To the Graduate Council:

I am submitting herewith a thesis written by Tammy LeAnn McKinley entitled "Economic Comparisons of Roundup to Alternative Strategies for Johnsongrass Control in No-Till Soybeans." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Economics.

Roland K. Roberts, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the council:

Associate Vice Chancellor and
Dean of The Graduate School

ECONOMIC COMPARISONS OF ROUNDUP TO ALTERNATIVE STRATEGIES FOR JOHNSONGRASS CONTROL IN NO-TILL SOYBEANS

A Thesis
Presented for the
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Degree
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Tammy LeAnn McKinley
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DEDICATION

This thesis is dedicated to my parents

E. B. "Bud" and Connie Hall

and my husband

Brian McKinley

who have always supported and encouraged

me in all that I have done.

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Abstract

In 1994 and 1995 field experiments were conducted at Milan, TN, using Roundup-Ready™ soybeans double cropped with wheat in a no-till planting system. Johnsongrass control chemicals were broadcast applied post-emergence at rates low, medium, high, and very high relative to label rates. The herbicides used were glyphosate (Roundup), quizalofop (Assure II), fluazifop-P (Fusilade DX), sethoxydim plus an adjuvant (Poast Plus), and clethodim (Select). Roundup was applied at rates of 0.368, 0.736, 1.10, and 1.47 lb a.i./acre. Assure II was applied at rates of 0.025, 0.05, 0.075, and 0.1 lb a.i./acre. Fusilade DX was applied at rates of 0.06, 0.12, 0.18, and 0.24 lb a.i./acre. Poast Plus was applied at rates of 0.08, 0.16, 0.24, and 0.32 lb a.i./acre. Finally, Select was applied at rates of 0.04, 0.08, 0.12, and 0.16 lb a.i./acre. The experimental design was a randomized complete block with plots measuring 10 feet wide by 30 feet long with 30-inch row spacing. Treatments in both years were replicated three times.

The objectives of this study were 1) compare the economic benefits of using Roundup versus alternative herbicides to control johnsongrass on Roundup-Ready™ soybeans and 2) compare profitability of Roundup on Roundup-Ready™ soybeans to alternative johnsongrass control herbicides on other soybean varieties.

Quadratic yield response functions were estimated through regression analysis for each herbicide for the individual years of the experiment (1994 and 1995) and for the combination of the two years (1994-1995). Profit-maximizing rates and yields were calculated for five herbicides using either the estimated yield response function or assuming a constant function based upon two criteria. The first criterion for a significant

function was that the Prob>F be less than 0.10 and the second was that there be diminishing physical product. The profit-maximizing rate and yield for each herbicide was then used in enterprise budgets to calculate returns to land, management, and risk.

Roundup proved to be the most cost effective herbicide in an economic comparison of returns achieved with Roundup on Roundup-Ready™ soybeans and those achieved by Assure II, Fusilade DX, Poast Plus, and Select on Roundup-Ready™ soybeans. Roundup was able to achieve the highest returns to land, management, and risk over the four alternative herbicides because of its lower cost and higher yields. Roundup's lower costs are attributed to its ability to control both grasses such as johnsongrass and broadleaf weeds therefore requiring fewer sprays. The four alternative herbicides required an additional herbicide (Storm) for broadleaf control therefore increasing the number of sprays required, which in turn, increase the machinery and labor costs.

Break-even yields for all alternative herbicides were calculated for 1994, 1995, and 1994-1995. These yields are those needed to be achieved by an alternative herbicide on any other variety of soybeans to have equivalent returns to those achieved by Roundup on Roundup-Ready™ soybeans using either Roundup's recommended or profit-maximizing rate. Comparisons were made between the calculated break-even yields and the yields associated with the recommended and profit-maximizing rates of the alternative herbicides. These yields were derived from the estimated yield response functions using the experimental data on Roundup-Ready™ soybeans.

Break-even yields calculated for alternative varieties and herbicides equating their returns to those achieved with the recommended rate of Roundup on Roundup-Ready™

soybeans were all equal to Roundup's yields. These break-even yields were equal to Roundup's yields due to their similar production costs. The break-even yields equating the alternative herbicide's returns to those achieved with the profit-maximizing rates of Roundup on Roundup-Ready™ soybeans ranged from 1 bushel less to 3 bushels greater than yields achieved by Roundup on Roundup-Ready™ soybeans. Comparisons made between the break-even yields and the yields for the recommended rates and profit-maximizing rates of the alternative herbicides on Roundup-Ready™ soybeans based on yield response functions derived from the experimental data, showed that the alternative herbicides did not achieve the break-even yields on Roundup-Ready™ soybeans.

The break-even methodology used in this paper demonstrates that scientists and practitioners can make economically justified recommendations or decisions regarding whether to plant Roundup-Ready™ soybeans without having side-by-side variety trial data to compare net returns. Based on this methodology, farmers would increase their return to land, management, and risk by planting Roundup-Ready™ soybeans if their expected yield from their traditional variety and herbicide were less than the break-even yield. Yields from side-by-side variety trials are important to obtain because they can help farmers develop yield expectations, reducing the uncertainty surrounding the Roundup-Ready™ soybean decision.

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Part 1: Introduction

Introduction

Johnsongrass (*Sorghum halepense*) is one of the ten worst weeds in the world and can be found in all major agricultural areas of the warm regions of the world (Holm, 1969). Johnsongrass competes with soybeans (*Glycine max*) for nutrients and moisture from the soil and for light. Black (1969) considered johnsongrass to be a very competitive species because of its high photosynthetic efficiency. Soybean yields can be reduced 23 to 42% by competition from johnsongrass (McWhorter and Hartwig, 1972). Williams and Hayes (1984) found that soybean yields could be reduced by 13 to 38% if johnsongrass competition was allowed to continue for 6 weeks and 47 to 69% if competition was allowed for 7 weeks. Williams and Hayes (1984) also found that a four-week period after planting with no johnsongrass competition would prevent loss in yield.

Competition from johnsongrass can not only reduce the quantity of soybeans yielded but also the quality (McWhorter and Hartwig, 1972). McWhorter and Anderson (1981) found that to obtain U.S. grade No. 1 soybeans requires a minimum of 95% control of johnsongrass. Johnsongrass control of less than 95% can cause more than 1% foreign material in the soybean harvest (McWhorter and Anderson, 1981). Roberts and Hayes (1989) stated in their study that the decision to control johnsongrass is often made independent of other weeds, since most often the herbicides used to control johnsongrass do not damage broadleaf weeds.

Preplant incorporated and postemergence herbicides for johnsongrass control have been studied for several years. Studies have been conducted to determine the control of johnsongrass using such postemergence herbicides as sethoxydim, quizalofop, fluazifop,

fluazifop-P, clethodim, and glyphosate (Banks and Bundschuh, 1989; Daniels et al, 1990; Driver and Frans, 1983; Finley and Harden, 1983; Harden and Viar, 1983; Johnson and Frans, 1991; Langemeier and Witt, 1986; Retzinger, 1982; Retzinger et al, 1983; Vidrine, 1989; Wiepke et al, 1983). These studies have found that all of the listed herbicides can provide good to excellent control of johnsongrass in soybeans. In no-tillage systems Banks and Bundschuh (1989) found that sethoxydim and fluazifop can give 85 to 99% control of johnsongrass with single applications and 95 to 100% with sequential applications. Johnson and Frans (1991) found similar control with sequential applications of sethoxydim, fluazifop-P, quizalofop, and clethodim which gave 49 to 90%, 83 to 98%, 76 to 87%, and 81 to 99% control of johnsongrass in conventional tillage systems, respectively. Driver and Frans (1983) found that a single application of sethoxydim gave only 54% control of johnsongrass as compared to the 76% control of johnsongrass with single application and 88% with sequential applications in no-tillage systems found by Finley and Harden (1983). Johnson et al (1990) stated that fluazifop-P can control johnsongrass 49 to 81% while quizalofop can control johnsongrass 86 to 97%. Wiepke et al (1983) found in their study that fluazifop gave 72 to 98% control of johnsongrass while sethoxydim gave 93 to 98% control.

Vidrine (1989) looked at the percent control of seedling and rhizome johnsongrass at 3 weeks after treatment (WAT) and johnsongrass at 12 WAT given by fluazifop-P, quizalofop, and sethoxydim in experiments in 1984 and 1985. Fluazifop-P gave 96 and 100% control of both seedling and rhizome control at 3 WAT in 1984 and 1985, respectively, while quizalofop and sethoxydim gave 99 and 100% and 77 and 99%

control, respectively in the same years. At 12 WAT fluazifop gave 88 and 93% control and quizalofop and sethoxydim gave 93 and 92% and 65 and 86% control, respectively. Glysophate has been shown to give up to 86 percent control of johnsongrass in no-till systems and 88 percent control in conventional systems with two applications using rope-wick applicators (Banks and Bundschuh). Wiepke et al (1983) found only 60% control of johnsongrass with glyphosate applied by wickbar.

The advent of Monsanto's Roundup-Ready™ soybeans has affected the control of johnsongrass. Through genetic engineering the glysophate tolerant gene was introduced into the soybean. Glysophate is the active ingredient in the herbicide, Roundup, produced by Monsanto. The main drawback with the use of Roundup on soybeans has been that even though the use of glysophate for johnsongrass control has been proven several times to be highly effective it has also been proven to be toxic to soybeans (Connell and Derting, 1973; Crawford and Rogers, 1973; McWhorter, 1972; Mullins et al, 1974; Overton et al, 1973; Overton et al, 1974; Worsham, 1972). Because of the toxicity of glysophate to soybeans, application of the chemical has to be after the johnsongrass is taller than the soybeans to avoid contact with the crop with rope-wick or recirculating applicators. With Roundup-Ready™ soybeans, Roundup can now be broadcast applied earlier in the growing period without worry of crop damage.

Monsanto lists on their world wide web site (1997, http://www.roundupready.com /soybeans.rrfeatures.htm) that some of the benefits from the use of Roundup-Ready™ soybeans are such things as yields not being sacrificed for weed control and possible use of only one herbicide instead of combinations to control weeds. Delanney, et al (1995),

found that even at rates twice the level needed for weed control there was no negative impact on yields of glysophate-tolerant soybeans. They also indicated that once these soybeans are available they will provide growers with alternative weed control programs that will help reduce costs. Their findings agree with Monsanto's claim that use of Roundup-Ready™ soybeans will be cost effective for producers (Monsanto, 1997, http://www.roundupready.com/soybeans.rrfeatures.htm). Griffin (1994) also indicated that Roundup-Ready™ soybeans may improve productivity and profitability for growers. Until now the emphasis of research regarding Roundup-Ready™ soybeans has been on technical improvements due to use of the variety. This study will compare the economic benefits of using Roundup versus alternative chemicals for control of johnsongrass on Roundup-Ready™ soybeans.

Objectives

The objectives of this study are to 1) compare the economic benefits of using Roundup versus alternative herbicides to control johnsongrass on Roundup-Ready™ soybeans and 2) compare profitability of Roundup on Roundup-Ready™ soybeans to alternative johnsongrass control herbicides on other soybean varieties.

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Part 2: Economic Evaluation of Roundup Compared With Alternative Johnsongrass Control Herbicides on Roundup-Ready™ Soybeans

Introduction

Johnsongrass (*Sorghum halepense*) is one of the ten worst weeds in the world and can be found in all major agricultural areas of the warm regions of the world (Holm, 1969). Johnsongrass competes with soybeans (*Glycine max*) for nutrients and moisture from the soil and for light. Soybean yields can be reduced 23 to 42 percent by competition from johnsongrass (McWhorter and Hartwig, 1972). Williams and Hayes (1984) also found that a four-week period after planting with no johnsongrass competition would prevent loss in yield. This competition can not only reduce the quantity yielded but also the quality (McWhorter and Anderson, 1981; McWhorter and Hartwig, 1972).

The control of johnsongrass with preplant incorporated to postemergence herbicides has been studied for several years. More recently, studies have been conducted to determine the control of johnsongrass using postemergence herbicides such as sethoxydim, quizalofop, fluazifop, fluazifop-P, clethodim, and glyphosate (Banks and Bundschuh, 1989; Daniels et al, 1990; Driver and Frans, 1983; Finley and Harden, 1983; Harden and Viar, 1983; Johnson and Frans 1991; Langemeier and Witt, 1986; Retzinger, 1982; Retzinger et al, 1983; Vidrine, 1989). These studies have found that these herbicides can provide good to excellent control of johnsongrass in soybeans. All of the listed herbicides except glyphosate, were applied broadcast and were able to control johnsongrass from 75 to 96 percent (Driver and Frans, 1983; Finley and Harden, 1983; Harden and Viar, 1983; Johnson and Frans, 1991). Glyphosate has been shown to give up to 86 percent control of johnsongrass in no-till systems and 88 percent control in

conventional systems with two applications using rope-wick applicators (Banks and Bundschuh, 1989).

Glyphosate is the active ingredient in the herbicide, Roundup, produced by Monsanto. The main disadvantage to the use of Roundup is toxicity to soybeans (Connell and Derting, 1973; Crawford and Rogers, 1973; McWhorter, 1972; Mullins et al, 1974; Overton et al, 1973; Overton et al, 1974; Worsham, 1972). To avoid contact with the crop, glyphosate has most commonly been applied with selective application equipment, often after the johnsongrass was taller than the soybeans. Through genetic engineering the glyphosate tolerant gene was introduced in the soybean to create Roundup-Ready™ soybeans. Roundup can now be broadcast applied earlier in the growing period without crop damage.

Monsanto lists on its world wide web site (1997, http://www.roundupready.com /soybeans.rrfeatures.htm) that some of the benefits from Roundup-Ready™ soybeans are that yields are not being sacrificed for weed control and that only one herbicide, Roundup, is used instead of combinations of herbicides to control both grasses and broadleaf weeds. Delanney, et al (1995), found that even at rates twice the level needed for weed control there was no negative impact on yields of glyphosate-tolerant soybeans. They also indicated that these soybeans will provide growers with alternative weed control programs that will help reduce costs. Their findings agree with Monsanto's claim that use of Roundup-Ready™ soybeans will be cost effective for producers (Monsanto, 1997, http://www.roundupready.com/soybeans.rrfeatures.htm). Griffin (1994) also indicated

that Roundup-Ready™ soybeans have potential to improve productivity and profitability for growers.

Until now the research emphasis has been on technical improvements resulting from using Roundup-Ready™ soybeans. The objective of this study was to compare the economic benefits of using Roundup versus alternative herbicides to control johnsongrass on Roundup-Ready™ soybeans. Johnsongrass control was the focus of this study because, as Roberts and Hayes (1989) stated, the decision to control johnsongrass is often made independent of other weeds, since most often the herbicides, such as those in this study, used to control johnsongrass do not damage broadleaf weeds.

Data

Field experiments were conducted in 1994 and 1995 at Milan, TN on Grenada silt loam soil with natural infestations of johnsongrass. Treatments included Roundup, quizalofop-P (Assure II), fluazifop-P (Fusilade DX), sethoxydim and adjuvant (Poast Plus), and clethodim (Select) herbicides broadcast applied postemergence to no-till Roundup-Ready™ soybeans double cropped with wheat (*Triticum aestivum*). Each herbicide was applied at four rates which were low, medium, high, and very high with respect to label rates. Roundup was applied at rates of 0.368, 0.736, 1.10, and 1.47 lb a.i./acre. Assure II was applied at rates of 0.025, 0.05, 0.075, and 0.1 lb a.i./acre. Fusilade DX was applied at rates of 0.06, 0.12, 0.18, and 0.24 lb a.i./acre. Poast Plus was applied at rates of 0.08, 0.16, 0.24, and 0.32 lb a.i./acre. Finally, Select was applied at rates of 0.04, 0.08, 0.12, and 0.16 lb a.i./acre. The recommended rates are 0.75 to 1.5,

0.034 to 0.069, 0.094 to 0.188, 0.19, and 0.094 to 0.125 lb a.i./acre for Roundup, Assure II, Fusilade DX, Poast Plus, and Select, respectively (Rhodes, 1997).

The experimental design was a randomized complete block with plots measuring 10 feet wide by 30 feet long with 30-inch row spacing. Treatments in both years were replicated three times. Prior to the experiment, all plots were fallowed in 1993. Prior to Roundup-Ready™ soybeans (cultivar 40-3-2) being planted in 1994, 80 lbs/acre of both P and K were applied as well as 30 lbs/acre of nitrogen as ammonium nitrate on November 2, 1993. Aldicarb (Temik) was applied in-furrow at a rate of 0.75 lb a.i./acre at planting on June 3, 1994. On June 4, 1994, paraquat (Gramoxone Extra) at 2 pt/acre and 0.25% Triton Ag98 were applied as a burndown treatment. Broadleaf weeds were controlled as needed with selective herbicide on June 23, 1994, to avoid possible antagonism. Johnsongrass control herbicides were broadcast postemergence on June 20, 1994 (17 days after planting). The soil was dry at the time of herbicide application. Johnsongrass control was evaluated on July 4, 1994 and July 12, 1994, where 0% equals no control and 100% is death of plants. Soybeans were harvested on November 4, 1994.

Prior to planting Roundup-Ready™ soybeans (cultivar 40-3-2) in 1995, 80 lbs/acre of P and K and 40 lbs/acre of nitrogen as ammonium nitrate were applied on November 7, 1994. Temik at 0.5 a.i. lbs/acre was applied in-furrow at planting on June 13, 1995. As a burndown treatment on June 15, 1995, 1 qt/acre of Roundup and 0.25% nonionic surfactant (NIS) were applied. On July 11, 1995, broadleaf weeds were controlled as needed. Johnsongrass control herbicides were broadcast applied postemergence on July 10, 1995 (27 days after planting). The soil was moist at the time

of herbicide application. Johnsongrass control was evaluated on July 19, 1995, and September 12, 1995, using criteria described above. Soybeans were harvested on October 31, 1995, and yields were adjusted to 13% moisture.

Methodology

Preliminary analysis of the data suggested that peak yield was achieved with the mid-application rates of the herbicides with lower yields at low and high rates. Therefore the following quadratic model was specified for each herbicide:

$$Y = a + bRT + cRT^2 + u$$

where Y is soybean yield in bu/acre, RT is the herbicide application rate in lb a.i./acre, u is a random error term, and a, b, and c are parameters to be estimated by regression.

Regression (SAS Institute, 1985) was used to estimate a soybean yield response function for each herbicide using the experimental data. Yield response functions were estimated for each year individually (1994 and 1995) because year-by-treatment interactions were found to exist. Response functions were also estimated for 1994 and 1995 combined.

The estimated response functions for 1994, 1995, and 1994-1995 were used to identify the profit-maximizing soybean yield and application rate for each herbicide. Two criteria were used to identify these yields and rates. First, if the estimated yield response function was statistically significant at the 10 percent level [(Prob>F) $\leq$ 0.10], the profit-maximizing rate was identified by equating the slope of the response model (marginal physical product) with the input-output price ratio (Doll and Orazem, 1992) as shown in Figure 1. The profit-maximizing rate was then used to calculate the corresponding yield.

If the regression equation was not significant [(Prob>F) > 0.10], a constant response function was assumed and the lowest experimental herbicide rate and the average yield over the four experimental rates were used as the profit-maximizing rate and yield as shown in Figure 2.

The second criterion used was the second derivative of the response function must be less than zero indicating diminishing marginal physical product. In other words, the signs of the linear and quadratic portions of the function must be positive and negative, respectively (Doll and Orazem, 1992). Again, if this criterion was not met, a constant response function was assumed and the lowest experimental herbicide rate and the average yield over the four experiment rates were used as the profit-maximizing rate and yield.

Enterprise budgets (Gerloff and Maxey, 1997) were developed to calculate returns to land, management, and risk for all herbicides for 1994, 1995, and 1994-1995. Presented in Table 1 as an example of the methods used is the budget for Roundup for 1994. The machinery complement used in the budgets included a 130-horsepower tractor and a 60-foot boom sprayer. These budgets included revenues from the sale of both soybeans and wheat and variable costs such as seed, herbicides, machinery repair, and fuel. Also included in these budgets were machinery depreciation and labor expenses. Returns to land, management, and risk for Roundup were compared to those achieved from the alternative herbicides.

Herbicide prices were from Tennessee Farmers' Cooperative suggested retail price list effective July 1, 1997. The soybean price received by farmers of $6.20/bu was from the wheat-soybeans no-tillage budget released in January 1997 (Gerloff and Maxey, 1997).

The Roundup-Ready™ soybean seed price was $26/50 lbs, which includes a $5 technology fee paid to Monsanto (Bob Montgomery, 1997, personal communication). These prices were used in determining profit-maximizing herbicide rates and yields and in the enterprise budgets to calculate net returns.

Results

The estimated quadratic soybean yield response functions for the five herbicides are presented in Table 2 for 1994, 1995, and 1994-1995. Seven of the 15 functions had Prob>F less than 0.10. One of those seven functions had a negative linear portion and positive quadratic portion which violated the second criteria mentioned previously.

Profit-maximizing rates and yields based on the estimated response functions and criteria mentioned above are presented in Table 3. Only six of the 15 functions were used as estimated to find the profit maximizing rate and yield. Of the nine functions assumed to be constant, three were for Assure II, two each for Roundup and Select, and one each for Fusilade DX and Poast Plus. Roundup had the highest profit-maximizing yield of 52 bushels/acre and Poast Plus had the lowest at 37 bushels/acre. All other yields ranged from 40 to 48 bu/acre.

Roundup achieved the highest returns to land, management, and risk (Table 3) in 1994 ($229.88) and 1995 ($195.75) and for the years combined ($208.07) while Poast Plus achieved the lowest in 1994 ($132.92), 1995 ($141.49) and for the years combined ($148.96). The next highest returns were associated with Select in 1995 ($194.49) due to its high yield. Roundup received the highest returns because its material and application cost was considerably lower (Table 3) than the other herbicides. Unlike the other herbicide

treatments, Roundup controls broadleaf weeds as well as johnsongrass (Rhodes, 1997). An additional herbicide spray was needed for broadleaf weed control when the other experimental herbicides were used, adding to cost. Consequently, the Roundup treatment had one-half the application costs of the other herbicide treatments. Higher application costs for the other herbicide treatments caused costs for the Roundup treatment to be considerably less thus increasing its returns to land, management, and risk relative to the other treatments. Higher yields also contributed to higher returns, except for Select in 1995.

Conclusion

In 1994 and 1995 field experiments were conducted in Jackson, TN, using Roundup-Ready™ soybeans double cropped with wheat in a no-till planting system. Johnsongrass control chemicals were broadcast applied post-emergence at rates low, medium, high, and very high relative to label rates. The herbicides used were Roundup, Assure II, Fusilade DX, Poast Plus, and Select.

Quadratic yield response functions were estimated through regression analysis for each herbicide for the individual years of the experiment (1994 and 1995) and for the combination of the two years (1994-1995). Profit-maximizing rates and yields were calculated for the five herbicides. These rates and yields were then used in enterprise budgets to calculate returns to land, management, and risk.

Roundup proved to be the best herbicide to use with Roundup-Ready™ soybeans because it was able to achieve the highest returns to land, management, and risk of the five herbicides. Roundup achieved these higher returns because of higher yields and lower

costs. Costs were lower because Roundup controls both grasses and broadleaf weeds, reducing both material and application costs.

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Appendix

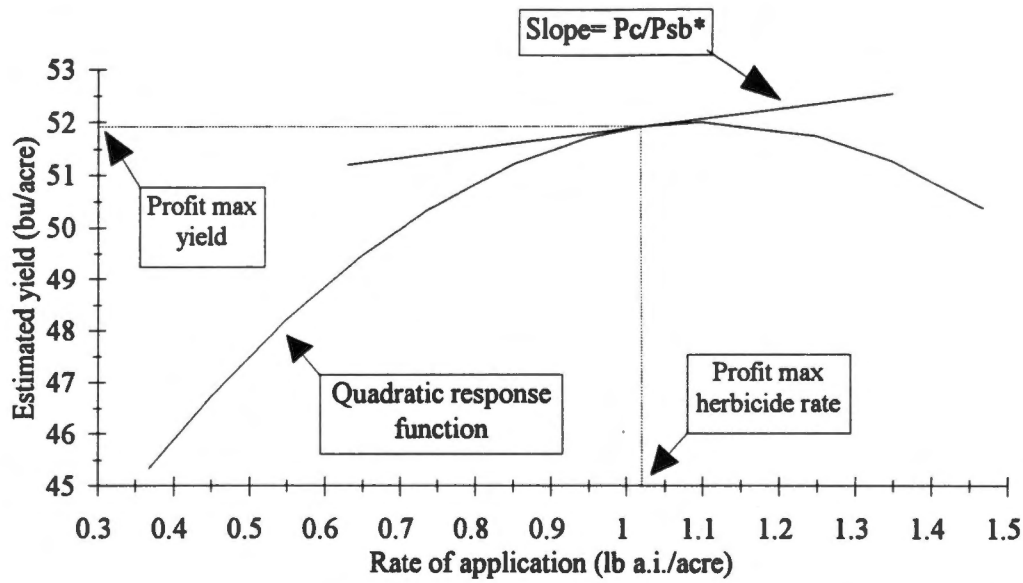


Figure 1: Example of using a quadratic yield response to calculate the profit-maximizing herbicide rate and yield

* Pc = price of chemical/lb a.i., Psb= soybean price received/ bu

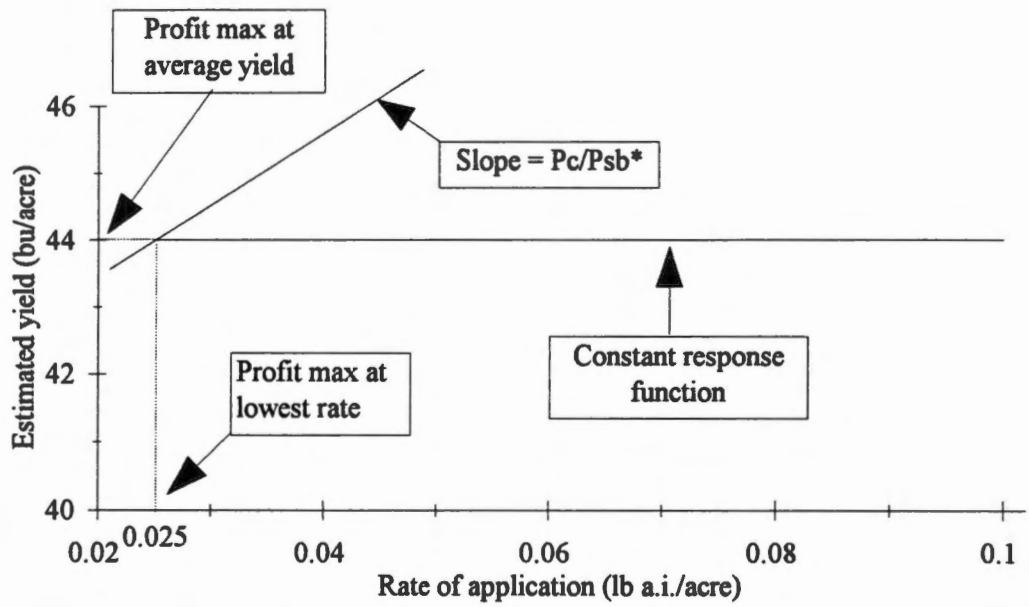


Figure 2: Example of using a constant yield response function to calculate the profit-maximizing herbicide rate and yield

*Pc = price of chemical/lb a.i., Psb = soybean received price/bu

Table 1: Estimated returns and expenses per acre for double cropped wheat and Roundup-Ready™ soybeans using Roundup, No-tillage, 1994

Item	Description	Unit	Quantity	Price ($)	Amount ($)
Revenue					
Wheat	Grain	bu.	45.00	3.15	141.75
Soybeans	Beans	bu.	52.00	6.20	322.40
Revenue Adjustment	Sparc Assessment	bu.	52.00	-0.031	-1.61
				Total Revenue	462.54
Variable Expenses					
Seed, Wheat	Treated/Fungicide	bu.	1.50	8.25	12.38
Seed	Soybeans	lb.	50.00	0.52	26.00
Inoculation	Vitavax M	bu.	0.83	2.50	2.08
Fertilizer	N(AN)	lb.	80.00	0.34	27.20
	P205	lb.	60.00	0.30	18.00
	K20	lb.	60.00	0.13	7.80
Lime	3 tons each 4 yrs.	ton	0.75	16.00	12.00
Weed Control					
Pre-plant					
	Gramoxone Extra	pt.	1.50	3.86	5.79
	Surfactant	ac.	0.20	3.00	0.60
Post-emerge					
	Roundup	lb. a.i.	1.02	13.00	13.26
Herbicide - Wheat	Harmony Extra	oz.	0.50	11.65	5.83
Fungicide - Wheat	Tilt	oz.	4.00	2.62	10.48
Machinery Repair		ac.	1.00	16.98	16.98
Machinery Fuel		ac.	1.00	8.15	8.15
Operating Capital	8 months	ac.	166.55	9.00%	10.00
Indemnity Fund	Soybeans	bu.	52.00	0.01	0.52
Indemnity Fund	Wheat	bu.	45.00	0.005	0.23
				Total variable expenses	177.29
Fixed Expenses					
Machinery Depreciation		ac.	1.00	29.45	29.45
Interest Expense	Machinery & Equip	ac.	1.00	15.54	15.54
Labor Expenses		hr.	1.66	6.25	10.38
				Total machinery, labor, and variable expenses	232.66
				Returns to land, management, and risk	229.88

Source: Gerloff and Maxey (1997)

Table 2: Estimated Roundup-Ready™ soybean yield response functions for five herbicides applied to Roundup-Ready™ soybeans, Milan, TN, 1994, 1995, and 1994-1995

Chemical and year	Equation†	Prob>F	R^2
Roundup			
1994	$Y = 36.99 + 27.21\ RT - 12.33\ RT^2$ (0.00)‡ (0.02) (0.04)	0.0179	0.5908
1995	$Y = 60.59 - 34.85\ RT + 16.63\ RT^2$ (0.00) (0.14) (0.18)	0.2375	0.2734
1994-1995	$Y = 48.79 - 3.82\ RT + 2.15\ RT^2$ (0.00) (0.80) (0.80)	0.9628	0.0036
Assure II			
1994	$Y = 31.75 + 492.67\ RT - 3866.67\ RT^2$ (0.00) (0.13) (0.13)	0.2873	0.2420
1995	$Y = 40.25 + 146.00\ RT - 1200.00\ RT^2$ (0.00) (0.69) (0.68)	0.9129	0.0200
1994-1995	$Y = 36.00 + 319.33\ RT - 2533.33\ RT^2$ (0.00) (0.16) (0.15)	0.3537	0.0942
Fusilade DX			
1994	$Y = 27.25 + 164.72\ RT - 347.22\ RT^2$ (0.00) (0.12) (0.30)	0.0149	0.6073
1995	$Y = 34.92 + 160.83\ RT - 578.70\ RT^2$ (0.00) (0.16) (0.13)	0.2451	0.2684
1994-1995	$Y = 31.08 + 162.78\ RT - 462.96\ RT^2$ (0.00) (0.06) (0.10)	0.0754	0.2182
Poast Plus			
1994	$Y = 33.58 - 27.71\ RT + 195.31\ RT^2$ (0.01) (0.80) (0.47)	0.0566	0.4718
1995	$Y = 3.83 + 275.00\ RT - 520.83\ RT^2$ (0.69) (0.03) (0.07)	0.0084	0.6545
1994-1995	$Y = 18.71 + 123.64\ RT - 162.76\ RT^2$ (0.01) (0.14) (0.42)	0.0016	0.4592
Select			
1994	$Y = 48.33 - 195.00\ RT + 1041.67\ RT^2$ (0.00) (0.46) (0.42)	0.6805	0.0820
1995	$Y = 18.00 + 512.50\ RT - 2187.50\ RT^2$ (0.11) (0.05) (0.09)	0.0732	0.4406
1994-1995	$Y = 33.16 + 158.75\ RT - 572.92\ RT^2$ (0.00) (0.39) (0.52)	0.3230	0.1020

† Y = soybean yield, RT = herbicide application rate

‡ Numbers in parentheses are Prob > |T|.

Table 3: Profit-maximizing rates, yields, costs, and returns to land, management, and risk for five herbicides applied to Roundup-Ready™ soybeans, Milan, TN, 1994, 1995, and 1994-1995

Herbicide and year	Rate†	Yield‡	Herbicide and application cost/acre§	Returns/acre
Roundup				
1994	1.02	52	$15.21	$229.88
1995 ¶	0.368	45	$6.22	$195.75
1994-1995 ¶	0.368	47	$6.22	$208.07
Assure II				
1994 ¶	0.025	44	$19.31	$176.50
1995 ¶	0.025	44	$19.31	$176.50
1994-1995 ¶	0.025	44	$19.31	$176.50
Fusilade DX				
1994	0.22	47	$30.37	$183.91
1995 ¶	0.06	43	$19.67	$169.98
1994-1995	0.16	45	$26.36	$175.60
Poast Plus				
1994 ¶	0.08	37	$19.98	$132.92
1995	0.26	40	$29.68	$141.49
1994-1995	0.35	42	$34.54	$148.96
Select				
1994 ¶	0.04	41	$19.41	$157.76
1995	0.11	48	$25.95	$194.49
1994-1995 ¶	0.04	42	$19.41	$164.08

† Profit-maximizing herbicide rates are in lb a.i./acre.

‡ Profit-maximizing yields are in bu/acre.

§ Excluding Roundup, herbicide cost include an additional herbicide (Storm) for broadleaf control. The cost of Storm and its application was estimated to be $14.51/acre. The cost of applying the experimental herbicides was $2.26/acre. An additional interest charge of 9% for 8 months of herbicide and variable application cost is included for all treatments.

¶ Minimum experimental rate and average yield over all experimental rates were used in calculations.

Part 3: Break-even Evaluation of Roundup-Ready™ Soybeans Compared with Alternative Soybean Varieties

Introduction

Roundup has been used for several years to control johnsongrass (*Sorghum halepense*) in soybeans (*Glycine max*) but toxicity to soybeans is its main drawback (Connell and Derting, 1973; Crawford and Rogers, 1973; McWhorter, 1972; Mullins et al., 1974; Overton et al., 1973; Overton et al., 1974; Worsham, 1972). This toxicity is caused by Roundup's active ingredient, glyphosate, which has required Roundup to be applied by selective application equipment after johnsongrass was taller than the soybeans. Through genetic engineering, a glyphosate-tolerant gene has recently been introduced into the soybean to create Roundup-Ready™ soybeans. Roundup can now be broadcast applied earlier in the growing period without crop damage.

The application of Roundup earlier in the growing period is important because as Williams and Hayes (1994) found, a four-week period after planting with no johnsongrass competition would prevent loss in yield. This not only will improve quantity yielded but johnsongrass competition also can reduce soybean quality (McWhorter and Anderson, 1981; McWhorter and Hartwig, 1972).

Monsanto (1997, http://www.RoundupReady.com/Soybeans.rrfeatures.htm) stated that another benefit from Roundup-Ready™ soybeans, other than yields not being sacrificed for weed control, is that only one herbicide, Roundup, is used instead of combinations of herbicides to control both grasses and broadleaf weeds. Delanney et al. (1995) indicated that these glyphosate-tolerant soybeans will provide growers with alternative weed control programs that will help reduce costs. Costs are reduced because other herbicides commonly used for johnsongrass control do not control broadleaf weeds,

which requires the grower to use combinations of herbicides to control both grasses and broadleaf weeds. The findings of Delanney et al. (1995) agreed with Monsanto's claim that use of Roundup-Ready™ soybeans will be cost effective for producers (Monsanto, http://www.RoundupReady.com/rrfeatures.htm, 1997). Griffin (1994) also indicated that Roundup-Ready™ soybeans have potential to improve productivity and profitability for growers.

Some basic economic analyses of side-by-side comparisons conducted by Asgrow (1997, http://www.asgrow.com/asgrowfarms/) were found. These economic analyses were based upon gross income which was calculated with the experimental soybean yields and a $7.00/bushel received price. They did not consider the differences in costs of conventional herbicide programs using conventional soybeans and Roundup using Roundup-Ready™ soybeans. The objective of this study was to compare profitability of Roundup on Roundup-Ready™ soybeans to alternative johnsongrass control herbicides on other soybean varieties by developing break-even yields for alternative varieties taking into consideration the differences in costs of the herbicide programs.

Data

Data used in this study were obtained from field experiments which were conducted in 1994 and 1995 at Milan, TN on Grenada silt loam soil with natural infestations of johnsongrass. The experimental design was a randomized complete block with plots measuring 10 feet wide by 30 feet long with 30 inch row spacing. Treatments in both years were replicated three times. Roundup, quizalofop-P (Assure II), fluazifop-P (Fusilade DX), sethoxydim plus adjuvant (Poast Plus), and clethodim (Select) were

broadcast applied postemergence to no-till Roundup-Ready™ soybeans double cropped with wheat (*Triticum aestivum*). They were applied at four rates which were low, medium, high, and very high with respect to label rates. Roundup was applied at rates of 0.368, 0.736, 1.10, and 1.47 lb a.i./acre. Assure II was applied at rates of 0.025, 0.05, 0.075, and 0.1 lb a.i./acre. Fusilade DX was applied at rates of 0.06, 0.12, 0.18, and 0.24 lb a.i./acre. Poast Plus was applied at rates of 0.08, 0.16, 0.24, and 0.32 lb a.i./acre. Finally, Select was applied at rates of 0.04, 0.08, 0.12, and 0.16 lb a.i./acre.

Methodology

Break-even analysis was used to compare profitability of Roundup on Roundup-Ready™ soybeans to alternative johnsongrass control herbicides on other soybean varieties. The aforementioned experimental data using Roundup and four alternative johnsongrass control herbicides on Roundup-Ready™ soybeans can be used to make the comparison. The comparison is possible because the four alternative herbicides can be broadcast on soybean varieties other than Roundup-Ready™, while Roundup can not. In other words, the cost of using, for example, Select to control johnsongrass is the same regardless of the soybean variety produced (except for seed costs), while the cost of using Roundup to control johnsongrass is specific to Roundup-Ready™ soybeans. If net returns to Roundup used on Roundup-Ready™ soybeans and the cost of using an alternative johnsongrass control herbicide on any other variety of soybeans were known, the yield could be found that causes the net returns for that other variety and herbicide to be equal to the net returns for Roundup-Ready™ soybeans using Roundup.

The following discussion shows how break-even analysis can be used to achieve the objective of this study for double cropped wheat and soybeans. Equation 1 sets net returns for Roundup-Ready™ soybeans double cropped with wheat using Roundup equal to net returns for any soybean variety double cropped with wheat using an alternative herbicide

$$1) \qquad P_W Y_W + P Y_R - C_R = P_W Y_W + P Y_O - C_O$$

where P_W is the wheat price/bu received by farmers, Y_W is the wheat yield/bu, P is the soybean price/bu received by farmers, Y_R is the yield/bu achieved using Roundup on Roundup-Ready™ soybeans, C_R is the total cost/acre of producing double cropped wheat and Roundup-Ready™ soybeans using Roundup, Y_O is the yield/bu achieved using an alternative herbicide on any other variety of soybeans, and C_O is the total cost/acre of producing double cropped wheat and any variety of soybeans using an alternative herbicide. If experimental data were available to determine all variables in equation 1 except Y_O, then break-even analysis could be used to find the Y_O that equates the left-hand with the right-hand side of equation 1.

Solving equation 1 for Y_O gives the break-even yield as follows

$$2) \qquad BEY = Y_R - C_R / P + C_O / P$$

where BEY (Y_O in equation 1) is the break-even yield for an alternative herbicide on any other variety of soybeans, and all other variables are as defined above. This is the equation that will be used in the calculations of the break-even yields for the four alternative herbicides.

The break-even yield provides important information to farmers as they decide whether or not to switch from traditional varieties to Roundup-Ready™ soybeans. If a profit-maximizing farmer expected to receive a yield less than the break-even yield using a traditional variety and one of the alternative herbicides, the farmer would choose to plant Roundup-Ready™ soybeans and use Roundup. If a yield greater than the break-even yield were expected, the farmer would not switch to Roundup-Ready™ soybeans and Roundup.

Yield response functions were required to perform the break-even analysis. Quadratic yield response functions were estimated by regression (SAS Institute, 1985) for each herbicide on Roundup-Ready™ soybeans using the experimental data. The functions were specified as follows:

$$1) \qquad Y_R = a + bRT + cRT^2 + u$$

where RT is the application rate of the herbicides, and u is a random error term, and a, b, and c are parameters to be estimated by regression.

The estimated yield response functions had to meet two criteria to be used as estimated. First, if the estimated yield response function was statistically significant at the 10 percent level [(Prob>F) $\leq$ 0.10], the profit-maximizing rate was identified by equating the slope of the response function (marginal physical product) with the input-output price ratio (Doll and Orazem, 1992). The profit-maximizing rate was then used to calculate the corresponding yield using the estimated yield response model. If the regression equation was not significant [(Prob>F) > 0.10], a constant response function was assumed and the lowest experimental herbicide rate and the average yield over the four experimental rates

were used as the profit-maximizing rate and yield. The second criterion used was the second derivative of the function had to be less than zero which indicates diminishing marginal physical product (Doll and Orazem, 1992). Again, if this criterion was not met, a constant response function was assumed and the lowest experimental herbicide rate and the average yield over the four experimental rates were used as the profit-maximizing rate and yield.

Two approaches were taken in the break-even analysis. The first approach was to use the recommended rates of all the herbicides, including Roundup, in calculating production costs (C_R and C_O). The yield for Roundup on Roundup-Ready™ soybeans (Y_R) was then calculated for the recommended Roundup rate using the estimated yield response function for Roundup on Roundup-Ready™ soybeans. The second approach was to calculate production costs for all herbicides (C_R and C_O) using the profit-maximizing rates of all the herbicides derived from the estimated yield response functions. The yield for Roundup (Y_R) was again calculated from the estimated yield response function using the profit-maximizing rate.

Comparisons were also made between the calculated break-even yields and yields associated with the recommended rates and profit-maximizing rates of the alternative herbicides on Roundup-Ready™ soybeans. These yields were calculated using the estimated yield response functions.

Enterprise budgets (Gerloff and Maxey, 1997) used in the break-even analysis were developed to calculate total costs for Roundup on no-tilled Roundup-Ready™ soybeans and for Assure II, Fusilade DX, Poast Plus, and Select herbicides on any no-

tilled variety of soybeans. These herbicides are commonly used postemergence to control johnsongrass. These budgets included variable expenses such as wheat seed, soybean seed, fertilizer, lime, weed control, and a 9 percent interest charge on variable costs for 8 months. Preplant weed control included in all budgets was paraquat (Gramoxone Extra) and a surfactant. Included in all budgets, except those for Roundup on Roundup-Ready™ soybeans, was a broadleaf weed control herbicide, bentazon plus acifluorfen (Storm), which required a separate spray. Roundup, unlike the alternative herbicides, is able to control broadleaf weeds as well as grasses, such as johnsongrass, and does not require an additional spray (Rhodes, 1997).

The machinery complement assumed in the enterprise budgets for herbicide application consisted of a 130-horsepower tractor and a 60-foot boom sprayer. Each application of herbicide required 0.03 machine hours. Labor hours were assumed to be 1.25 times machine hours. The extra broadleaf weed control spray for herbicides other than Roundup doubled the machine and labor hours/acre needed for weed control. Herbicide application cost included machinery repair, fuel, depreciation, interest expense, and labor costs.

Herbicide prices were from the Tennessee Farmers' Cooperative suggested retail price list effective July 1, 1997. The soybean price received by farmers of $6.20/bushel and the wheat received price and yield of $3.15/bu and 45 bushels, respectively, were obtained from the double cropped wheat and soybean no-tillage budget released in January 1997 (Gerloff and Maxey, 1997). The soybean seed price for the alternative varieties was $16.00/50 lbs (Roger West, 1997, personal communication). The Roundup-Ready™

soybean seed price was $26/50 lbs, which includes a $5 technology fee paid to Monsanto (Bob Montgomery, 1997, personal communication). Herbicide recommended rates were obtained from the 1997 Weed Control Manual for Tennessee Field Crops (Rhodes, 1997). If there was a range of rates listed for the alternative herbicides, the mid point of the range was used as the recommended rate. The recommended rates used for Assure II, Fusilade DX, Poast Plus, and Select on any variety of soybeans were 0.05, 0.14, 0.19, and 0.11 lb a.i./acre, respectively (Rhodes, 1997). The recommend rate for Roundup on Roundup-Ready™ soybeans was 1 lb a.i./acre (Rhodes, 1997). Profit-maximizing rates of all herbicides were obtained using the aforementioned soybean and herbicide prices and the estimated yield response functions.

Results

Presented in Table 1 are the costs associated with the production of double cropped wheat and any variety of soybean using the recommended rate of Fusilade DX as an example of methods used to calculate the total costs for the herbicides. Table 2 presents results for the recommended rates of Roundup and the alternative herbicides. The second column of Table 2 contains the total costs for producing double cropped wheat and Roundup-Ready™ soybeans using the recommended rate of Roundup and total costs for producing double cropped wheat and any variety of soybeans using the recommended rates of the alternative herbicides. The costs associated with the recommended rate of Roundup on Roundup-Ready™ soybeans are basically equivalent to those associated with the alternative herbicides. Assure II and Fusilade DX have total costs less than Roundup by $2.58 and $0.51, respectively, while Poast Plus and Select

have higher total costs by only $0.37 and $0.42, respectively. These results suggest that the higher seed cost for Roundup-Ready soybeans was offset by lower herbicide and application costs relative to the alternative herbicides.

Also shown in Table 2 are the break-even yields for the recommended rates of the alternative herbicides on any other soybean variety. These break-even yields are all equivalent to the yields of 52, 45, and 47 bushels for the recommended rate of Roundup on Roundup-Ready™ soybeans for 1994, 1995, and the years combined, respectively. The break-even yields are equivalent to Roundup's yields due to the herbicide costs being similar. These break-even yields indicate that farmers under similar circumstances to those in this study must have yields from alternative varieties of soybeans equivalent to those for Roundup on Roundup-Ready™ soybeans to have equal net returns. That these break-even yields are equal to those achieved by Roundup on Roundup-Ready™ soybeans does not mean they are easily achieved.

Shown in the fourth and fifth columns of Table 2 are the estimated yields associated with the recommended rates of the herbicides based upon the yield response functions derived from the experimental data on Roundup-Ready™ soybeans and the difference between the break-even yields and the estimated yields. The estimated yields range from 1 to 15 bushels lower than the needed break-even yields, except for Select in 1995 which has an estimated yield 3 bushels greater than its break-even yield. Although the alternative herbicides need to achieve yields on any other variety of soybeans equal to yields for Roundup on Roundup-Ready™ soybeans, in most cases the estimated yields and

differences show that on Roundup-Ready™ soybeans these herbicides were not able to achieve high enough yields.

Table 3 presents the results of the comparisons of the profit-maximizing rates of Roundup on Roundup-Ready™ soybeans with the profit-maximizing rates of the alternative herbicides on any other variety of soybeans. The total costs of producing double cropped wheat and soybeans using the profit-maximizing rates of the five herbicides are shown in the second column. Total cost for the profit-maximizing rate of Roundup on Roundup-Ready™ soybeans in 1994 is greater than the costs for the profit-maximizing rates of the alternative herbicides except for Fusilade DX. This is due to the increase in the seed cost for Roundup-Ready™ soybeans over the alternative varieties which is not offset by the lower herbicide costs. The total costs for the profit-maximizing rate of Roundup on Roundup-Ready™ soybeans for 1995 and the two years combined are less than the costs for the profit-maximizing rates of the alternative herbicides on any other variety of soybeans. This result indicates that the higher seed cost was offset by lower herbicide costs, mostly because the profit-maximizing rates of Roundup were relatively low in these years.

Shown in the third column of Table 3 are the break-even yields for the alternative herbicides. The break-even yields for 1994 for all the alternative herbicides are 1 bushel less, except for Fusilade DX which is 2 bushels more than the 52-bushel yield for the profit-maximizing rate of Roundup on Roundup-Ready™ soybeans. The break-even yields for 1995 for Assure II and Fusilade DX are equivalent to the yields for Roundup's profit-maximizing rate on Roundup-Ready™ soybeans. For Poast Plus and Select, the

break-even yields for 1995 are 2 and 1 bushel greater, respectively, than the 45-bushel yield for the profit-maximizing rate of Roundup on Roundup-Ready™ soybeans. The break-even yields for Assure II and Select on any other soybean variety for the two years combined are equal to the yields for the profit-maximizing rate of Roundup on Roundup-Ready™ soybeans because their costs of production are similar. The break-even yields for Fusilade DX and Poast Plus are 2 and 3 bushels greater than those achieved by Roundup on Roundup-Ready™ soybeans. These break-even yields indicate that farmers with similar circumstances to those in this study will need to receive from 1 bushel less to 3 bushels greater yields from other varieties and herbicides than the yields achieved from Roundup on Roundup-Ready™ soybeans to have equivalent returns using the profit-maximizing rates.

Presented in the fourth and fifth columns are the estimated yields for the profit-maximizing rates of the alternative herbicides on Roundup-Ready™ soybeans derived from the estimated yield response functions and the differences between the break-even and the estimated yields. The estimated yields of Roundup-Ready™ soybeans for the profit-maximizing rates of the alternative herbicides are from 1 to 14 bushels less than the break-even yields, except for Select in 1995 where the estimated yield is more than the break-even yield. Although the alternative herbicides need to achieve yields within 1 to 3 bushels of the yields for Roundup on Roundup-Ready™ soybeans, in most cases these estimated yields show that on Roundup-Ready™ soybeans the profit-maximizing rates of the alternative herbicides were not able to achieve the high yields needed.

Conclusion

Break-even yields for Assure II, Fusilade DX, Poast Plus, and Select applied to non-Roundup-Ready soybean varieties were calculated for 1994, 1995, and 1994-1995. These yields were those needed for an alternative herbicide on any other variety of soybeans to have equivalent returns to those achieved by Roundup on Roundup-Ready™ soybeans. The data used to develop the estimated yield response functions, which were used to calculate the profit-maximizing yields and rates, were from field experiments conducted at Milan, TN, in 1994 and 1995.

Break-even yields calculated for alternative varieties and herbicides equating their returns to those achieved with the recommended rate of Roundup on Roundup-Ready™ soybeans were all equal to Roundup's yields. These break-even yields were equal to Roundup's yields due to their similar production costs. The break-even yields equating the alternative herbicides' returns to those achieved with the profit-maximizing rates of Roundup on Roundup-Ready™ soybeans ranged from 1 bushel less to 3 bushels greater than yields achieved by Roundup on Roundup-Ready™ soybeans. The closeness of these break-even yields to the yields achieved by Roundup on Roundup-Ready™ soybeans does not necessarily mean that these break-even yields are easily obtained.

Comparisons were made between the break-even yields and the yields for the recommended rates and profit-maximizing rates of the alternative herbicides on Roundup-Ready™ soybeans based on yield response functions derived from the experimental data. Estimated yields for both the recommended and profit-maximizing rates of the alternative herbicides were lower than the break-even yields by 1 to 15 bushels, except for Select in

1995 which had greater estimated yields than its break-even yields. These lower estimated yields indicate that although the alternative herbicides on any other soybean variety need to achieve only within 1 to 3 bushels of the yields achieved by Roundup on Roundup-Ready™ soybeans, these yields were not achieved on Roundup-Ready™ soybeans.

Scientists and practitioners would usually want to compare economic returns from Roundup on Roundup-Ready™ soybeans with returns from other herbicides on non-Roundup-Ready varieties before making an economically justified recommendation or decision about planting Roundup-Ready™ soybeans. Currently, such side-by-side comparisons are not being made. The break-even methodology used in this paper demonstrates that scientists and practitioners need not wait for side-by-side comparisons before making economically based decisions about whether or not to plant Roundup-Ready™ soybeans. Based on this methodology, farmers would increase their return to land, management, and risk by planting Roundup-Ready™ soybeans if their expected yield from their traditional variety and herbicide were less than the break-even yield. Yields from side-by-side variety trials are important to obtain because they can help the farmers develop yield expectations, reducing the uncertainty surrounding the Roundup-Ready™ soybean decision.

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Appendix

Table 1: Estimated costs per acre for double cropped wheat and any soybean variety using the recommended rate of Fusilade DX herbicide, No-Tillage

Item	Description	Unit	Quantity	Price ($)	Amount ($)
Variable Expenses					
Seed, Wheat	Treated/Fungicide	bu.	1.50	8.25	12.38
Seed	Soybeans	lb.	50.00	0.32	16.00
Inoculation	Vitavax M	bu.	0.83	2.50	2.08
Fertilizer	N(AN)	lb.	80.00	0.34	27.20
	P205	lb.	60.00	0.30	18.00
	K20	lb.	60.00	0.13	7.80
Lime	3 tons each 4 yrs.	ton	0.75	16.00	12.00
Weed Control					
Pre-plant					
	Gramoxone Extra	pt.	1.50	3.86	5.79
	Surfactant	ac.	0.20	3.00	0.60
Post-emerge					
	Storm	pt.	1.50	8.40	12.60
	Fusilade DX	lb a.i.	0.14	63.05	8.83
Herbicide - Wheat	Harmony Extra	oz.	0.50	11.65	5.83
Fungicide - Wheat	Tilt	oz.	4.00	2.62	10.48
Machinery Repair		ac.	1.00	17.24	17.24
Machinery Fuel		ac.	1.00	8.32	8.32
Operating Capital	8 months	ac.	165.15	9.00%	9.91
Indemnity Fund	Wheat	bu.	45.00	0.01	0.23
			Total variable expenses †		175.29
Fixed Expenses					
Machinery Depreciation		ac.	1.00	29.76	29.76
Interest Expense	Machinery & Equip	ac.	1.00	15.75	15.75
Labor Expenses		hr.	1.69	6.25	10.56
		Total machinery, labor, and variable expenses			231.36

Source: Gerloff and Maxey (1997)

† Total variable expenses exclude an indemnity fund charge for soybeans.

Table 2: Total costs and break-even yields for double cropped wheat and any soybean variety for recommended rates of four herbicides and the estimated yield using the recommended rates of five herbicides on Roundup-Ready™ soybeans, Milan, TN, 1994, 1995, and 1994-1995

Herbicide	Total costs/acre	Break-even yield (bu/acre)	Estimated yield using recommended rate (bu/acre)	Difference† (bu)
Roundup				
1994	$231.87		52	
1995	$231.87		45	
1994-1995	$231.87		47	
Assure II				
1994	$229.29	52	44	8
1995	$229.29	45	44	1
1994-1995	$229.29	47	44	3
Fusilade DX				
1994	$231.36	52	44	8
1995	$231.36	45	43	2
1994-1995	$231.36	47	45	2
Poast Plus				
1994	$232.24	52	37	15
1995	$232.24	45	37	8
1994-1995	$232.24	47	36	11
Select				
1994	$232.29	52	41	11
1995	$232.29	45	48	-3
1994-1995	$232.29	47	42	5

† Difference is the break-even yield minus the estimated yield using the recommended rate.

Table 3: Total costs and break-even yields for double cropped wheat and any soybean variety for profit-maximizing rates of four herbicides and the estimated yield using the profit-maximizing rates of five herbicides on Roundup-Ready™ soybeans, Milan, TN, 1994, 1995, and 1994-1995

Herbicide	Total costs/acre	Break-even yield (bu/acre)	Estimated yield using profit-maximizing rate (bu/acre)	Difference† (bu)
Roundup				
1994	$232.14		52	
1995	$223.15		45	
1994-1995	$223.15		47	
Assure II				
1994	$225.65	51	44	7
1995	$225.65	45	44	1
1994-1995	$225.65	47	44	3
Fusilade DX				
1994	$236.71	53	47	6
1995	$226.01	45	43	2
1994-1995	$232.70	49	45	4
Poast Plus				
1994	$226.32	51	37	14
1995	$236.02	47	40	7
1994-1995	$240.87	50	42	8
Select				
1994	$225.75	51	41	10
1995	$232.29	46	48	-2
1994-1995	$225.75	47	42	5

† Difference is the break-even yield minus the estimated yield using the profit-maximizing rate.

Part 4: Summary

Summary

Roundup proved to be the most cost effective herbicide in an economic comparison of returns achieved with Roundup on Roundup-Ready™ soybeans and those achieved by Assure II, Fusilade DX, Poast Plus, and Select on Roundup-Ready™ soybeans. Roundup was able to achieve the highest returns to land, management, and risk over the four alternative herbicides because of its lower cost and higher yields. Roundup's lower costs are attributed to its ability to control both grasses such as johnsongrass and broadleaf weeds therefore requiring fewer sprays. The four alternative herbicides required an additional herbicide (Storm) for broadleaf control therefore increasing the number of sprays required, which in turn, increase the machinery and labor costs.

Break-even yields calculated for alternative varieties and herbicides equating their returns to those achieved with the recommended rate of Roundup on Roundup-Ready™ soybeans were all equal to Roundup's yields. These break-even yields were equal to Roundup's yields due to their similar production costs. The break-even yields equating the alternative herbicide's returns to those achieved with the profit-maximizing rates of Roundup on Roundup-Ready™ soybeans ranged from 1 bushel less to 3 bushels greater than yields achieved by Roundup on Roundup-Ready™ soybeans. Comparisons made between the break-even yields and the yields for the recommended rates and profit-maximizing rates of the alternative herbicides on Roundup-Ready™ soybeans based on yield response functions derived from the experimental data, showed that the alternative herbicides did not achieve the break-even yields on Roundup-Ready™ soybeans.

The break-even methodology used in this paper demonstrates that scientists and practitioners can make economically justified recommendations or decisions regarding whether to plant Roundup-Ready™ soybeans without having side-by-side variety trial data to compare net returns. Based on this methodology, farmers would increase their return to land, management, and risk by planting Roundup-Ready™ soybeans if their expected yield from their traditional variety and herbicide were less than the break-even yield. Yields from side-by-side variety trials are important to obtain because they can help farmers develop yield expectations, reducing the uncertainty surrounding the Roundup-Ready™ soybean decision.

Vita

Tammy LeAnn (Hall) McKinley was born in Knoxville, Tennessee, on July 5, 1973 to E.B. "Bud" and Connie Hall. She has one brother, Tony Hall. Tammy is the wife of Brian McKinley. She attended schools in the public system of Loudon County, Tennessee, where she graduated from Lenoir City High School in May of 1991.

In August of 1991, she enter Pellissippi State Technical Community College in Knoxville, Tennessee. In January 1994, she transferred to The University of Tennessee, Knoxville. In December 1995, she received a Bachelor of Science degree with a major in Agricultural Economics and a minor in Business Administration. In January 1996, she entered the Master's program in the Agricultural Economics and Rural Sociology Department at The University of Tennessee, Knoxville. Tammy received her Master of Science degree in Agricultural Economics in December 1997.

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