

Comparing Roundup Ready and Conventional Soybean Yields 1999

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Abstract

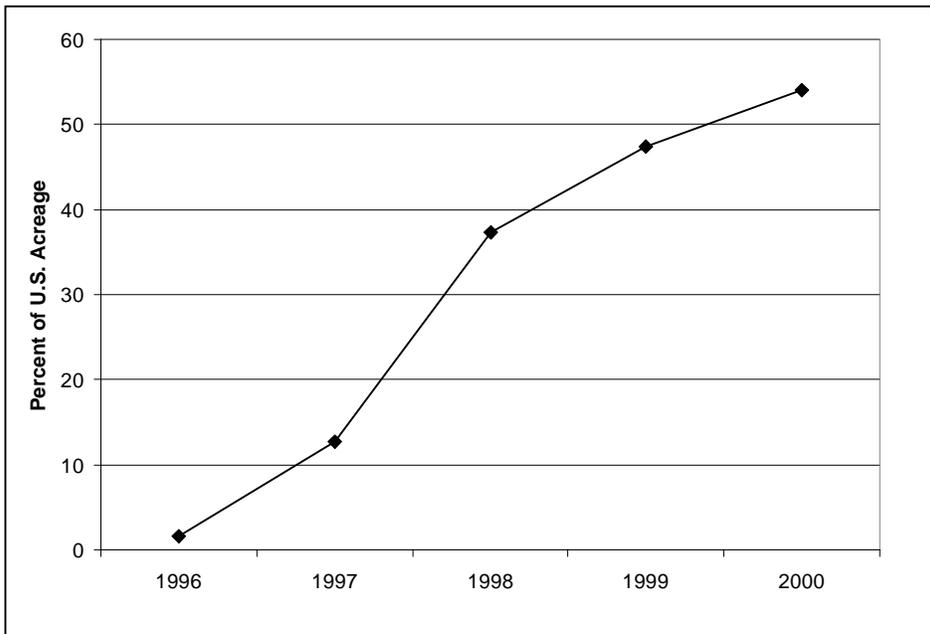
Much has been written about the apparent discrepancy in yield potential between Roundup Ready soybean varieties and their conventional counterparts. Nearly all of this commentary is based on results of university run variety trials. Variety trials assess yield potential, among other variety performance characteristics, in experiments conducted under weed free conditions. Therefore, these trials do not replicate the experience that growers have in the field under true growing conditions, where competition with weeds, and variability in weed control, also affect yields. Based on variety trials conducted in 8 northern states, the average difference in yield potential between Roundup Ready soybean varieties and conventional varieties decreased from 4% in 1998 to 3% in 1999. It is expected that this difference will be even smaller when the results of trials conducted this past summer are analyzed. An analysis of the 1999 trials in comparison to an earlier analysis of 1998 trials is presented. Context is provided for the proper interpretation of the variety trials.

Background

Roundup Ready soybeans were genetically modified to withstand treatment with the herbicide glyphosate (Roundup) by inserting a gene from a soil bacterium, which allows for the continued production of essential amino acids that would otherwise cease after the herbicide treatment. Roundup is an effective, broad spectrum herbicide that would normally destroy a growing crop. The insertion of the soil bacterium gene allows growers to use Roundup over their crop, controlling weeds while leaving the crop unharmed.

Roundup Ready soybeans have proved extremely popular with U.S. farmers since their introduction in 1996. In only 5 years, adoption increased to 54% of total soybean acreage planted in 2000 (Figure 1).

Figure 1. Roundup Ready Soybean Adoption



Sources: Marshall, USDA NASS 2000

By most accounts, the popularity of Roundup Ready soybeans is due to the simplicity of a weed control program that relies on one herbicide to control a broad spectrum of weeds without crop injury or crop rotation restrictions. Before the introduction of Roundup Ready soybean varieties, growers would choose between many herbicides, often applying three or more active ingredients, some of which would cause damage to the growing soybean plants, or cause harm to crops that commonly follow soybeans (Gianessi and Carpenter 2000).

In light of such rapid adoption of the technology, it was troubling when researchers began reporting lower yield potential in Roundup Ready varieties compared to conventional varieties. In 1998, researchers at the University of Wisconsin compiled results from variety trials conducted in 8 northern states, finding that Roundup Ready yields were 4% lower than conventional yields, on average (Oplinger, et al. 1998).

However, some analysts distorted this finding, asserting that this difference was due to an inherent problem with the Roundup Ready varieties resulting from the process of genetic modification (Benbrook).

Interpreting Variety Trials

When assessing the impact that the adoption of Roundup Ready soybeans has had on grower yields, two areas of research contribute to understanding. The first is weed control research comparing weed control strategies. The second type of research is variety trials, where the yield potential of conventional and Roundup Ready varieties have been compared.

In weed control trials, weed control programs are compared in terms of efficacy against particular weed species and resulting yields. The purpose of these types of studies is to determine optimal herbicide application rates and timing to achieve control of various weeds. In general, these tests are conducted using a single variety. Recently, researchers have chosen to use Roundup Ready varieties in order to include Roundup treatments in their studies. Yield differences in these studies are due to more effective weed control and from avoiding crop injury. However, since only one variety is used in each study, the yield potential of the variety is not directly considered. It is difficult to generalize about the results from the weed control studies, although there seems to be no resounding yield advantage or disadvantage in the Roundup Ready systems compared to conventional programs. Researchers in Minnesota concluded that the yields are about the same (Breitenbach, et al.).

Variety trials are conducted by state universities to assess the characteristics of varieties that will be available to growers the following year. The trials assess yield and other variety performance characteristics, such as maturity, lodging, protein and oil content, and resistance to pathogens and soybean cyst nematode, and are generally

maintained weed free, in order to eliminate competition from weeds as a factor influencing yield. Variety trials do not always include all of the varieties that are commercially available in an area. It is also unknown which of the varieties that are included in the trials are the most commonly planted.

Overall differences in yield potential between Roundup Ready varieties and conventional varieties from variety trials are most likely due to differences in the agronomic background of the varieties in which the Roundup Ready trait is available. The Roundup Ready trait was introduced into a single soybean variety that is appropriate to growing conditions in a limited growing area. It is through conventional breeding that the Roundup Ready trait is introduced into more and more varieties. Conventional breeding is a process that can take several years, in order to perform enough “backcrossing” to recapture the agronomic characteristics of the recipient variety. Therefore, it was expected that it would take several years for seed companies to make the Roundup Ready trait available in the highest-yielding elite varieties.

1999 Variety Trial Results

The analysis of yield performance of Roundup Ready varieties from 1999 state university variety trials was structured to be comparable to a previously conducted analysis of 1998 trials (Oplinger, et al. 1998). Therefore, the same states were included in this analysis as were included in the analysis of 1998 trial results.

Each of the states included in the analysis conducted soybean variety trials of Roundup Ready varieties alongside trials of conventional varieties. Only in one state, Wisconsin, were the trials combined, while in Iowa, conventional checks were included in the Roundup Ready trials. Several trials have been excluded from the analysis. Particular trials were excluded because the Roundup Ready and conventional trials were not conducted in proximity to each other, management practices such as row spacing or

planting date were different between the trials, or the trials in a location were adversely affected by environmental conditions.

The results from variety trials are published each year, including yields for each variety entry in each testing location. State and regional averages for Roundup Ready and conventional varieties were computed based on these published variety trials reports. Yield testing of Roundup Ready varieties was more extensive in 1999 than in 1998. In the 8 states included in the 1998 and 1999 analyses, the number of Roundup Ready varieties that were included in the variety trials was higher in 1999, than in 1998. In 1998, the ratio of conventional to Roundup Ready entries was 1.7 to 1. In 1999, the ratio was 0.9 to 1. Also, the number of locations where Roundup Ready varieties were tested alongside conventional varieties increased from 18 in 1998 to 29 in 1999. Nearly 9400 entries are included in the calculations presented here, 4443 conventional and 4955 Roundup Ready. In all cases, the Roundup Ready varieties were treated with Roundup, while conventional varieties were treated with conventional herbicides.

Overall, Roundup Ready varieties yielded 97% of the conventional yields, averaged across all trials in all states. Table 1 shows the relative average yields of Roundup Ready varieties in comparison to conventional varieties by state for 1998 and 1999. In five of the eight states included in the analysis, the disparity in yields between Roundup Ready and conventional varieties was smaller in the 1999 trials than in 1998, indicating the availability of the Roundup Ready trait in higher yielding varieties.

The average yields of Roundup Ready and conventional varieties were also calculated by region for each state and compared. (See Table 2.) Relative yields of Roundup Ready varieties expressed as a percentage of conventional variety yields ranged from 82% in Central Minnesota to 109% in Central Ohio.

Table 1. State Average Yield Performance of Roundup Ready Relative to Conventional Varieties 1998 and 1999

	1998¹	1999²
Illinois	103%	102%
Iowa	93%	95%
Michigan	97%	101%
Minnesota	92%	91%
Nebraska	88%	97%
Ohio	97%	89%
South Dakota	90%	94%
Wisconsin	97%	100%
Overall Average	96%	97%

¹ Source: Oplinger

² Calculation based on Beuerlein, et al.; Hall, et al.; Michigan State University; Nelson, et al.; Oplinger, et al. 1999; University of Illinois; University of Minnesota; Voss, et al.

Benbrook's Analysis

Dr. Charles Benbrook released an analysis of 1998 variety trial results that relies heavily on the analysis conducted by the researchers in Wisconsin (Benbrook). Benbrook borrows results from the Wisconsin analysis, recalculating some key figures, and extends the analysis with a more in-depth review of results from trials conducted in Southern Wisconsin and Central and Southern Minnesota.

Benbrook begins his discussion of yield comparisons by noting that “[t]he most accurate method is to compare yields in properly conducted side-by-side trials carried out with near-isogenic lines that differ only in the possession of the glyphosate-tolerance gene.” With this comment, he misleads his readers by implying that his analysis is based on such trials, when in reality the variety trials that he analyzes compares varieties that differ in many characteristics besides the Roundup Ready trait.

The analysis continues by reporting the results from the analysis conducted by Wisconsin researchers, with an important difference: Benbrook has recalculated the

bottom line results. Three overall averages were presented by the Wisconsin researchers, comparing Roundup Ready and conventional yields for all entries, for the top five varieties and for the top variety. The Wisconsin researchers clearly present their average differences, 4%, 5% and 6%, for the three comparisons, respectively. Benbrook derives different and larger numbers, 5%, 6% and 7%, respectively. It is unclear why Benbrook diverges from the results as calculated in the original analysis.

Benbrook continues his analysis by reviewing results from trials conducted in Minnesota and Wisconsin. He has constructed a comparison in which he evaluates yields of the best conventional variety compared to the best Roundup Ready variety by maturity group for entries from 10 seed companies. He states:

In many cases, the only difference between the two varieties is the insertion of the genetic material that makes the Roundup Ready variety able to survive applications of Roundup herbicide. This sort of comparison comes closest to isolating the physiological impacts of the genetic transformation required to make the soybean plant tolerant to applications of glyphosate herbicide. These impacts are the causes of RR soybean yield drag.

However, for reasons stated above, it is likely that these varieties are different in other characteristics besides the Roundup Ready trait, including inherent yield potential. Indeed, it is impossible to identify in the variety trial reports which varieties have similar genetic backgrounds.

Benbrook labels the difference in potential yields a yield “drag,” implying that the Roundup Ready trait or the insertion process has caused the difference in yields. Yet his analysis has not isolated the cause of the difference in yields. In reality, this difference is at least partly a yield “lag” which will disappear as the trait is incorporated into more and more varieties, including the highest yielding elite varieties.

Researchers in Nebraska have attempted to isolate yield “lag” from yield “drag” by comparing the yields of Roundup Ready and non-Roundup Ready “sister lines,” with

similar genetic backgrounds. Isogenic, or nearly genetically identical, lines were unavailable. Yields of the Roundup Ready sister lines were 5% lower than the non-Roundup Ready sister lines, which is interpreted as evidence of yield “drag” (Elmore, et al.). No further published research into this question of yield “drag” was located. Monsanto has reported findings that yields were no different in their comparisons of isogenic Roundup Ready and non-Roundup Ready soybeans (Delannay, et al.). However, this data has not been published.

The selection of Minnesota and Wisconsin for in-depth analysis by Benbrook is also misleading, as one would reach different conclusions if two other states had been chosen. For instance, in Illinois and Michigan, Roundup Ready varieties outyielded conventional varieties in 1998 variety trials in several areas.

Benbrook’s analysis has recently been taken by others as a definitive statement on the impact that Roundup Ready soybeans has on yields. A report released by the Wallace Center of Winrock International adopts Benbrook’s analysis, reporting that “[t]he physiological impacts of genetically transforming soybean plants to tolerate the herbicide glyphosate have initially caused a drag on yields” (Ervin, et al.). Benbrook and those that cite him fail to carefully consider other causes of the observed yield differences.

Summary

Variety trials provide useful information to farmers that assists them in selecting varieties appropriate for particular growing conditions and management needs. Since the introduction of Roundup Ready soybeans, trials have included more and more Roundup Ready varieties, tested alongside conventional varieties. On average, it appears that the Roundup Ready varieties yield slightly less than the conventional varieties. Based on 1998 and 1999 trials, this gap appears to be narrowing, from 4% to 3%. As the Roundup Ready trait is introduced into the highest yielding varieties, it is expected that this

difference will disappear, or even be overcome. However, one must be cautious in interpreting the results of variety trials as many other factors besides yield potential, such as costs and weed control efficacy, affect growers' planting decisions and, ultimately, yields.

Table 2. Regional Yield Performance of Roundup Ready and Conventional Varieties 1998 and 1999.

State	Region	1998 ¹				1999 ²					
		Conventional		RR		% ³	Conventional		RR		% ³
		bu/acre	n	bu/acre	n		bu/acre	n	bu/acre	n	
Iowa	Northern (3 locations)	59	231	56	129	96	55.5	201	51.4	190	93
Iowa	Central (3 locations)	65	231	60	123	93	55.2	198	53.9	187	98
Iowa	Southern (3 locations)	58	139	54	88	93	55.6	100	52.5	152	94
Illinois	Region 1 ⁴	61	186	64	119	104	49.8	280	50.9	304	102
Illinois	Region 2 ⁴	54	203	51	144	94	58.5	268	59.9	336	102
Illinois	Region 3 ⁴	50	155	56	95	113	57.3	108	59.3	141	103
Illinois	Region 4						58.5	118	61.2	157	105
Illinois	Region 5 ⁴	66	70	67	43	102	51.3	162	52.9	240	103
Illinois	Region 6						47.7	136	46.1	164	97
Illinois	Urbana-7" rows						61.6	69	63.6	36	103
Michigan	Central (4 locations)	60	128	51	52	86	57.3	252	56.9	278	99
Michigan	South ⁵	72	121	76	55	105	63.1	180	63.8	237	101
Minnesota	North ⁶						44.9	52	44.3	32	99
Minnesota	Central ⁶	64	112	60	63	92	63.9	94	52.6	95	82
Minnesota	South ⁶	67	144	62	102	94	51.5	102	49.0	141	95
Nebraska	Northeast (1 location)						39.3	59	33.4	65	85
Nebraska	East/South Central ⁷	53	41	45	60	86	55.8	172	55.8	154	100
Nebraska	Southeast ⁸	61	57	58	52	95	59.7	128	60.3	136	101
Nebraska	Central (1 location)						59.3	33	56.3	51	95
Ohio	North (2 locations)	66	84	65	64	98	56.3	114	48.9	176	87
Ohio	Central (2 locations)	55	90	53	71	96	47.0	134	51.3	184	109
Ohio	South (2 locations)	60	57	57	52	94	55.1	106	48.9	145	89
South Dakota	Armour						45.4	115	44.4	175	98
South Dakota	Beresford						43.2	130	44.0	198	102
South Dakota	Brookings	49	144	44	102	90	53.1	172	47.4	153	89
South Dakota	Watertown						51.6	114	48.0	114	93

Table 2. Regional Yield Performance of Roundup Ready and Conventional Varieties 1998 and 1999 (continued)

State	Region	1998 ¹				1999 ²					
		Conventional		RR		% ³	Conventional		RR		% ³
		bu/acre	n	bu/acre	n		bu/acre	n	bu/acre	n	
Wisconsin	North (3 locations)					40.0	34	42.6	14	107	
Wisconsin	North Central (4 locations)					56.9	248	58.8	168	103	
Wisconsin	Central (3 locations)	72	70	70	40	97	58.0	183	56.4	153	97
Wisconsin	South ⁹	70	111	68	60	97	66.9	319	64.2	317	96
Overall			5172		3067	96	55.2	4443	53.6	4955	97

¹ Source: Oplinger, et al. 1998

² Calculations based on Beuerlein, et al.; Hall, et al.; Michigan State University; Nelson, et al.; Oplinger, et al. 1999; University of Illinois; University of Minnesota; Voss, et al.

³ Average yield of Roundup Ready varieties relative to average yield of conventional varieties.

⁴ Includes results from trials conducted at 1 location in 1998 and 2 locations in 1999.

⁵ Includes results from trials conducted at 4 locations in 1998 and 3 locations in 1999.

⁶ Includes results from conventional trials conducted in 3 locations in each region and Roundup Ready trials conducted in 2 locations in each region.

⁷ Includes results from trials conducted at 1 location in 1997 and 2 locations in 1999.

⁸ Includes results from trials conducted at 1 location in 1998 and 2 locations in 1999.

⁹ Includes results from trials conducted at 3 locations in 1997 and 4 locations in 1999.

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