Evidence of the Magnitude and Consequences of the Roundup Ready Soybean Yield Drag from University-Based Varietal Trials in 1998

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Executive Summary

Over half the soybeans planted in the United States in 1999 are varieties genetically engineered to tolerate applications of the broad-spectrum, contact herbicide glyphosate manufactured by Monsanto Company (Trade Name, Roundup). Just a small fraction of soybeans produced in 1996 were "Roundup Ready" -- varieties able to tolerate direct applications of glyphosate herbicide.

The rapid adoption of Roundup Ready (RR) soybeans has been unprecedented in the history of American row-crop agriculture. No new genetic trait, nor any pesticide has so dramatically gained market share in such a short period of time.

Roundup Ready soybeans have proven so popular with farmers because they greatly simplify the task of managing weeds and help farmers avoid a variety of problems associated with other herbicide-based weed management systems. They have proven especially popular among farmers who must complete weed management practices on a timely basis over hundreds to thousands of acres of soybeans.

The success of RR soybeans is remarkable in light of the magnitude of the so-called Roundup Ready "yield drag." Under most conditions extensive evidence shows that RR soybeans produce lower yields than possible if farmers planted comparable but non-engineered varieties.

This report reviews the results of over 8,200 university-based soybean varietal trials in 1998 and reaches the following conclusions regarding the magnitude of the RR soybean yield drag –

- The yield drag between top RR varieties compared to top conventional varieties averages 4.6 bushels per acre, or 6.7 percent.
- When comparing average yields across the top 5 varieties tested in 8 states, the yield drag averages 4.1 bushels, or 6.1 percent.
- Across all varieties tested, the yield drag averages 3.1 bushels, or 5.3 percent.
- In some areas of the Midwest, the best conventional variety sold by seed companies produces yields on average 10 percent or more higher than comparable Roundup Ready varieties sold by the same seed companies.

It is important to place the RR soybean yield drag in perspective. From 1975 to 1994 soybean yields rose on average about 0.5 bushels per year. In 1999 the RR soybean yield drag could result in perhaps a 2.0 to 2.5 percent reduction in national average soybean yields, compared to what they would likely have been if seed companies had not dramatically shifted breeding priorities to focus on herbicide tolerance. If not reversed by future breeding enhancements, this downward shift in soybean yield potential could emerge as the most significant decline in a major crop ever associated with a single genetic modification.

On whether RR soybean systems reduce pesticide use and increase grower profits, our analysis shows that –

- RR soybean systems are largely dependent on herbicides and hence are not likely to reduce herbicide use or reliance. Claims otherwise are based on incomplete information or analytically flawed comparisons that do not tell the whole story.

- Farmers growing RR soybeans used 2 to 5 times more herbicide measured in pounds applied per acre, compared to the other popular weed management systems used on most soybean fields not planted to RR varieties in 1998. RR herbicide use exceeds the level on many farms using multitactic Integrated Weed Management systems by a factor of 10 or more.

- There is clear evidence that Roundup use by farmers planting RR soybeans has risen markedly in 1999 because of the emergence of a degree of tolerance to Roundup in several key weed species, shifts in weeds toward those less sensitive to Roundup, price cuts and aggressive marketing.

- Roundup use on soybeans may well double from 1998 levels within the next few years. But if current trends continue in the way RR technology is used, the efficacy and market share of Roundup may then fall just as quickly.

- The RR soybean yield drag and technology fee impose a sizable indirect tax on the income of soybean producers, ranging from a few percent where RR varieties work best to over 12 percent of gross income per acre.

The remarkable popularity of Roundup Ready soybeans, despite their cost and the significant yield drag associated with their use, is evidence of the difficulty and high cost of today's herbicide-dependent soybean weed management systems. The rapid evolution of weeds better able to withstand applications of Roundup reinforces the need for more integrated, multiple tactic weed management systems.

A. Soybean Weed Management – A Never-Ending Challenge

Year in, year out dealing with weeds is the toughest pest management problem facing soybean farmers. Perhaps the only tougher challenge facing growers is finding a way to make a decent profit, especially in years like 1999 when surplus supplies and soft demand depresses prices.

Dr. Donald Wyse, a weed scientist at the University of Minnesota, highlights the dominant role weeds play in shaping Midwest row-crop farming systems --

> "Weeds are the major deterrent to the development of more sustainable agriculture systems…[they] dictate most of the crop production practices (e.g., tillage, herbicides, cultivation, row spacing)…It must be emphasized that current cropping systems enhance weed populations, forcing farmers to use tillage or herbicide inputs to manage weed problems." (Wyse, 1994)

Each year farmers have to deal with a few to a half-dozen species of grass weeds, and another few to half-dozen broadleaf weeds. It's not a question of whether weeds will pose a threat to yields, but which ones and –

- How tough will they be to control?
- What impacts will control measures have, directly and indirectly, on the health of soybean plants and crop yields?
- What will weed management cost?
- How will weed management systems impact the environment and soil quality both near-term and over many years?

A poor weed management job in one year can make matters worse for years to come. It takes years of careful attention to detail in weed management for farmers to reduce the number of weed seeds in the soil profile enough to make a significant difference in the weed pressure in subsequent years. Even then, some weed seeds can move great distances with the wind, so no farmer is in complete control of his or her weed management future.

Poor weed control costs farmers money and pride. There is nothing more visible in a soybean field than a tall patch of foxtail or velvetleaf wafting in the breeze above the crop canopy. When it comes time to harvest a field, patches of weeds can slow down the combine and lead to uneven maturation and drying of the crop. Weeds also compete with the growing crop for sunlight, water and nutrients. The greater the number of weeds, especially early in the season, the bigger the threat to yields.

Little Real Progress

Weeds pose roughly as much trouble for farmers in 1999 as they did in 1959, despite billions in expenditures on herbicides and hundreds of millions more invested in research, development and registration of new herbicides (Benbrook et al., 1996). Why? Because farms have gotten bigger and more specialized and many changes in agronomic practices have actually tipped the playing field to the advantage of certain weeds.

To reduce soil erosion losses and to cover large acreage fast with minimal demands on human labor, conventional farmers have all but abandoned some proven, non-chemical weed management tactics. For 40 years the USDA and soil conservation advocates have supported the trend toward conservation or reduced tillage.

Primary tillage is carried out to kill or damage perennial weeds, bury weed seeds and prepare a seedbed but it also exposes the soil surface to the erosive effects of rainfall and wind, a disadvantage on highly erodible land. Tillage with lighter equipment, called cultivation, is carried out after crops have emerged to help manage weeds. Cultivation is an effective, low-cost way to suppress weed populations and remains the back-bone of non-chemical weed management systems. Yet for a variety of reasons farmers have moved away from even this sort of tillage. One of the major reasons is the trend toward narrow row planting systems, solid seeded fields and no-tillage systems.

Another is that pulling steel across fields is expensive. It takes a lot of fuel and tillage equipment requires constant repair and maintenance. Plus, large machines are needed to cover large farms quickly with limited labor inputs. The bigger the machine, the more capital tied up and the greater the pressure to cover more ground. It’s a vicious circle that tends to lead farmers progressively away from multi tactic, non-chemical weed management systems.

Integrated Weed Management systems are proven and profitable alternatives to systems largely dependent on herbicides (Tillman, 1998; Drinkwater et al., 1998; see also multiple research reports from the Aldo Leopold Center for Sustainable Agriculture at Iowa State University and annual progress reports from the Practical Farmers of Iowa, see http://www.agron.iastate.edu/pfi/). They can reduce reliance on herbicides and lower costs with no loss of yields but they take planning, skill and commitment. Key components for success include a proper rotation, tillage and planting systems designed to get crops off to a fast start, and mechanical cultivation to combat weeds when they are small and most vulnerable. Success depends on developing a good understanding of the biological processes and cycles unfolding on the farm. Careful timing and considerable skill in the integration of multiple tactics is essential.

The human dimension is actually perhaps the dominant constraint. Individuals with the skill and experience needed to properly operate cultivation equipment do not yet qualify for the endangered species list, but their numbers are falling fast with no end in sight. Money to pay wages is not the only issue since weed management costs have clearly rising over the last 15 years. The $15.00 increase in per acre herbicide expenditures on most farms would pay for two to three additional passes with a cultivator.

Herbicides are the primary weed management tactic on 95 percent plus of the land growing soybeans because it has become easier to get the job done with herbicides than with multitactic systems. It has become easier because of years of public and private investment in knowledge and infrastructure dedicated to the delivery and application of herbicides, and years of relative neglect to research, education, and technology development dedicated to improving the ease and efficiency of non-chemical weed control practices and systems. Priorities have not shifted in a vaccuum. Heavy advertisement has reinforced the notion that "progress" equals applying the latest herbicide.

But even without much support from the private sector or public research programs, farmers practicing sustainable methods or producing for the organic market have continued to refine non-chemical and reduced chemical weed management systems and have cut the costs of weed management to half or less of some neighboring farms using herbicide-based systems (see the sections on weed management in *Pest Management at the Crossroads*, Benbrook, C. et al., 1996).

Moving Targets

Weeds have great capacity to adapt and evolve. Two Iowa State University weed scientists, Dr. Bob Hartzler and Dr. Doug Buhler, have studied one reason -- weed emergence patterns. In 1998 research, they found that different weeds emerge at different points during the season.[1] In Northeast Iowa, fall panicum first emerged 50 days after initial emergence of giant ragweed. Across the state, there was almost a two-month span during which new weed species emerged.

The long period during which different species emerge for the first time is a special problem for farmers planting Roundup Ready soybeans. This is because Roundup works only on growing weeds. Farmers must wait for weeds to emerge to apply Roundup. But if they wait too long, weeds can get too big of a jump and some will only be stunted by Roundup application, requiring a second treatment or application of another active ingredient.

Making matters worse, several weed species can germinate for a month or more, including some of the most difficult to control late season weeds like waterhemp and morningglory. As a result, a properly timed early season application may miss soon-to-germinate weeds that can then cause problems later in the season.

Evolutionary changes in weeds have steadily pushed farmers to seek out "stronger medicine" in dealing with annual problem weeds. As a result, expenditures on herbicides doubled in the 1980s, rising from around $13.00 per acre in 1988 to over $26.00 per acre

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[1] For more information, see the extensive weed management resources on the Iowa State University Extension weed management site at <http://www.weeds.iastate.edu/mgmt/qtr98-4/emergencepatterns.htm>.

(see “Table 1, Soybeans – Seed and Chemical Production Expenses in Corn Belt States, 1975-1997,” Benbrook, 1999). Competition-driven price reductions starting in 1998 are likely to keep expenditures on herbicides from rising for the next few years despite increased reliance and use.

Weed shifts and the emergence of tolerant and/or resistant weeds are the dominant mechanisms likely to undermine the long-term effectiveness of any herbicide-based system that is relied upon too widely or intensively.[2] Weed shifts reflect a change in the relative proportions of different weed species present in a field. The emergence of weeds resistant to a given herbicide, on the other hand, is a genetically-driven evolutionary phenomenon which occurs within a species present in a field.

In the case of Roundup Ready soybeans, evidence has emerged already that such shifts and natural adaptation are occurring. Iowa State University researchers have documented glyphosate resistance in waterhemp species (see footnote for source). This particular species of weed is highlighted in the 1998 edition of the Weed Control Manual as the most worrisome “Up and Coming Weed” both nationwide and in the North Central region (Meister, 1998). Reasons why include the emergence of resistance to triazine and ALS herbicides and its ability to withstand Roundup applications (for an up to date overview by Iowa weed scientist Bob Hartzler, see <http://www.weeds.iastate.edu/mgmt/qtr98-4/roundupfuture.htm>).

Soybean farmers in the Midwest are also reporting that velvetleaf and smartweed species are tolerating application rates of Roundup that were effective just last year. Over the next few years, weed scientists anticipate that the gradual shift toward weed species that can tolerate Roundup will continue, requiring farmers to change their mix of practices. If even a small percentage of growers respond instead by just increasing rates of Roundup application and/or spraying more often, this could generate enough selection pressure to lead to the emergence of genetically resistant strains of commonplace weeds. In all likelihood these strains would quickly spread and all growers would then have to switch to other herbicides and control tactics.

Ironically the remarkable success of Roundup Ready soybeans in the marketplace sets the stage for problems in the field. Regardless of how well a given herbicide or weed management system is working, tomorrow’s problem-weed is just around the corner. The more uniform the weed management system in an area, the quicker new problem-weeds are likely to emerge. The greater a farmer’s reliance on herbicides, especially one or a few products, the more likely it becomes that resistance weed species will emerge. These are the lessons of weed management history that are not being adequately heeded as the biotechnology revolution reshapes the American soybean industry.

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[2] For a good overview of these potential risks, see Dr. Mike Owen’s 1997 review of herbicide-tolerant technology (Owen, 1998).

B. Methods to Compare Yields

Two major methods are used to compare the yields of Roundup Ready soybean varieties to the yields of non-engineered soybeans. One involves comparing average yields across many different trials, or across many farms. The problem with such comparisons is that many variables are not controlled. Average yield differences might be explained by genetic difference or by other factors.

The most accurate method is to compare yields in properly conducted side-by-side trials carried out with near-isogenic lines[3] that differ only in the possession of the glyphosate-tolerance gene. Such trials are the most reliable way to isolate the consequences of genetic differences, all other things being equal.

Most land grant universities in states with significant acreage of soybeans carry out soybean yield trials to provide farmers with impartial, accurate data on the performance of different varieties. (Internet-accessible sources of land grant university soybean trial data are listed in the references). The trials are typically conducted in different regions of a state and cover different maturity groups[4]. In some states, trials are carried out using a variety of tillage and planting systems.

In this report we compare soybean yield trial data from university trials, the most impartial data available. We have drawn heavily on a University of Wisconsin analysis of over 8,200 soybean yield trials carried out in eight states in 1998. This definitive assessment of the Roundup Ready soybean yield drag was done by Dr. E. S. Oplinger, Dr. M. J. Martinka, and Dr. K. A. Schmitz and is entitled "Performance of Transgenic Soybeans in the Northern U.S." [5]

State Varietal Trial Results

In Tables 1 and 2 we report the differences in the yields of Roundup Ready ("RR") in contrast to conventional ("Conv") varieties in eight states, drawing on the data reported in the Oplinger summary report. Each table offers three comparisons – trial means across all varieties, the mean of the top five varieties tested, and the top varieties tested.

Table 1 reports bushels harvested per acre and Table 2 presents the RR yield drag in two ways – the difference in bushels per acre between the Roundup Ready varieties and conventional varieties, and second, as a percent of the yield of conventional varieties.

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[3] By "near identical isogenic lines" we mean two varieties that are nearly identical in terms of their genetic makeup, except for the insertion of a specific gene or trait.

[4] Soybean varieties are often sold and studied within "maturity groups." In general, the longer the maturity period for a variety, the higher the expected yields. It is therefor inappropriate to compare the yields harvested of a long season variety in contrast to a short season one.

[5] This paper is accessible online at http://www.biotech-info.net/soybean_performance.pdf. The summary table from this paper is accessible at http://www.biotech-info.net/yield_performance.pdf. A slide presentation by Dr. Oplinger further summarizing their findings is accessible at http://www.uwex.edu/ces/soybean/slides/1998%20ASTA%20Expo/sld001.htm.

Table 1. Roundup Ready (RR) Soybean Yield Compared to Conventional (Conv) Varieties in Eight States, 1998 **[Bushels per Acre]**

States	Trial Mean		Top Five Varieties		Top Variety	
	Conv	RR	Conv	RR	Conv	RR
Illinois	58	60	65	65	67	67
Iowa	61	57	64	60	66	60
Michigan	66	64	74	69	78	70
Minnesota	66	61	73	67	74	69
Nebraska	58	51	65	58	66	60
Ohio	60	58	67	63	69	65
South Dakota	49	44	54	50	56	51
Wisconsin	71	69	85	82	87	84

Source: *'Performance of Transgenic Soybeans - Northern U.S.'*, E.S. Oplinger, M.J. Martinka, K.A. Schmitz. For details by State, see Table 1. Yield Performance of "Roundup Ready" vs. Conventional (CN) Soybean Varieties in the Northern U.S., 1998

Oplinger data show that the –

- RR soybean yield drag ranges from 0 percent to 10 percent among the top varieties and averages 7 percent, or 5 bushels per acre.

- Across the top 5 varieties tested, the yield drag ranges from 0 percent to 11 percent, and averages 6 percent.

Table 2. Roundup Ready (RR) Soybean and Conventional Variety Yields by State, 1998			
States	Bushel per Acre Yield Difference, Conventional to RR Varieties --		
	Trial Mean	Top Five Varieties	Top Variety
Illinois	2.0	0.0	0.0
Iowa	-4.0	-4.0	-6.0
Michigan	-2.0	-5.0	-8.0
Minnesota	-5.0	-6.0	-5.0
Nebraska	-7.0	-7.0	-6.0
Ohio	-2.0	-4.0	-4.0
South Dakota	-5.0	-4.0	-5.0
Wisconsin	-2.0	-3.0	-3.0
Average Eight States	**-3.1**	**-4.1**	**-4.6**
States	Percent Yield Drag per Acre --		
	Trial Mean	Top Five Varieties	Top Variety
Illinois	3.4%	0.0%	0.0%
Iowa	-6.6%	-6.3%	-9.1%
Michigan	-3.0%	-6.8%	-10.3%
Minnesota	-7.6%	-8.2%	-6.8%
Nebraska	-12.1%	-10.8%	-9.1%
Ohio	-3.3%	-6.0%	-5.8%
South Dakota	-10.2%	-7.4%	-8.9%
Wisconsin	-2.8%	-3.5%	-3.4%
Average Eight States	**-5.3%**	**-6.1%**	**-6.7%**

Source: *'Performance of Transgenic Soybeans - Northern U.S.'* , E.S. Oplinger, M.J. Martinka, K.A. Schmitz. For details by State, see Table 1. Yield Performance of "Roundup Ready" vs. Conventional (CN) Soybean Varieties in the Northern U.S., 1998

Oplinger and colleagues end their report with a prediction and straightforward conclusion from their analysis of the RR soybean yield drag in 1998 –

> "It is anticipated that soybean growers will continue to increase acres planted to RR varieties and will sacrifice maximum yield for ease of weed control." (Oplinger et al., 1999).

2. Yield Drag Estimates by Seed Company

A second way to estimate the RR soybean yield drag is to compare the best conventional variety offered by a given seed company in a given maturity group to the best Roundup Ready variety in the same or a similar maturity group. 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 cause of RR soybean yield drag. Seed and biotechnology companies are working hard now to find ways to retain tolerance to glyphosate without adversely effecting the ability of the soybean plant to grow and protect itself against pathogens, insects and other sources of stress.

We reviewed detailed state trial data from tests carried out in Southern Wisconsin (Tables 3 and 4) and in central and southern Minnesota (Tables 5 and 6). For 10 seed companies selling both RR and conventional soybean varieties in Southern Wisconsin, Table 3 reports differences in yields for the top RR variety in contrast to the top conventional, the mean RR to the mean conventional, and the lowest yielding RR compared to the lowest yielding conventional. Because of their size, Tables 3, 4, 5, 6 and 7 appear at the end of this document.

The average Roundup Ready yield drag in Southern Wisconsin across these 10 companies was –

- 4.7 bushels, or 6.2 percent in the case of the top RR and conventional variety;
- 4.4 bushels, or 5.9 percent in the case of the mean RR and conventional variety; and
- 3.5 bushels, or 4.8 percent at the low-end of the yields.

Note how consistent these findings are compared to the percentage differences reported in Table 2. Yield comparisons across 8 states, and in Southern Wisconsin across the soybean varieties offered by 10 companies tell the same story. The RR yield drag among the top variety tested is 6-7 percent and the yield drag is consistently greater among the higher yielding varieties in contrast to average ones.

Table 4 captures just the percent differences in yields across the 10 companies based on trials conducted in Southern Wisconsin.

In central Minnesota testing (see Table 5) the RR soybean yield drag averaged 13.1 percent, or 9.3 bushels per acre across 14 comparisons. Again, the comparisons are between the highest yielding RR variety in a given maturity group to the highest yielding conventional variety in the same or very similar maturity group. In 3 of 14 cases the yield drag exceeded 20 percent. In this part of Minnesota, the highest yield drag was 27 percent and the lowest was 3 percent.

Table 6 reports the same data in southern Minnesota, a major soybean producing area where many more varieties are offered for sale. This table again matches the top RR and conventional varieties by company within a maturity group. In this region the average yield drag was much smaller, only 2.8 percent across 50 comparisons.

Differences in yields were also much more variable, ranging from a yield advantage of 18 percent to a yield drag of 15 percent. This variability suggests that in several cases genetic characteristics other than tolerance to Roundup herbicide differed across the varieties compared. Future comparative assessments of yield performance should strive to control for other genetic differences, a task that will require contacting individual seed companies to request information on the differences between varieties.

Economic Impacts of the RR Yield Drag

Table 7 projects the farm-level economic impacts of the yield drag associated with the planting of Roundup Ready soybean varieties. Note the table does not address differences in herbicide expenditures or in other facets of weed management. It simply places into perspective the two relatively easy-to-measure consequences of planting RR soybeans – the yield drag and the technology fee.

The average yield drag in bushels per acre appears in the second column, and as a percent of conventional yields in the third. The dollar value of the yield drag is based on a soybean price of $5.25 per bushel. The “Added Cost of the RR System” is the sum of the “Dollar Value of Yield Drag” plus the average $8.00 technology fee associated with the planting of an acre of RR soybeans. The last column expresses the added cost as a percent of gross income.

In four of eight states, farmers choosing to plant Roundup Ready soybeans incurred added costs equal to over 10 percent of gross income per acre. The added cost is lowest in Illinois, where it averaged about 2.3 percent of gross income per acre, and highest in Michigan, at $50.00 per acre or over 12 percent of gross income.

The added costs associated with Roundup Ready varieties are sizable compared to total seed plus herbicide expenditures, which typically run about $45.00 to $60.00 per acre. Accordingly, for some farmers the decision to grow RR soybeans may come close to doubling the cost of seed plus weed management systems when both the direct and indirect consequences of growing RR soybeans are taken into account. In Illinois and on some farms throughout the Midwest, RR varieties perform as well or even better than conventional varieties, despite the yield drag associated with all varieties. Seed and biotechnology companies are working to understand why. Answers will no doubt guide future efforts to bred improved varieties for the western and northern Cornbelt or to modify agronomic practices to better exploit the genetic yield potential in RR varieties.

Clearly, additional factors need to be taken into account to come up with a complete assessment of the economic impacts of RR soybeans. The amount of money spent on herbicides per acre varies widely across the Midwest and as a function of agronomic practices and field conditions. Most data suggest that those farmers using RR soybean systems with greatest success under conditions of relatively low weed pressure can get by with one application per year and costs somewhat below the average.

But an increasing number of farmers need two applications of Roundup and one of at least one additional active ingredient. There are little or no herbicide cost-savings on such farms relative to growers planting conventional varieties and using Integrated Weed Management. A myriad of price incentives, volume discounts, product guarantees and rebates has made it very difficult to compare the actual costs of herbicide based systems and will continue to plague those making such comparisons for some time to come.

3. USDA Survey Data

Each year the U.S. Department of Agriculture (USDA) carries out an Agricultural Resource Management Study (ARMS) that includes surveys of agricultural chemical use and cropping practices in each state. On June 25, 1999 the USDA's Economic Research Service (ERS) released an analysis of 1996, 1997, and 1998 ARMS survey data entitled "Genetically Engineered Crops for Pest Management."[6] This short report contains three tables that have led to much discussion and many misleading statements.

The first table in the ERS report covers the percent of acres planted to *Bt*-transgenic and herbicide tolerant varieties since 1996, as well as the percent of production. The data is organized by regions and aggregated to cover "All Surveyed States."

In the case of herbicide-tolerant soybeans, acres planted to Roundup Ready soybeans are combined with acres planted to sulfonylurea and imidazolinone tolerant soybeans. Accordingly, it is not possible to isolate the growth in acres planted to Roundup Ready varieties, even though it is widely accepted that most of the increase in acres planted to herbicide tolerant varieties have involved Roundup Ready seed.

In all surveyed states, the percent of soybean acres planted to herbicide tolerant varieties rose from 7.4 percent in 1996 to 44.2 percent in 1998. In crop season 1999 at least 50 percent of the nation's soybeans are Roundup Ready (personal communication, Dr. Matt Liebman, Iowa State University).

Table 2 in the ERS report covers mean yields on acres planted to transgenic varieties compared to mean yields from acres planted to all other seeds. The Table reports the percent difference in mean yields on farms adopting the technologies compared to those planting all other seeds. In the case of herbicide-tolerant soybeans, the yield differences vary from an 8 percent yield drag in the Eastern Uplands region in 1998 to a 24.2 percent yield advantage in the Prairie Gateway region in 1998.

In a preface to the tables, the authors of the ERS report state several caveats about using mean yields from survey data to compare the genetic potential of different crop

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[6] The report is accessible on the Internet through the ERS "Issues Center – Biotech," at http://www.econ.ag.gov/whatsnew/issues/biotech/ A link to this report and analysis of it can be found on the Ag BioTech InfoNet website at http://www.biotech-info.net/bt-transgenics.html, under "General Discussion and Opinions."

varieties. The authors state appropriately that conditions other than the genetic differences between Roundup Ready and conventional seed varieties might account for some or all the observed differences in yields. The authors conclude that –

> "Thus, differences between mean estimates for yields and pesticide use from survey results cannot necessarily be attributed to the use of genetic engineering technology since the results are influenced by many other factors not controlled for, including irrigation, weather, soils, nutrient and pest management practices, other cropping practices, operator characteristics, pest pressures, and others." ("Caveats About Using Comparisons of Means," ERS report, "Genetically Engineered Crops for Pest Management")

We concur with the ERS analysts. The only reliable conclusions one can draw from the ERS data are that –

- the acreage devoted to herbicide tolerant varieties is growing (not disputed);
- soybean yields on farms growing herbicide tolerant seed compared to conventional seed have varied greatly from year to year and from one region to another; and
- there have been modest shifts in the reliance on herbicides as measured by acre-treatments.

It is impossible to tell from the data reported by ERS what portion of the variability in yields is attributed to natural factors like soil, weather and pest pressure, or management factors, in contrast to genetic differences in the seed planted. It is likely, for example, that Roundup Ready adopters include a higher percentage of farmers who are aggressive managers covering large acreage. The bigger the farm, the greater the economic value of the flexibility inherent in Roundup Ready systems. Adopters may also choose to plant the higher-priced Roundup Ready seeds on their better land. Clearly, more detailed analyses will be required to understand more fully the differences between the agronomic practices and pest management systems on farms planting RR soybeans in contrast to conventional varieties.

4. Why Roundup Ready Varieties Sometimes Out-Yield Conventional Soybeans

No one or no seed company claims that the insertion of the genes conferring resistance to Roundup into a soybean variety increases the variety's genetic yield potential, other things being equal. Still, on some farms in some regions and in some trials, Roundup Ready soybeans out-yield otherwise similar conventional varieties. Indeed, this is one of the major reasons they have proven so popular with farmers. It is important to understand why this occurs in order to accurately project the magnitude of the Roundup Ready yield drag under truly comparable conditions.

Seed companies have worked hard to insert the RR gene and trait into their best commercial varieties for various soil types and maturity groups. There are two ways that the RR soybean version of these best commercial varieties could produce higher yields --

- More effective weed control than otherwise attainable; and/or
- Less crop injury from applications of other herbicides or weed management practices like cultivation.

In most RR soybean systems growers must tolerate a certain degree of early-season weed pressure. To work, Roundup must be applied to green, growing weeds. Optimal results with RR beans require careful timing of the first application. If the application is made soon after weeds germinate, the farmer will avoid setting the crop back but might suffer some yield loss from later season weed pressure. Sometimes farmers have to apply a second application of Roundup to clean up fields, increasing the cost of the system and causing some damage to plants. The need for a second application can be avoided by delaying the first application, but this risks a certain degree of early season weed competition. Hence, RR weed management systems that rest solely on Roundup applications are likely to result in weed competition at least as great as in other well-managed systems.

In the field, farmers have come to expect a very high level of weed control, expectations reinforced by the proliferation of new chemistry, emergence of herbicide-tolerant varieties, and the marketing and performance guarantee programs offered by herbicide manufactures. Major across-the-board price reductions since 1997 are another factor leading to increased rates of application. In early 1998 Monsanto announced about a 25 percent reduction in the price of Roundup. Soon thereafter Dupont and American Cyanamid announced comparable, and in some cases even steeper reductions in the prices of their competing herbicides, as they struggled to slow the loss of market share to Roundup.

And so most experts agree that greater seed and product choice and lower herbicide prices has resulted in very aggressive and generally successful soybean weed management in recent years. If weed pressure and competition does not account for much of the observed differences in yields between RR and conventional varieties, what does?

Most farmers not using a Roundup Ready based system are applying either sulfonylurea or imidazolinone herbicides. Most university soybean trials also incorporate routine applications of these products in their side-by-side comparisons. These herbicides are known to cause some stunting and damage to soybeans early in the season, as clearly documented in the extensive performance trials carried out in 1998 by Iowa State University scientists.[7] Soybeans grown in areas with long seasons tend to be better

[7] Go the Iowa State University extension weed mamangement homepage at http://www.weeds.iastate.edu/ and then to the section "1998 Weed Research Results Now Online." At each of several locations around the state, different teams of researchers carried out multiple trials assessing herbicide performance. Many

able to overcome early season soybean herbicide injury, although a variety of environmental and chemical interactions can undermine this capacity.

These highly-active herbicides can also reduce soybean yields through other mechanisms such as lessening the availability of phosphorous or impairing the plant's immune response. But regardless of the mechanism – direct injury or indirect soil ecosystem or plant health impacts – it is clear that Roundup Ready systems sometimes produce higher yields because they avoid some of these problems associated with other herbicides. For this reason the RR yield drag is actually somewhat greater than suggested by current university trials. To more accurately isolate the magnitude of physiological RR yield drag under various conditions, university trials should be extended to include comparison plots where Integrated Weed Management and non-chemical systems are used.

The Devil in Weed Management Details

In general the better the growing season and the more even the crop stand, the better the chance that the soybean crop will fully recover from early season weed pressure and/or herbicide-based crop injury.

But all sorts of complicated interactions can arise between herbicides, surfactants, insecticides, application methods and timing, weather, tillage methods and soil conditions. These interactions sometimes create unforeseen problems. Wet and cool springs can delay the microbial degradation of herbicides and increase carry-over damage, while also slowing crop emergence and favoring certain hard to control weeds. Dry years can undermine the efficacy of certain herbicides and enhance the odds of a whole new set of adverse interactions. Soils with low pH levels can cause problems, as can mixing herbicides with certain soil insecticides.

These interactions are, moreover, inherently unpredictable. Their adverse consequences – and impact on the farmer's bottomline – are often unavoidable once the conditions set the interactions in motion. Farmers have so eagerly adopted Roundup Ready soybean technology, despite higher costs and evidence of a yield drag, in order to avoid these headaches and periodic losses. It is also why seed and biotechnology companies have bred IMI (imidazolinone) and STS (sulfonylurea) herbicide-tolerant soybean varieties -- to avoid soybean crop injury either from direct applications to herbicide tolerant seeds or carry-over from cornfields treated the year before with these often very persistent herbicides.

C. Impacts of Roundup Ready Soybean Systems on Pesticide Use

The benefit of planting a herbicide-tolerant variety is to gain added flexibility in when herbicides can be applied. Growers spending the extra money on herbicide tolerant

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studies were designed to determine optimal ways to incorporate residual pre- or post-plant herbicides into RR soybean systems. Early season injury to soybean plants from other herbicides is a recurrent focus of researchers and a growing concern among farmers.

seeds have made an implicit decision to largely rely on herbicides as their major weed management tool. Hence, it is no surprise that reliance on herbicides is greater in herbicide tolerant systems compared to Integrated Weed Management systems that include non-chemical practices such as rotations, cultivation, and use of cover crops.

Roundup Ready soybeans are a new technology. The first significant acreage was planted in 1997. Adoption rose dramatically in 1998 and is expected to grow further in 1999. Still relatively few acres have been planted to Roundup Ready soybeans more than two times, so it is way too early to determine the severity and impacts of weed shifts and resistance on pesticide use.

Still, the signs are not encouraging. Slipping efficacy is being reported by farmers across the Midwest, especially in control of velvetleaf and ragweed species.[8] Many are reporting inadequate control of these weeds after applying Roundup Ultra at a rate of 24 ounces per acre (0.75 pounds active ingredient) but good control at 32 to 48 ounces per acre. A rate of 24 ounces worked acceptably well on these weeds in most regions of the Midwest in 1996 and 1997.

Weed shifts are occurring, perhaps rather swiftly and even the first case of RR soybean induced resistance – in waterhemp species – is either here or just around the corner. So regardless of whether RR soybeans have reduced reliance and use in 1996-1998, it is clear that both are rising and will continue to do so until more balanced, multitactic weed management systems become the norm.

Reliance on Herbicides

Both in the near-term and longer-run it is tricky to measure changes in reliance on and use of herbicides. No single measure of herbicide use is a reliable indictor of reliance. Pounds applied per acre is misleading because some herbicides are effective at just a fraction of an ounce per acre while others require applications well over 1 pound per acre.

The biological activity and persistence of herbicides also vary greatly, as does the toxicity of herbicides. Accordingly, it is difficult to reach reliable judgements regarding changes in herbicide use without an in-depth look at just what changes have occurred, both in terms of the products applied, how often they are applied, and their rates of application. These data, coupled with measures of herbicide toxicity and persistence, make it possible to reach conclusions regarding changes in reliance over time and the risks stemming from herbicide use.

While the planting of RR soybeans will sustain a high level of reliance on herbicides, there are two ways on a given farm that Roundup Ready soybean systems can reduce herbicide "use."

[8] For example, see several posts by farmers between July 4 and July, 9 1999 on the “IPM Talk” discussion section of AgOnline, http://www.agriculture.com/scgi/Agtalk/. Click on “IPM Talk” and review messages on the topic “reduced rate herbicides.”

First, growers might switch from "old" chemistry herbicides that are applied at 1.5 to 3.0 pounds active ingredient per acre to Roundup-based system involving maybe .75 to 1.5 pounds of Roundup per acre. Farmers using some of the new low-dose materials, or planting STS soybeans (soybeans resistant to sulfonylurea herbicides) can sometimes achieve excellent control with less than one-tenth pound of active ingredient per acre.

Such reductions in herbicide use, measured by acre-treatments or pounds applied, are brought about by the switch to more biologically-active and persistent chemistry effective at lower use rates, not through reduction in reliance on herbicides.

An example -- RR soybean systems in 1998 required, on avergae, about 1.0 pound active ingredient per acre. This level of use is 10- to 20-times greater than the herbicide required with conventional seeds on farms using sulfonylurea herbicides, and is at least 5 times more active ingredient than several of the new low-dose herbicides like sulfentrazone. Hence, any claims that RR soybeans reduce herbicide use are incomplete without the phrase "...reduced COMPARED TO WHAT??" If the goal is minimizing herbicide use there are clearly far better – and cheaper -- ways for farmers to move forward.

Use Trending Upward

Experience in the field in 1999 suggests strongly that use of Roundup this year will rise perhaps 15 percent to 25 percent above 1998 in terms of average pounds of Roundup applied per acre. In 1998 USDA data show that the average rate per crop year for Roundup on soybeans was 0.92 pounds and there were on average 1.3 applications per acre. In 1999, use will trend upward to perhaps 1.6 applications per acre and 1.2 pounds per acre on average.

To place this level of Roundup use in perspective, in 1998 well less than 0.5 pounds of herbicide were applied to the vast majority of soybean acres not treated with Roundup. On perhaps 15 percent to 20 percent of the acres, the rate was well under 0.25 pounds. So compared to these systems, RR soybeans are heavily herbicide dependent. Moreover, because of weed shifts, resistance, price cuts and aggressive marketing, Roundup use is bound to rise sharply in the next few years, hastening the day when farmers will be forced to seek new solutions.

What comes next is the soybean farmer’s $64,000.00 question. It remains to be seen whether any company or public research institution will come forward with answers that cut to the core of soybean weed management challenges. In the current economic and policy climate, this vital task might be left to growers themselves.

Table 3. Performance of Roundup Ready (RR) and Conventional Soybean Varieties by Company, 1998 Varietal Trials in Southern Wisconsin

Company	Variety	Maturity Group	Yield	Yield Difference: Conventional to RR: Bushels per Acre	Yield Difference: Conventional to RR: Percent Yield Drag
Asgrow					
Top RR	AG 2301	2.3	73	-4	-5.2%
Top Conventional	A 2553	2.5	77		
Mean RR	-	-	70	-7	-9.1%
Mean Conventional	-	-	77		
Low RR	AG 1901	1.9	68	-9	-11.7%
Low Conventional	A 2553	2.5	77		
Cole					
Top RR	Dyna-Gro 3266RR	2.5	73	-1	-1.4%
Top Conventional	Dyna-Gro 3252	2.5	74*		
Mean RR	-	-	69.3	-2.5	-3.5%
Mean Conventional	-	-	71.8		
Low RR	Dyna-Gro 3214RR	2.1	67	1	1.5%
Low Conventional	Dyna-Gro 3233	2.5	66		
Dairyland					
Top RR	DSR-215/RR	2	69*	-4	-5.5%
Top Conventional	DST2124	2	73*		
Mean RR	-	-	68.7	-3.6	-5.0%
Mean Conventional	-	-	72.3		
Low RR	DSR-293/RR	2.8	68	-3	-4.2%
Low Conventional	DSR-277	2.8	71		
Dekalb					
Top RR	RR 2300	2.3	72	-4	-5.3%
Top Conventional	CX 253	2.5	76		
Mean RR	-	-	68.1	-4.5	-6.2%
Mean Conventional	-	-	72.7		
Low RR	CX 256RR	2.5	65	-4	-5.8%
Low Conventional	CX 230	2.3	69		
Golden Harvest					
Top RR	X 198RR	1.9	70	-6	-7.9%
Top Conventional	X 251	2.4	76		
Mean RR	-	-	68	-0.7	-1.0%
Mean Conventional	-	-	68.7		
Low RR	H-1238RR	2.3	67*	2	3.1%
Low Conventional	H-1184	1.8	65*		
Kaltenberg					
Top RR	KB 215RR	2.1	68	-7	-9.3%
Top Conventional	KB 248	2.4	75		
Mean RR	-	-	67.5	-5	-6.9%
Mean Conventional	-	-	72.5		
Low RR	KB 249RR	2.4	67	-2	-2.9%
Low Conventional	KB 214	2.1	69		

Table 3. Performance of Roundup Ready (RR) and Conventional Soybean Varieties by Company, 1998 Varietal Trials in Southern Wisconsin

Company	Variety	Maturity Group	Yield	Yield Difference: Conventional to RR	
				Bushels per Acre	Percent Yield Drag
M/W Genetics					
Top RR	G 2445RR	2.4	69	-8	-10.4%
Top Conventional	G 2380	2.3	77		
Mean RR	-	-	68	-7	-9.3%
Mean Conventional	-	-	75		
Low RR	G 2210RR	2.2	67	-6	-8.2%
Low Conventional	G 2711	2.7	73		
Pioneer					
Top RR	92B71	2.7	69	0	0.0%
Top Conventional	92B61	2.6	69		
Mean RR	-	-	66	-1.3	-2.0%
Mean Conventional	-	-	67.3		
Low RR	92B01	2	64	-2	-3.0%
Low Conventional	92B23	2.2	66		
Stine					
Top RR	2091-4	2	68*	-8	-10.5%
Top Conventional	2499-0	2.4	76		
Mean RR	-	-	67	-4.6	-6.4%
Mean Conventional	-	-	71.6		
Low RR	1980-4	1.9	65	-3	-4.4%
Low Conventional	2500	2	68		
Terra					
Top RR	E 1980RR	1.9	72	-5	-6.5%
Top Conventional	E 248	2.4	77		
Mean RR	-	-	68.7	-7.3	-9.6%
Mean Conventional	-	-	76		
Low RR	TS 253RR	2.5	66	-9	-12.0%
Low Conventional	TS 277	2.7	75		
	Average Ten Companies				
	Top RR & Conventional			**-4.7**	**-6.2%**
	Mean RR & Conventional			**-4.4**	**-5.9%**
	Low RR & Conventional			**-3.5**	**-4.8%**

*More than one variety produced the same yield.

Source: Compiled by Benbrook Consulting Services, based on the 1998 Wisconsin Soybean Variety Tests, Southern Region (Table 6).

Table 4. Yield Drag Associated with the Roundup Ready (RR) and Conventional Soybean Varieties Sold by Ten Companies: 1998 Southern Wisconsin Varietal Trials

Company	Yield Drag as Percent of Top Conventional Yield Compared to --		
	Top RR	Mean RR	Low RR
Asgrow	-5.2%	-9.1%	-11.7%
Cole	-1.4%	-3.5%	1.5%
Dairyland	-5.5%	-5.0%	-4.2%
Dekalb	-5.3%	-6.2%	-5.8%
Golden Harvest	-7.9%	-1.0%	3.1%
Kaltenberg	-9.3%	-6.9%	-2.9%
M/W Genetics	-10.4%	-9.3%	-8.2%
Pioneer	0.0%	-2.0%	-3.0%
Stine	-10.5%	-6.4%	-4.4%
Terra	-6.5%	-9.6%	-12.0%
Average Ten Companies	**-6.2%**	**-5.9%**	**-4.8%**

Source: Compiled by Benbrook Consulting Services, based on the 1998 Wisconsin Soybean Variety Tests, Southern Region (Table 6).

Table 5. Performance of Top Yielding Roundup Ready (RR) and Conventional Soybean Varieties by Company, and Maturity Date*; 1998 Varietal Trials in Minnesota, Central Zone

Company	Variety	Maturity Date	Yield	Yield Difference: Conventional to RR	
				Bushels per Acre	Percent Yield Drag
Croplan					
Roundup Ready	RT1557	9/17	58	-2	-3.3%
Conventional	L1475	9/18	60		
Dairyland					
Roundup Ready	DSR-152/RR	9/20	61	-8	-11.6%
Conventional	DSR-180/STS	9/20	69		
Kruger					
Roundup Ready	K-14RR	9/21	62	-8	-11.4%
Conventional	K-1990	9/20	70		
KSC/Challenger					
Roundup Ready	K-10RR	9/15	57	-12	-17.4%
Conventional	K-1414	9/17	69		
Mustang					
Roundup Ready	M-111	9/17	61	-9	-12.9%
Conventional	M-1160	9/18	70		
Mustang					
Roundup Ready	M-144	9/20	63	-3	-4.5%
Conventional	M-1167	9/19	66		
Pioneer					
Roundup Ready	91B52	9/18	59	-4	-6.3%
Conventional	9163	9/18	63		
Prairie Brand					
Roundup Ready	PB-1790RR	9/21	63	-10	-13.7%
Conventional	PBR-169+	9/21	73		
Ramy					
Roundup Ready	1555RR	9/19	55	-6	-9.8%
Conventional	1525	9/19	61		
Sands					
Roundup Ready	EXP 1557RR	9/18	57	-12	-17.4%
Conventional	EXP 1444	9/18	69		
Stine					
Roundup Ready	1794	9/21	57	-16	-21.9%
Conventional	1680	9/21	73		
Terra					
Roundup Ready	E1181RR	9/17	62	-3	-4.6%
Conventional	TS107	9/17	65		
Wensman					
Roundup Ready	W2118RR	9/17	60	-17	-22.1%
Conventional	W3148	9/18	77		
Yield King					
Roundup Ready	K-191RR	9/22	55	-20	-26.7%
Conventional	K-1943+	9/22	75		
		Average Roundup Ready	**59.3**	**-9.3**	**-13.1%**
		Average Conventional	**68.6**		

*For each company, the closest match was selected by maturity date.

Source: Compiled by Benbrook Consulting Services, based from the *'Variety Trials Results'* by Crookston, Moorhead and Shelly found at http://www.extension.umn.edu/Documents/D/C/Other.

Table 6. Performance of Top Yielding Roundup Ready (RR) and Conventional Soybean Varieties by Company, and Maturity Date*; 1998 Varietal Trials in Minnesota, Southern Zone

Company	Variety	Maturity Date	Yield	Yield Difference: Bushels per Acre	Yield Difference: Percent Yield Drag
Asgrow					
Roundup Ready	AG2201	9/19	64	5	8.5%
Conventional	A1 923	9/18	59		
Asgrow					
Roundup Ready	AG2301	9/21	60	-6	-9.1%
Conventional	A2247	9/21	66		
Dahlman					
Roundup Ready	818RR	9/15	61	4	7.0%
Conventional	Russel	9/16	57		
Dairyland					
Roundup Ready	DSR-241/F	9/19	64	2	3.2%
Conventional	DSR-180/S	9/19	62		
DeKalb					
Roundup Ready	CX191RR	9/20	65	-3	-4.4%
Conventional	CX205	9/20	68		
Dyna Gro					
Roundup Ready	3173RR	9/20	60	-3	-4.8%
Conventional	3188	9/20	63		
Golden Harvest					
Roundup Ready	165RR	9/19	67	1	1.5%
Conventional	H-1184	9/19	66		
Golden Harvest					
Roundup Ready	H-1207RR	9/21	60	-3	-4.8%
Conventional	H-1214	9/21	63		
Great Lakes					
Roundup Ready	GL2000RR	9/24	64	-1	-1.5%
Conventional	GL2451	9/24	65		
Kaltenberg					
Roundup Ready	X160RR	9/20	63	-1	-1.6%
Conventional	KB221	9/20	64		
Kaltenberg					
Roundup Ready	KB209RR	9/22	64	-4	-5.9%
Conventional	KB208	9/21	68		
Kaltenberg					
Roundup Ready	KB159RR	9/23	63	-2	-3.1%
Conventional	KB248	9/24	65		
Kruger					
Roundup Ready	K-24APR	9/20	65	1	1.6%
Conventional	K-2242	9/20	64		
Kruger					
Roundup Ready	K24RR	9/21	65	0	0.0%
Conventional	K-2303	9/21	65		

Table 6. Performance of Top Yielding Roundup Ready (RR) and Conventional Soybean Varieties by Company, and Maturity Date*; 1998 Varietal Trials in Minnesota, Southern Zone

Company	Variety	Maturity Date	Yield	Yield Difference: Bushels per Acre	Yield Difference: Percent Yield Drag
KSC/Challenger					
Roundup Ready	K-22RR	9/19	62	-7	-10.1%
Conventional	K-2125	9/20	69		
KSC/Challenger					
Roundup Ready	K-191RR	9/21	65	-4	-5.8%
Conventional	K-2343	9/22	69		
Latham					
Roundup Ready	406RR Bra	9/17	60	-4	-6.3%
Conventional	410 Brand	9/18	64		
Latham					
Roundup Ready	EX-656RR	9/20	63	-4	-6.0%
Conventional	660 Brand	9/20	67		
Latham					
Roundup Ready	EX-426RR	9/23	65	-2	-3.0%
Conventional	621 Brand	9/22	67		
Mustang					
Roundup Ready	M-208	9/20	59	-3	-4.8%
Conventional	E-201	9/19	62		
Mustang					
Roundup Ready	M-202	9/22	64	-2	-3.0%
Conventional	M-2218	9/22	66		
Mycogen					
Roundup Ready	5214	9/22	60	-8	-11.8%
Conventional	J-251	9/21	68		
Northstar					
Roundup Ready	2023RR	9/18	57	-6	-9.5%
Conventional	2302	9/19	63		
PBR					
Roundup Ready	PBR-1997I	9/21	67	4	6.3%
Conventional	PBR-218	9/21	63		
Pioneer					
Roundup Ready	92B05	9/15	66	10	17.9%
Conventional	9163	9/15	56		
Pioneer					
Roundup Ready	92B21	9/19	65	1	1.6%
Conventional	92B23	9/19	64		
Prairie Brand					
Roundup Ready	PB-2124R	9/21	67	1	1.5%
Conventional	PB-197	9/21	66		
Prairie Brand					
Roundup Ready	PB-2090RI	9/24	67	1	1.5%
Conventional	PB-235	9/24	66		

Table 6. Performance of Top Yielding Roundup Ready (RR) and Conventional Soybean Varieties by Company, and Maturity Date*; 1998 Varietal Trials in Minnesota, Southern Zone

Company	Variety	Maturity Date	Yield	Yield Difference: Bushels per Acre	Yield Difference: Percent Yield Drag
Profiseed					
Roundup Ready	4201	9/21	67	-2	-2.9%
Conventional	2557	9/22	69		
Profiseed					
Roundup Ready	4249	9/24	57	-10	-14.9%
Conventional	2413	9/24	67		
Ramy					
Roundup Ready	1995RR	9/20	60	-6	-9.1%
Conventional	2195	9/21	66		
Ramy					
Roundup Ready	2195RR	9/22	63	-9	-12.5%
Conventional	2198	9/22	72		
Ramy					
Roundup Ready	2085RR	9/23	65	-1	-1.5%
Conventional	2550	9/23	66		
Renze					
Roundup Ready	R1909R	9/20	64	-2	-3.0%
Conventional	R2098	9/20	66		
Renze					
Roundup Ready	R2009R	9/23	65	0	0.0%
Conventional	R2297	9/22	65		
Sands					
Roundup Ready	EXP 9619F	9/21	67	6	9.8%
Conventional	EXP 2027	9/20	61		
Sands					
Roundup Ready	SOI 245RF	9/23	63	-8	-11.3%
Conventional	EXP 2435	9/24	71		
Sansgaard					
Roundup Ready	S-2100RR	9/18	61	-6	-9.0%
Conventional	S-190X	9/18	67		
Sansgaard					
Roundup Ready	S-245XRR	9/20	62	1	1.6%
Conventional	S-199X	9/20	61		
Sansgaard					
Roundup Ready	S-233XRR	9/23	62	-10	-13.9%
Conventional	S-237X	9/22	72		
Stine					
Roundup Ready	1991-4	9/21	66	1	1.5%
Conventional	1970	9/21	65		
Terra					
Roundup Ready	E-1481RR	9/16	60	-4	-6.3%
Conventional	E1 58	9/16	64		

Table 6. Performance of Top Yielding Roundup Ready (RR) and Conventional Soybean Varieties by Company, and Maturity Date*; 1998 Varietal Trials in Minnesota, Southern Zone

Company	Variety	Maturity Date	Yield	Yield Difference: Bushels per Acre	Yield Difference: Percent Yield Drag
Terra					
Roundup Ready	E2081RR	9/20	60	-6	-9.1%
Conventional	TS194	9/19	66		
Thompson					
Roundup Ready	T-3178RR	9/15	58	-2	-3.3%
Conventional	EX7217	9/16	60		
Thompson					
Roundup Ready	T-3215RR	9/21	66	-2	-2.9%
Conventional	T-3222	9/21	68		
Thompson					
Roundup Ready	T-3208RR	9/23	63	-2	-3.1%
Conventional	EX7705	9/24	65		
Wensman					
Roundup Ready	W 2178RR	9/16	63	0	0.0%
Conventional	W 3148	9/15	63		
Wensman					
Roundup Ready	W2198RR	9/21	65	-6	-8.5%
Conventional	W3207	9/21	71		
Yield King					
Roundup Ready	K-19FRR	9/20	65	6	10.2%
Conventional	K-2323STS	9/21	59		
Yield King					
Roundup Ready	K-20RR	9/23	64	-6	-8.6%
Conventional	K2525A	9/22	70		
Average Roundup Ready			**63.2**	**-2.0**	**-2.8%**
Average Conventional			**65.2**		

*For each company, the closest match was selected by maturity date.

Source: Compiled by Benbrook Consulting Services, based from the *'Variety Trials Results'* by Crookston, Moorhead and Shelly found at http://www.extension.umn.edu/Documents/D/C/Other.

Table 7. Farm Level Economic Impacts of the Roundup Ready Soybean Yield Drag in 1998: Top Yielding RR to Conventional Varieties

	Number of Companies	Average Yield Drag [Bushels/Acre]	Average Percent Yield Drag	Dollar Value of Yield Drag*	Added Cost of RR System*	Added Cost as Percent of Gross Income
State Varietal Trial Comparisons						
Minnesota: Central	14	-9.3	-13.1%	$48.75	$56.75	15.8%
Minnesota: Southern	50	-2.0	-2.8%	$10.61	$18.61	5.4%
Wisconsin: Southern	10	-4.7	-6.2%	$24.68	$32.68	8.3%
Oplinger Summary Data						
Illinois	-	0	0.0%	$0.00	$8.00	2.3%
Iowa	-	-6	-9.1%	$31.50	$39.50	11.4%
Michigan	-	-8	-10.3%	$42.00	$50.00	12.2%
Minnesota	-	-5	-6.8%	$26.25	$34.25	8.8%
Nebraska	-	-6	-9.0%	$31.50	$39.50	11.4%
Ohio	-	-4	-6.0%	$21.00	$29.00	8.0%
South Dakota	-	-5	-9.0%	$26.25	$34.25	11.6%
Wisconsin	-	-3	-3.4%	$15.75	$23.75	5.2%

*Assumes a soybean price of $5.25 per bushel and an average "Technology Fee" of $8.00 per acre.

Source: Compiled by Benbrook Consulting Services from state varietal trial data and (Oplinger, et al., 1999).

References

Benbrook, C, 1999. "World Food System Challenges and Opportunities: GMOs, Biodiversity, and Lessons from America's Heartland," Paper presented January 27, 1999 at the University of Illinois World Food Sustainable Agriculture Program. Accessible in Adobe Acrobat format on Ag BioTech InfoNet at http://www.biotech-info.net/costs.html#cost_returns.

Benbrook, C., Groth, E., Hansen, M., and S. Marquardt, 1996. *Pest Management at the Crossroads*, Consumers Union, Yonkers, New York.

Drinkwater, L.E., Wagoner, P, and M. Sarrantino, 1998. "Legume-based cropping systems have reduced carbon and nitrogen losses," *Nature*, Vol. 396: 262-265.

Hager, A., and M. McGalmery, 1998. "Corn Herbicide/Insecticide Interactions," Univeristy of illinois Cooperative Extension. Accessible at http://spectre.ag.uiuc.edu/cespubs/pest/articles/v983f.html.

Oplinger, E. S. Oplinger, Martinka, M.J., and K. A. Schmitz, 1999. "Performance of Transgenic Soybeans in the Northern U.S.," Accessible in Adobe Acrobat format at http://www.biotech-info.net/herbicide-tolerance.html#soy.

Owen, M., 1999. "North American Developments in Herbicide Tolerant Crops," Paper presented at the 1997 British Crop Protection Conference, Brighton, England. Accessible at http://www.weeds.iastate.edu/weednews/Brighton.htm.

Tilman, D., 1998. "The greening of the green revolution," *Nature*, Vol. 396: 211-212.

Wyse, D, 1994. "New Technologies and Approaches for Weed Management in Sustainable Agriculture Systems," *Weed Technology*, Vol. 8: pages 403-407.

Soybean Yield Trial Data

Minnesota: James H. Orf , Philip J. Schaus, Leland L Hardman, and Arthur S. Killam, "1998 Soybean Variety Trial Results," Minnesota Agricultural Experiment Station,. Department of Agronomy and Plant Genetics, University of Minnesota, St. Paul, MN 55108. Accessible on the Internet at http://www.extension.umn.edu/Documents/D/C/DC7349.html.

Wisconsin: Oplinger, E.S., Martinka, J.M., Schmitz, K.A., and C.R. Grau, 1999. "1998 Wisconsin Soybean Variety Tests," Department of Agronomy, College of Agricultural and Life Sciecnes, Univeristy of Wisconsin-Madison. Accessible in Adobe Acrobat format on the Internet at < http://www.uwex.edu/ces/soybean/>.