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# Economic Value of Preemergence ALS Herbicides in Soybeans

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# ECONOMIC VALUE OF PREEMERGENCE ALS HERBICIDES IN SOYBEANS

by

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One of the pressing issues in university and industry weed management programs is herbicide resistance. Growers across the Midwest are facing weeds that are impacting yield and evolving resistance to multiple sites of action groups such as EPSP Synthase Inhibitors (5-enolpyruvyl-shikimate-3-phosphate), PPO inhibitors (protoporphyrinogen oxidase) , and HPPD inhibitors (4-hydroxyphenylpyruvate dioxygenase). Due to competitive weed infestations and potential resistance, it can be very costly and difficult to select an effective herbicide program for growers. Data was collected by Kara Koester at the Southern Illinois University Carbondale Research Center in Belleville, Illinois during the 2019 growing season. A regression model was used to test how or if any individual ALS inhibitor (acetolactate synthase) brings any yield benefits to their weed management program. A dummy variable was used to test whether Liberty, Roundup, location-NORTH, or if using a PRE-application has a statistical impact on yield. Lastly, an opportunity cost analysis was conducted to determine whether paying more up front for more site of action groups and more effective ALS inhibitors was beneficial. This data will help growers understand why paying more for more effective active ingredients and site of action groups in their herbicide program will reduce the amount of times they will have to spray in a year or prevent resistance when weeds are too tall to spray.

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# CHAPTER 1

## INTRODUCTION

The United States is the leading soybean producing country in the world (Shahbandeh, 2020). More than 80 percent of soybeans are grown in the upper Midwest with Illinois, Indiana, and Iowa being the largest producing states (Shahbandeh, 2020). The 2019 soybean production in the US totaled 3.5 billion bushels with an average yield of 47 bushels per acre according to the USDA (McGinnis, 2020). In a recent article from the Illinois Soybean Association, Illinois soybean growers produced 532 million bushels of soybeans in 2019. Illinois averaged a yield of 54 bushels per acre during that year (Schleusener, 2020). The United States is also ranked second globally in exports.

Soybeans are important in crop production for many reasons. According to the North Carolina Soybeans Producers Association (2019), soybeans are roughly 18% oil and 38% protein. The first major use for soybeans is animal feed. After the soybean is processed and the oil is removed, the high-quality baked protein fiber is used for animal feed for beef and dairy cattle, poultry, and pork (NCSPA, 2019). From a recent study published by the Illinois Soybean Association (2020), soybean meals are fed to poultry (67%), pork (21%), and cattle (10%). The 2 percent remaining is fed to the aquatic animals such as fish, shrimp, and other farm animals.

The second major use is for human consumption and industrial uses from the soybean oil. The soybean oil is used in vegetable oil, salads dressings, margarine, tuna, baked bread, crackers, and many more. It is also heavily relied on for frying and baking from food companies and restaurants. Industrial uses include biodiesel, lubricants, solvents, paints, and tires (United Soybean Board, 2020).

This kind of soybeans data can show how important soybeans are in crop production.

They are used in numerous and various ways that some may not know. It is critical that growers can maximize every opportunity to provide high yields.

Growers are often asked what keeps them awake at night in terms of inputs. They get asked what worries them the most, weeds, diseases, or pests? Typically, most are that the weeds are the biggest concern on their farm operation (Gage, 2019). Weeds are considered one of the greatest detriments in soybean production. They can reduce yields by not only competing with crops but with water, nutrients, and sunlight as well. Any weeds left uncontrolled can invite disease and insects and can produce to seed leading to more problems for future crops. However, another common point of topic in the farming industry is the cost it takes to control those targeted weeds. Many producers do not like using a two-pass program due to the cost it takes to spray a preemergence and post emergence application but wonder why there are so many weeds in a particular field.

There is a large collection of literature from universities and researchers that states what weed resistance is, how it can be prevented, and how it is affecting farmers today by only using a one-pass program. There are also many sources on the effectiveness of individual herbicides on specific small and large seeded broadleaf weeds and their injury on soybeans. This study will look at a two-pass herbicide program that farmers and retailers can use that have minimal if any crop injury and controls both large and small seeded broadleaf weeds. It also looks at how certain treatment programs give more consistent weed control and can prevent resistance because of the effectiveness of the active ingredients in the herbicide. Lastly, it will demonstrate how they can save money on a per day basis based on how many days each treatment program is effective before new weed growth breaks through.  As most row crop herbicide studies are tested through analysis of variance (ANOVA) to find the common between variables of different

groups, this study will use a regression analysis. A regression analysis is a statistical method used to establish the relationship between the dependent and independent variables. It will test yield based on the number of days after the POST only treatment has been applied, usage of a preemergence herbicide, the North or South side of the field, or usage of Roundup or Liberty.

# CHAPTER 2

## REVIEW OF LITERATURE

Figuring out what weeds are the most problematic in the field and what herbicides are most effective on those weeds is critical for the growers and retailers to consider the best weed management practices. Common waterhemp (*Amaranthus rudis)* is said to be one of the most problematic small seeded broadleaf weed in Illinois (FarmProgress, 2012). Typically, the most successful herbicide group applied to control common waterhemp is a PPO inhibitor (Group 14). However, studies have found that these group 14 herbicides, such as Authority, Fierce XLT, and Valor, can cause soybean injury under certain weather conditions such as cool and wet conditions or when soybean seedlings are breaking through the soil surface during a heavy rain (Jhala, 2017). A typical symptom at emergence is a seedling with necrosis (reddish/brown) on the hypocotyl. Normally, PPO injury on cotyledons will survive. The best way to check is to open the cotyledon. If the neck is firm and the inside is green, it is likely they will survive (Jhala, 2017). After emergence, PPO injury may also occur on the leaves that received the application that includes yellowing (chlorosis) and the browning on the leaf surface (necrosis). Since most PPO herbicides are contact herbicides, it will only show injury on the sprayed leaves. This is a more common timing of PPO injury. When or if growers see these injuries in soybeans, they become uncertain on whether they want to keep using these PPO inhibitors (Group 14). They believe it may reduce yield, however, in most cases it will not.

One of the primary goals to this research is to find a preemergence herbicide that will have minimal to no crop injury to the soybeans and still control common waterhemp. Prefix and Boundary both are most effective on certain grasses and broadleaf weeds. Prefix contains active ingredients of s-metolachlor (Group 15) and sodium salt of fomesafen (Group 14). Boundary

contains active ingredients of s-metolachlor (Group 15) and metribuzin (Group 5). Soybeans have a very good crop tolerance (minimal crop injury if any) to Prefix and Boundary and they are effective on small seeded broadleaf weeds. Based on previous data, both Prefix and Boundary have a crop injury of one, which is said to be rarely significant and has a weed control rating for waterhemp of eighty percent (Young, et al., 2015). However, researchers have shown that Prefix and Boundary are not as effective on large seeded broadleaf weeds. Some of the targeted large seeded broadleaf weeds that had heavy infestations in this study were giant ragweed (*Ambrosia trifida)*, morningglory (*Ipomoea*), and velvetleaf (*Abutilon theophrasti*). Prefix and Boundary may control only sixty percent or less of these specific weeds.

Farmers have a difficult time understanding why a two-pass program should be used. There are many sources that state a preemergence (PRE) followed by (fb) a postemergence (POST) application provides the most consistent way of controlling problematic weeds. There are a few disadvantages to a PRE fb POST application approach. One being that there must be an adequate rainfall after the PRE has been applied to activate the herbicide. Research shows that 0.5 – 1 inch of rain is typically required within the first week of application (Jhala, 2017). Other disadvantages of a PRE fb POST approach are the cost of a two-pass program and the time it takes. Many farmers believe that they can get away with just a PRE or just a POST application, however, many times that is not realistic. A PRE only approach is not effective enough on tough weeds such as common waterhemp, giant ragweed, or high grass populations. A POST only approach makes it very difficult to control herbicide-resistant weeds without the use of a PRE. There is also a chance of needing a second POST application for later emerging weeds. Even though using a PRE fb POST method may increase the weed control program cost, there are overall benefits that comes with it. One of these benefits include an increase in yield. In a study

looking at the benefits of preemergence herbicides in roundup ready soybeans prepared by Purdue University (Johnson, et al., 2008), an application of a PRE and POST application increased yield by 4 to 9 bushels an acre compared to a POST only application. A PRE-application can also allow for enough weed control in case the POST application may have to be delayed due to weather or for weeds that may emerge or continue to grow to reduce risk of problems at harvest (Michigan State University, 2006). It also allows for less competition because the weeds are smaller and easier to control (Johnson, et all., 2008).

Many growers question why the few weeds that are in their fields must be controlled by so many herbicides or herbicides with multiple active ingredients in it. The reason is herbicide resistance.

A subject undergoing strong studies throughout universities and weed scientists currently is the prevention of herbicide resistance. As a PRE fb POST has numerous benefits, one of the most crucial to consider is herbicide resistance. Herbicide resistance is the inherited ability of an individual plant to survive a herbicide application that would kill a normal population of the same species. Resistant weeds often can survive applications at rates that are much greater than recommended rates. The first herbicide resistant weed in the US was in the 1950's (Buhler, 2020).

However, glyphosate (Roundup), was commercialized in 1974 and used primarily for burndown and perennial weed control. Glyphosate has been characterized as a "once-in-a-century herbicide" (Duke and Powles, 2008). It had several attributes such as its high effectiveness of in-crop weed control, environmentally and toxicologically safe properties, low cost, exceptional ability to be the one herbicide that targets the EPSPS group (5-enolpyruvyl-shikimate-3-phosphate synthase). Most importantly, the introduction of glyphosate-resistant

crops helped define this herbicide and made growers ecstatic. Since then, an overreliance of glyphosate has been used worldwide resulting in a considerable selection for glyphosate-resistant weeds. The first report of glyphosate-resistance in a weed species was rigid ryegrass from an orchard in Australia in 1996 (Hartzler, 2003). Since then, there are currently 48 species that are herbicide-resistant to glyphosate in the world. To date, weeds have evolved resistance to 23 of the 26 known herbicide sites of action and to 167 different herbicides (HRAC-Herbicide Resistance Action Committee, 2020).

According to HRAC (2020), a monoculture crop production, a lack of cultural weed control techniques and the frequent use of herbicides with a similar or only one site of action, can all enhance the possibility and risk of selecting for resistance. To prevent resistance, polyculture crop production will allow the rotation of herbicides to use a different site of action each growing season. Different crops also have different competitiveness and the stronger competitiveness the crop has, the better chance it has to restrict seed production. Cultural weed control techniques such as tillage, fertilizer applications, irrigation, and cover crops should all be taken into consideration for maximum weed control (HRAC 2020). Lastly, the “rule” to any weed management program is to include as many site of action groups as possible to control the target weeds. Herbicide resistance can evolve in a field by using the same herbicide or herbicides with the same site of action and sprayed multiple times in a year. Hartzler and Anderson (2016), both indicate that in addition to using multiple effective sites of action, effective label rates, and proper timing of these applications is critical to maintaining maximum weed control.

Hager (2017), adds on to this group of literature, though, goes a step further. He states that a PRE fb POST application is beneficial, however, adding a preemergence soil residual can be more valuable to growers. Decades ago, it was very common to apply one or more soil

residual herbicides to Illinois soybean acres. In the 1980's, the opportunity for a total POST weed control program shifted away from the commonly used ALS soil residual herbicides to be used in the new total POST program. The total POST program did not last long though. It reached its peak due to the overreliance use of glyphosate and the adoption of glyphosate-resistant crops. A shift in a soil residual has been proclaimed in Illinois soybean acres again due to the fast-developing levels of glyphosate-resistance in many weed species (Hager, 2017).

There are many sources that states a PRE fb POST and applying more than one soil residual is the most valuable and consistent weed control practice to maximize yield. This should be considered when growers are deciding where and how they want to spend their money on inputs. Growers should consider what some of the most effective soil residuals are based on the problematic weeds that they have on their farm. As stated previously, Prefix and Boundary were two herbicides that had minimal injury if any and was effective on controlling small seeded broadleaf weeds such as common waterhemp. The next consideration is based on how the large seeded broadleaf weeds will be effectively controlled.

Tranel and Wright (2002), know that ALS herbicides are the most widely used in the world. According to a credible weed control guide, FirstRate (*cloransulam-methyl*, Classic (*chlorimuron)*, Pursuit (*imazethapyr)*, and Scepter (*imazaquin* ) have fair to excellent weed control on large seeded broadleaf weeds. Under certain weather condition, FirstRate, has a relative seventy to eighty percent weed control rating on giant ragweed and annual morning-glory species. It has an eighty to ninety percent control on velvetleaf species at 0.6 ounces per acre. Pursuit, has a relative weed control rating of seventy to eighty percent on annual morning-glory, sixty to seventy percent on giant ragweed, and eighty to ninety percent on velvetleaf at 4.0 ounces per acre. Classic, will have acceptable control on velvetleaf, however, will only suppress

giant ragweed and annual morning-glory at 1.25-3.0 ounces per acre. Finally, Scepter, has a relative seventy to eighty percent weed control rating for giant ragweed, morning-glory, and velvetleaf under certain weather conditions at 2.86 ounces per acre. All four of these ALS inhibitors (Group 2) have a crop tolerance of zero or one which means they very rarely show any injury symptoms on crops (Young, et al., 2015).

# CHAPTER 3

## DATA AND METHODS

Data for this study was organized and collected by Kara Koester in the 2019 growing season in Belleville, Illinois (38.512688, -89.841980). This location has very natural and heavy weed infestations. This research was conducted in one field, dividing the north and south so that different POST treatments, Roundup (Glyphosate) and Liberty (Glufosinate) could be applied. Belleville used a reduced till cultural practice. The soybean variety used in this study was GLXMA (Glycine Max) LLGT27's and was planted on June 12, 2019. This study used a randomized complete block design. The plot sizes were 10 feet wide by 27 feet long and were treated using a CO2 backpack sprayer with a 7.5-foot boom. The nozzles used were XR's 8002 at 30 PSI. The weed management program consisted of a nontreated, POST only, and PRE fb POST treatments. The PRE-fb-POST herbicide list included Prefix, Boundary, Prefix/Classic, Boundary/Classic, Prefix/FirstRate, Boundary/FirstRate, Prefix/Pursuit, Boundary/Pursuit, Prefix/Scepter, Boundary/Scepter, Authority MTZ, Authority XL, Authority First, Valor XLT, Fierce XLT, Fierce MTZ, and Zidua Pro. There is one POST only treatment (6 plots total) on both sides of the field that were sprayed with Roundup or Liberty based on the location of the field. The preemergence applications were sprayed at the same time on June 12, 2019. There was a significant amount of rain within ten days of the preemergence application of 1.92 inches. The POST only treatment (Application B) was sprayed on July 8 when the weeds were 4-6 inches. All POST treatments (Applications C) were sprayed when each individual plot had 4-6 inch weeds in them. Two out three plots for one treatment had to have 4-6 inch weeds to apply the POST treatment (application C). The first set of C application were applied on July 12. The next dates after that were July 17, 23, and 28. These dates can help distinguish the effectiveness and

soil residual support that each herbicide program had.

The data set in this study included 114 observations. The dependent variable being explained was grain yield. The independent variables that were being tested are the number of days after application B was applied, PRE, North, Roundup, and Liberty. The number of days after application B is to see how long each individual herbicide program is effective before regrowth occurs. The PRE variable means that it is being tested on whether each individual plot has a PRE applied to it or not. Roundup and Liberty are both two different POST treatments that were applied either on the north or south side of the field. PRE, North, Roundup, and Liberty are all number variables that represents categorical data so it was only necessary to use them as dummy variables. To use dummy variables in a regression analysis, you must compare against a basis. The basis is set =0 (absence) and all of the other coefficients are =1 (presence) and compared to the basis variable.

The following expanded regression model was used in this research:

(1) $\text{Soybean Yield} = \beta_0 + \beta_1(\text{Number of Days}) + \beta_2(\text{PRE}) + \beta_3(\text{North}) + \beta_4(\text{Roundup}) + \beta_5(\text{Liberty}) + \varepsilon.$

The results to this test determined whether the independent variables have a relationship with yield and whether the coefficients have a statistical significance based on a t-Test.

Opportunity cost is also a factor in this study. This economic analysis will look at the value each herbicide treatment gives on a per day basis. It will be conducted by dividing the cost of each herbicide treatment by the number of days after application B was applied (July 8). The cost of each herbicide program is given in dollars per acre and on a cash and carry account. The

cost of each herbicide was provided from two retailers, Nutrien and FS, for the 2020 growing season and averaged between the two. This research shows growers that more money may come out of the expense account, however, putting more effective site of actions will lower the cost per day, because it is more effective on the target weeds and will delay the POST application. This delay in the POST application can allow farmers or retailers to do other things during that time such as maintenance, spray other fields, scout fields on a regular basis, make more detailed recommendations when trying to sell products, or maybe go to the lake for a day.

It is likely that the number of days after application B will not be statistically significant to the soybean yield. The PRE fb POST herbicide programs should increase yield more than POST only or non-treated plots. It is expected that the South should result in an increase in yield due to it being a Liberty POST treatment, which typically has a little better weed control under certain conditions than Roundup.

It is very likely that the herbicide programs with FirstRate in them will be one of the higher weed management cost for growers compared to other treatments, however, it should have one of the lowest cost per day because of the residual and weed control it provides.

# CHAPTER 4

## RESULTS

The results from the regression model can be viewed on Table 1. The coefficient of the constant term (B0) is 38.567 and the t-Statistic is 13.231. The constant term represents the south nontreated yield of 38.567 bushels per acre. Number of days had a coefficient of -0.076 and a t-Statistic of -0.882. The number of days that the POST treatment is delayed does not have any significant relationship with yield as it has an almost zero coefficient. The coefficient of Liberty is 19.254 and has a t-Statistic of 5.342. When Liberty increased by one, yield will increase by 19.254 bushels per acre, all else equal. Roundups coefficient was 12.813 with a t-Statistic of 3.555. Yield would increase by 12.813 bushels per acre if Roundup increased by one, all else equal. The coefficient of PRE is 3.000 with a t-Statistic of 1.308. If a PRE was used in the herbicide program, it increased yield by 3 bushels per acre than if a POST only was applied, all else equal. The NORTH coefficient was 9.133 with a t-Statistic of 2.216, while the north nontreated plot increased by 9.133 more bushels per acre than the south side.

Using a 95% confidence level and a critical value 1.96, the use of a PRE and the number of days are not statistically significant in explaining yield in this study. A good indication on why the PRE was not significant was because there were not enough observations that had POST only treatments to see a difference. The independent variables Liberty, Roundup, and North all have a statistical relationship with yield.

The cost per day of each herbicide program is shown on table 2. Herbicide programs that had at least 2 or more site of actions might have cost more, however, had the most effectiveness on the target weeds, therefore, delayed the POST applications longer. This resulted in a lower cost per day. This analysis also showed that FirstRate was an active ingredient in many of the

herbicide programs that has the lowest cost per day and maximum number of days after application B (20 days). For example, Authority First contains Spartan and FirstRate at 6.4 ounces while delaying the POST application by 20 days and resulted in an average of $1.54 per day. Prefix tank mixed with FirstRate contains S-Metolachlor, Sodium Salt of Fomesafen and cloransulam. It delayed the POST application for the north side 20 days and the south side 15 days and averaged $2.03 per day. Boundary and Pursuit, contains S-Metolachlor, Metribuzin, and Imazethapyr and delayed the POST application by only 4 days and averaged a cost of $7.44 per day. This analysis can show that even if multiple site of actions are tank mixed, they must still be herbicides that are effective on the target weeds.

# CHAPTER 5

## DISCUSSION

The overall results of this study are very accurate in comparison to other studies previously from universities and industry researchers when focusing on weed management practices and looking at the effectiveness of each herbicide and its soil residual. This study shows that using a PRE and POST does have a beneficial gain. It also shows that paying more for a weed management can pay off in the end and allow for more days in between each application to do other productive things. It also results in a lower cost per day compared to a herbicide that is not as effective on certain weeds or have as long of a residual.

One suggestion for future studies in this area of focus is to add or change a few of the herbicide programs to consist the study of PRE-only, PRE fb POST, and POST only treatments. This would help gain observations and obtain a better visual on how a PRE fb POST weed management practice is beneficial to yield compared to PRE only or POST only treatments. Another suggestion for future studies would be to add another soybean technology. Enlist soybeans is the new trending system growers are looking to use in the next couple of years because of the tough restrictions with Dicamba on Xtend soybeans. This would give more data on Enlist soybeans and whether there is a yield difference between the two systems. This study can show that using a PRE fb POST is beneficial, however, it must contain herbicides that are effective on the problem weeds.

Table 1

Dependent Variable: YIELD
Method: Least Squares
Date: 03/25/20 Time: 14:34
Sample: 1 114
Included observations: 114

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 38.56667 | 2.914793 | 13.23136 | 0.0000 |
| DAYS | -0.076274 | 0.086503 | -0.881749 | 0.3799 |
| LIBERTY | 19.25403 | 3.603937 | 5.342498 | 0.0000 |
| ROUNDUP | 12.81264 | 3.603937 | 3.555179 | 0.0006 |
| PRE | 3.000435 | 2.294313 | 1.307771 | 0.1937 |
| NORTH | 9.133333 | 4.122139 | 2.215678 | 0.0288 |

| | | | |
|---|---|---|---|
| R-squared | 0.446005 | Mean dependent var | 60.31693 |
| Adjusted R-squared | 0.420357 | S.D. dependent var | 6.631136 |
| S.E. of regression | 5.048569 | Akaike info criterion | 6.127283 |
| Sum squared resid | 2752.709 | Schwarz criterion | 6.271293 |
| Log likelihood | -343.2551 | Hannan-Quinn criter. | 6.185729 |
| F-statistic | 17.38950 | Durbin-Watson stat | 2.190935 |
| Prob(F-statistic) | 0.000000 | | |

Table 2

| Treatment | Rate/Ac | # of Days NORTH | # of Days SOUTH | AVERAGED COST PER DAY NORTH | AVERAGED COST PER DAY SOUTH |
|---|---|---|---|---|---|
| Valor XLT | 3.5 oz | 15 | 15 | $ 1.26 | $ 1.26 |
| Fierce XLT | 4.5 oz | 20 | 15 | $ 1.43 | $ 1.91 |
| Authority First | 6.4 oz | 20 | 20 | $ 1.54 | $ 1.54 |
| Prefix/FirstRate | 2 pt, .6 oz | 20 | 15 | $ 1.74 | $ 2.32 |
| Boundary/FirstRate | 2 pt, .6 oz | 20 | 15 | $ 2.13 | $ 2.84 |
| Authority XL | 6.4 oz | 9 | 9 | $ 2.19 | $ 2.19 |
| Boundary/Scepter | 2 pt, 2.86 oz | 15 | 9 | $ 2.19 | $ 3.65 |
| Fierce MTZ | 1 pt | 9 | 9 | $ 2.76 | $ 1.37 |
| Prefix/Scepter | 2 pt, 2.86 oz | 9 | 9 | $ 2.79 | $ 2.79 |
| Prefix/Classic | 2pt, 1.92 oz | 15 | 9 | $ 2.95 | $ 4.91 |
| Prefix | 2 pt | 4 | 4 | $ 3.01 | $ 3.01 |
| Boundary/Classic | 2 pt, 1.92 oz | 15 | 4 | $ 3.47 | $ 13.00 |
| Boundary | 2 pt | 4 | 4 | $ 4.96 | $ 4.96 |
| Zidua Pro | 6 oz | 4 | 4 | $ 5.07 | $ 5.07 |
| Prefix/Pursuit | 2 pt, 4 oz | 4 | 4 | $ 5.49 | $ 5.49 |
| Boundary/Pursuit | 2 pt, 4 oz | 4 | 4 | $ 7.44 | $ 7.44 |
| Authority MTZ | 18 oz | 4 | 4 | $ 9.99 | $ 9.99 |

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