Treatment	*Flowering Date*		*Physiological Maturity*		*Mature Plant Height*		*Seed Weight*
	1998-99 6 Env†.	*1999 4 Env.*	*1998-99 7 Env.*	*1999 4 Env.*	*1998-99 8 Env.*	*1999 4 Env.*	*1999 2 Env.*
	—days from May 31—		—days from May 31—		———inches———		—g/100—
Glyphosate	57*	54	112	112	37.9a	38.8b	14.6a
Ammonium sulfate	57	54	112	112	38.1a	39.1a	14.4b
Water	—	54	—	112	—	39.2a	14.6a

†Env = Number of environments

*Means followed by the same letter within a column are similar (P≤0.05).

Table III. Varieties and lines included in the glyphosate gene effect study. These were all either Maturity Group II or III varieties adapted to the locations of the trials.

1	Asgrow 2704-LL	Liberty/STS resistant
2	Pioneer 9323-STS	STS resistant
3	Golden Harvest H1359-STS	STS resistant
4	Hoegemeyer 232	Normal-high yield
5	Desoy 2343	Normal-high yield
6	M/W Genetics 2711	Normal-high yield
7	Pioneer 92B51	GR (Glyphosate Resistant) also in other study
8	Asgrow AG3002	GR also in other study
9	NC+ 2.4N	Non-GR sister of #10
10	NC+ 2.5RR	GR resistant
11	NC+ 3.2N	Non-GR sister of #12
12	NC+ 3.2RR	GR resistant
13	Stine EX25N	Non-GR sister of #14
14	Stine EX25RR	GR resistant
15	Stine 2170	Non-GR sister of #16
16	Stine 2174	GR resistant
17	Stine 2250	Non-GR sister of #18
18	Stine 2254	GR resistant

Did the glyphosate gene or its insertion affect soybean growth or development? Yes. Weight of 100 seed of the nonglyphosate-resistant sister lines was 0.6 grams heavier (in 1999) and the plants were 0.7 inches shorter than the glyphosate-resistant sisters *(Table IV)*. Other variables monitored were similar between the two variety groups.

Did the glyphosate gene or its insertion affect soybean yield? Yes. On average, nonglyphosate-resistant sister lines yielded 5 percent (3 bushels per acre) more than the glyphosate-resistant sisters when averaged over all locations and both years *(Figure 3)*. Nonglyphosate-resistant sister grain yields were greater than those of their associated glyphosate-resistant sisters in two of the five pairs. This 5 percent difference is a yield drag. Results were similar in the single-year analyses (data not shown). Grain yields of sister-line pairs are shown in *Figure 4*. The greater number of data points below the 1:1 ratio line indicates that the nonglyphosate-resistant sisters yielded more on the average than their glyphosate-resistant sister counterparts.

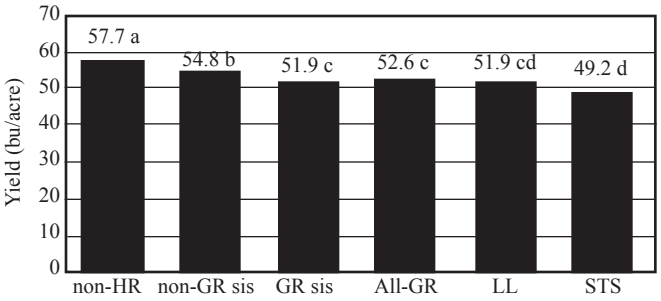

Figure 3. Comparisons of herbicide-resistant (HR) and nonherbicide-resistant soybeans, University of Nebraska, 1998-1999. Non-GR sis = nonglyphosate-resistant sister lines; GR = Glyphosate-resistant sister lines; LL = Liberty Link cultivars; STS = cultivars resistant to STS. Columns with the same letters on tops are similar (P ≤ 0.05).

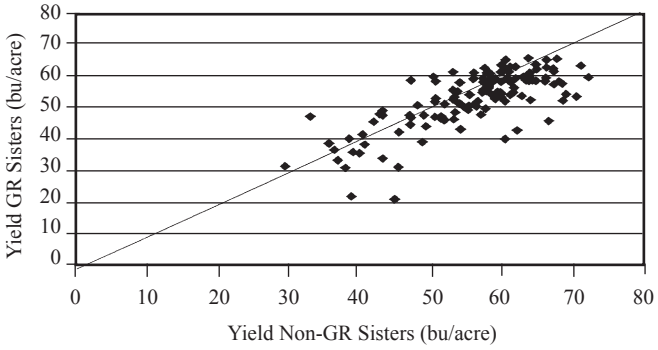

Figure 4. Yield of glyphosate-resistant sisters compared to their respective nonglyphosate-resistant sisters at four locations in two years. Each of the 132 markers represents yield data of sister line pairs from the same replicate, location, and year. Markers below the line indicate that the nonglyphosate-resistant sister yielded better than its glyphosate-resistant sister (r = correlation coefficient). University of Nebraska, 1998 and 1999.

The high-yield, nonherbicide-resistant varieties yielded 5 percent more (57.7 bu/a) than the nonglyphosate-resistant

Table IV. Seed weights and plant heights of nonglyphosate-resistant sister lines and their glyphosate-resistant sisters differed. Other growth and development characteristics of these two variety groups were similar.

Variety Group (Entry numbers in each group)	*Flowering days from May 31*	*1999 Seed wt*	*Lodging at R7†*	*Plant height at Mat. (R7)*	*Maturity (R7) days from May 31*	*Maturity (R8) days from May 31*	*Grain moisture*
		—g/100—		—inches—			—%—
Non-GR Sisters (9, 11, 15, 17)	43.6a*	14.7a	1.6 a	33.9 b	111.9a	120.4a	10.0a
GR Sisters (10, 12, 16, 18)	43.7a	14.1 b	1.4a	34.6a	112.7a	121.7a	10.0a
No. of locations reporting data 1998/1999	2/4	0/3	4/4	4/4	3/4	3/1	4/4

†1 to 5 scale with 1 = erect and 5 = prostrate; R7 = Physiological maturity
*Means followed by the same letter within a column are similar (P≤0.05).

sisters (54.8 bu/a) *(Figure 3)*. This 5 percent difference is a yield lag. The glyphosate-resistant gene in the glyphosate-resistant sisters therefore reduced soybean yield 5 percent compared to the nonglyphosate-resistant sisters. This 5 percent is a yield drag. When this is added to the 5 percent yield lag, the glyphosate-resistant sisters yielded 10 percent less than the high-yield, non-herbicide-resistant varieties.

What Does This All Mean?

Yields were suppressed with glyphosate-resistant soybean varieties relative to their sister lines, but we found no effect of spraying glyphosate on glyphosate-resistant varieties. The research reported here demonstrates that a 5 percent yield suppression was related to the gene or its insertion process and another 5 percent suppression was due to variety genetic difference. Producers should consider the potential for 5 percent to 10 percent yield differentials between glyphosate-resistant and nonglyphosate-resistant varieties as they evaluate the overall profitability of producing soybean. However, producers should consider that yields are often reduced far more than 5 percent or 10 percent if weeds are not controlled. Variety choices are best based on:

1) previous weed pressure and success of control measures in specific fields,
2) the availability and cost of herbicides,
3) availability and cost of herbicide-resistant varieties, and
4) yield.

Variety choices should not be made solely on whether varieties are herbicide resistant. Based on our results from this study, the yield suppression appears associated with the glyphosate-resistant gene or its insertion process rather than glyphosate damage to the soybeans.

Two interrelated concerns are worth discussion. First, since the demand for glyphosate-resistant soybeans is high, breeding efforts on nonglyphosate-resistant cultivars by commercial seed firms will likely decrease proportionately. Thus, yield potential gains of nonglyphosate-resistant cultivars over time may be less than those of glyphosate-resistant cultivars. Second, and as result of this and the reported 5 percent yield suppression associated with the glyphosate-resistant gene, long-range yield potentials are also less than if soybean breeder efforts and associated gains in yield potential of nonglyphosate-resistant soybeans were maintained. If the trend continues, we may look back on this time and likely see little or no gain in genetic yield potentials at the beginning of the 21st century.

Project Summary

Yield suppressions were observed.
Yield drag from glyphosate application was not observed.
Yield drag from glyphosate-resistant gene = 5 percent.
Yield lag from variety genetic differences = 5 percent.

Information Resources

Elmore, R. W., F. W. Roeth, L. A. Nelson, C. A. Shapiro, R. N. Klein, S. Z. Knezevic, and A. Martin. 2001. Glyphosate-resistant soybean cultivar yields compared to sister lines. Agron. Journal. 93(2):408-412.

Elmore, R. W., F.W. Roeth, R. N. Klein, S. Z. Knezevic, A. Martin, L. A. Nelson, and C. A. Shapiro. 2001. Glyphosate-resistant soybean cultivar response to glyphosate. Agron. Journal. 93(2):404-407.

These publications are also available at:
http://screc.unl.edu/Research/research.htm

For more information on this research contact Roger Elmore at: **relmore1@unl.edu**

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