COTTON GROWER ADOPTION OF WEED RESISTANCE MANAGEMENT PRACTICES

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Abstract

This study examines cotton grower adoption of ten different weed resistance management practices using survey data from 401 Delta, Southeastern, and Southern Plains producers. About 95% of growers always or often adopted five or more resistance management practices, while more than 70% always or often adopted seven or more practices. Growers that planted a greater share of cotton acres to Roundup® or Roundup Ready® Flex varieties scouted for weeds before applying herbicides more frequently and started with a clean field more frequently. Greater reliance on Roundup Ready® varieties was negatively associated with adoption of supplemental tillage to control weeds. This last result is consistent with survey findings that growers were more likely to practice no-till or minimum tillage on Roundup® or Roundup Ready® Flex acreage.

Introduction

In 2008, more than 80% of U.S. cotton and corn acreage and more than 90% of soybean acreage were planted to transgenic glyphosate-tolerant, Roundup Ready® seed varieties (USDA, AMS; USDA, NASS). Many studies report significant pecuniary and non-pecuniary benefits to growers from using glyphosate-tolerant varieties (Gianessi, 2008; Marra, Pardey, and Alston, 2002; Marra and Piggott, 2006; Mensah, 2007; Piggott and Marra, 2008). The evolution of glyphosate-resistant weeds, however, threatens the sustainability of these benefits. Commodity groups, extension specialists, and Monsanto have recommended that growers adopt various best management practices (BMPs) to prevent or delay the spread of glyphosate-resistant weeds (Steckel, Hayes and Rhodes, 2004; Burgos, et al., 2006; Stewart, 2008; Culpepper, York, and Kichler 2008; Monsanto 2009a, 2009b). This study examines the frequency of adoption of ten different best management practice (BMPs) to prevent or delay weed resistance. It also examines which factors encourage or discourage more frequent adoption of these BMPs. While the present article focuses on cotton growers, it is part of a larger study using primary data collected from over 1,200 cotton, corn and soybean growers.

Data

Data was collected via a telephone survey conducted by Marketing Horizons for Monsanto in November-December of 2007. The survey was designed to be a random, representative sample of corn, cotton, and soybean growers from the Great Plains, eastward. Data collection was restricted to farms with 250 or more acres of the targeted crop. Responses were obtained from 401 cotton growers, 402 corn growers and 402 soybean growers. While growers were “targeted” to respond to questions about a particular crop, they often also produced other crops. For example, many cotton growers who were asked detailed questions about cotton production also grew corn or soybeans.

The survey included four sections. The first asked questions about operator and farm characteristics. These included operator education and experience, acres operated, percentage of operated land owned, acres of different crops grown, acreage planted with herbicide tolerant crops, crop rotation practices, and extent of livestock production. The second section asked growers about their current weed management; adoption of weed resistance best management practices (BMPs); herbicides and/or tillage used for pre-plant, pre-emergent and post-emergent weed control; and timing and frequency of post-emergent weed management. The third section asked growers their attitudes regarding various weed management concerns such as crop yield, crop yield risk, crop price, crop price risk, herbicide costs, seed costs, overhead costs, labor and management time, crop safety, operator and worker safety, environmental safety, erosion control, and convenience. The fourth section asked growers about the cost of their weed management program and the value of the benefits they derived using a Roundup Ready® weed management program.

The potential for pests or weeds to develop tolerance or resistance to pest management strategies that focus on a single mode of action is well established in the literature. However, successful strategies for reducing the risk of pest tolerance or resistance are also well documented. For this study, weed resistance practices were categorized into ten separate BMPs:

1. Scouting fields before herbicide applications
2. Scouting fields after herbicide applications
3. Start with a clean field, using either a burndown herbicide application or tillage
4. Controlling weeds early when they are relatively small
5. Controlling weed escapes and preventing weeds from setting seeds
6. Cleaning equipment before moving from field to field to minimize spread of weed seed
7. Using new commercial seed as free from weed seed as possible.
8. Using multiple herbicides with different modes of action
9. Using tillage to supplement herbicide applications
10. Using the recommended application rate from the herbicide label.

Growers could choose among five responses when asked how frequently they adopted a BMP: (1) always, (2) often, (3) sometimes, (4) rarely, and (5) never. There were six BMPs always practiced by a majority of growers (Table 1). There were three BMPs, however, that a significant number of growers never practiced. These included cleaning equipment before moving between fields (24%), rotating herbicide mode of action (12%), and using supplemental tillage (26%).

Table 1. Frequency of Weed Resistance Best Management Practice (BMP) Adoption (Percent of Respondents)

BMP	Always	Often	Sometimes	Rarely	Never
Use new commercial seed as free from weed seed as possible	81%	9%	5%	2%	2%
Use the recommended application rate from the herbicide label	77%	17%	4%	1%	0%
Start with a clean field, using a burndown application or tillage	67%	13%	13%	3%	4%
Scout fields before a herbicide application	64%	22%	9%	2%	2%
Scout fields after a herbicide application	60%	24%	12%	2%	1%
Control weeds early when they are relatively small	57%	35%	7%	1%	0%
Control weed escapes and prevent weeds from setting seeds	44%	38%	15%	2%	1%
Clean equipment before moving between fields	25%	14%	22%	16%	24%
Use multiple herbicides with different modes of action	18%	20%	36%	13%	12%
Use tillage to supplement weed control	13%	12%	30%	18%	26%

Table 2. Frequency of Weed Resistance BMP Adoption (Percent of Respondents)

BMP	Often or Always	Sometimes	Rarely or Never
Use new commercial seed as free from weed seed as possible	91%	5%	4%
Use the recommended application rate from the herbicide label	94%	4%	1%
Start with a clean field, using a burndown application or tillage	80%	13%	7%
Scout fields before a herbicide application	87%	9%	4%
Scout fields after a herbicide application	84%	12%	3%
Control weeds early when they are relatively small	92%	7%	1%
Control weed escapes and prevent weeds from setting seeds	82%	15%	3%
Clean equipment before moving between fields	38%	22%	39%
Use multiple herbicides with different modes of action	38%	36%	25%
Use tillage to supplement weed control	25%	30%	45%

Table 2 combines the share of BMPs practiced often or always, then rarely or never for the same data. There are seven practices that 80% of cotton growers practice frequently (always or often): use new seed (91%), follow label rate (94%), start with a clean field (80%), scout before (87%), scout after (84%), control weeds early (92%), and control weed escapes (82%) (Table 2). Again, one can see that the remaining three BMPs – rotating modes of action, cleaning equipment, and supplemental tillage – were practiced less frequently (Table 2).

Considering the full sample of all growers, cotton growers were more likely to practice more BMPs often or always than were corn or soybean growers (Figure 1). More than 70% of cotton growers practice seven or more BMPs often or always, compared to 58% of corn producers and 55% of soybean producers. About 45% of cotton growers practiced eight or more BMPs often or always compared to 35% for corn growers and 24% for soybean growers. About 95% of cotton growers always or often adopted 5 or more BMPs.

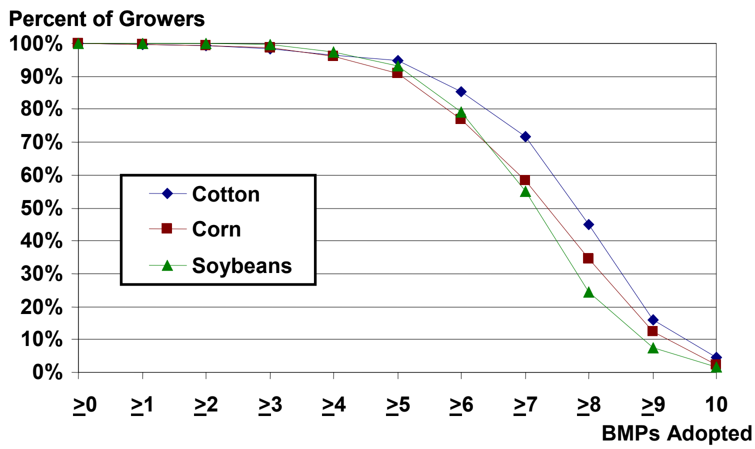

Figure 1. Percentage of growers often or always adopting BMPs by total number of BMPs adopted

Methods

Data concerning BMP adoption was analyzed in two ways. First, multivariate count data analysis was used to identify which factors explained the total number of BMPs a grower adopted frequently (often or always). For example, which factors help predict whether a grower will adopt eight practices frequently as opposed to seven? Next, multivariate ordered probit and binary probit regressions were estimated to identify factors that help explain how frequently a grower practiced a particular BMP.

For the multivariate regression analyses, in addition to the Marketing Horizons survey data, county-specific variables were also created using data from the USDA, National Agricultural Statistics Service (NASS). These included the coefficient of variation (CV) of county crop yields of the targeted crop. CV is the standard deviation of yields divided by the mean of yields over ten years. The yield CV was included to test the hypothesis that growers in counties with greater yield risk had different patterns of BMP adoption. Growers were asked what they expected their target crop yields would be. An index was created that was the ratio of growers' expected yields to their counties' average yields. This variable was included to test the hypothesis that growers with higher than average county yields (perhaps better managers or growers farming under conditions that are more favorable) were more likely to adopt BMPs more frequently.

Multivariate count data regressions were estimated to identify factors determining the total number of BMPs growers adopt often or always. The number of BMPs a grower adopts often or always can only be an integer from 0, 1, 2, up to 10. This means Poisson (or other count data) regressions are more appropriate than standard linear regression (Greene, 1997). A Poisson regression assumes that the mean and variance of the dependent variable are equal. This assumption can overestimate the statistical significance of regression parameter estimates when there is over-dispersion (variance greater than the mean) or underestimate their statistical significance when there is under-dispersion (variance less than the mean). However, estimation here followed McCullagh and Nelder who fit a Poisson regression that relaxes this restriction. McCullagh and Nelder use the Pearson chi-square method to estimate a scale parameter s, such that $s = 1$ if the mean and variance are equal, $s > 1$ if the variance exceeds the mean (over-dispersion) and $s < 1$if the variance is less than the mean (under-dispersion).

Results and Discussion

Table 3 reports results of Poisson count data regressions where the dependent variable is the total number of weed BMPs that a grower reported using either often or always. Results are reported with and without state fixed effects. Based on a likelihood ratio test, we could reject the hypothesis of no state-level effects. However, only three states individually have statistically significant effects. The default state is Iowa and the regression coefficients for Illinois, Indiana, and Kansas were all positive and significant.

Explanatory variables included:

- Dummy variables for target crop grown an indicator of whether or not a grower sold livestock
- Years of grower education and of farming experience
- Total crop acres and percent of cropland owned
- Percent of target crop planted to Roundup Ready seed varieties in previous year
- Grower expected yield as a percent of county average yield
- The coefficient of variation of target crop yield in the grower's county
- The Herfindahl Concentration Index (this index increases as a grower becomes more specialized in a particular crop)
- Percent of counties in a grower's crop reporting district reporting resistance
- Dummy variable indicating resistance reported in a grower's county
- Dummy variable indicating that the grower listed weed resistance was a concern in an open-ended question about weed management concerns (growers were not asked directly if resistance was a concern).

Only Poisson regression results are reported here, although Poisson and negative binomial specifications yielded similar results. Compared to the default (corn growers), cotton growers adopted more BMPs (Table 3). This difference was less significant in model with state effects, however. There was no significant difference between soybean and corn growers in the regressions. The number of BMPs adopted:

- increased with a grower's level of education
- increased as growers with expected yields increased relative to the county average
- was lower in counties with more variable yields (measured by the county yield CV)
- was lower in crop reporting districts that reported more resistance problems.

In regressions with state effects, the number of years of farming experience was negatively associated with the number of BMPs adopted, suggesting that younger farmers tend to adopt more BMPs. Separate models estimated by target crop did not perform well and so are not reported here—for the separate corn and soybean models, the null hypothesis of all zero coefficients (except for the constant) could not be rejected at the 5% level of significance.

In sum, younger, more educated growers who expect to obtain higher than average yields practiced a greater number of BMPs often or always. Growers in regions with greater percentage yield variability practiced fewer BMPs. The relationship between local resistance episodes and grower BMP adoption was mixed. Growers in crop reporting districts (comprised of multiple counties) that had more counties reporting resistance practiced fewer BMPs. Yet, growers farming in counties reporting resistance, tended to adopt more BMPs. This latter relationship was not significant, however. Cotton growers and larger operators appeared to adopt more BMPs, but this affect was attenuated by including state-specific effects. The attenuating effect of state variables may come from the fact that there was no overlap of growers in surveyed cotton and corn states and only a small overlap between surveyed cotton and soybean growers. Hence, there is a relatively high correlation between the state dummy variables and the cotton grower dummy variable.

Ordered and binary probit regressions were run for each of the ten BMPs, both with and without state-specific fixed effects. For cotton growers alone, this entailed 40 separate regressions. Table 4 summarizes these regression results for cotton growers. The first column lists explanatory variables. These are the same as for the Poisson regressions except crop-specific dummy variables are excluded because the regressions only included cotton growers. The next two columns show the individual BMP that the explanatory variable affected significantly. For the ordered probit regressions a (+) symbol indicates that the variable increases the probability of more frequent practice of a BMP. Growers can choose between always, often, sometimes, rarely, or never. The (+) sign means that the variable increases the probability of practicing more frequently (on this spectrum), relative to less frequently. For the binary probit, the (+) symbol indicates that the variable decreased the probability that the grower rarely or never adopted a BMP. In both cases, the (+) implies adoption that is more frequent. In turn, a (–) symbol implies that the explanatory variable discourages more frequent adoption of the BMP. BMPs are listed only if the explanatory was significant at the 10% level, at least.

Table 3. Poisson regression estimates of for number of weed BMPs adopted (data pooled across cotton, soybean, and corn growers)

Dependent Variable: Total Number of BMPs adopted				
	State Effects		No State Effects	
Explanatory Variable	Coefficient	Significance	Coefficient	Significance
Intercept	1.798	0.000	1.797	0.000
Soybean Grower	-0.009	0.64	-0.016	0.393
Cotton Grower	0.080	0.100	0.074	0.002
Raised Livestock	-0.002	0.913	-0.006	0.686
Education	0.011	0.01	0.012	0.003
Years Farming	-0.001	0.059	-0.000	0.143
Crop Acres	0.00001	0.148	0.00001	0.085
Percent of Cropland Owned	0.000	0.304	0.000	0.252
Percent Roundup-Ready Acres	0.000	0.53	0.000	0.532
Percent Yield Difference	0.0000	0.037	0.0000	0.054
County Yield Coefficient of Variation	-0.358	0.006	-0.314	0.007
Herfindahl Concentration Index	0.074	0.124	0.056	0.22
Percent Acres with Custom Herbicide Applications	0.000	0.489	0.000	0.580
Weed Resistance in Crop Reporting District	-0.002	0.016	-0.001	0.053
County Weed Resistance	0.047	0.172	0.050	0.142
Resistance a Concern	0.005	0.756	0.006	0.69
IL*	0.057	0.040		
IN *	0.078	0.042		
KS *	0.179	0.001		
s (Scale)	0.332		0.335	
Likelihood Ratio Test Statistic	91.302	0.000	61.875	0.000
d.f.	32		15	

* Only significant individual state effects reported.

In both the ordered probits (to examine frequency of adoption) and binary probits (to examine probability of rarely/never adopting a BMP) two variables had a robust impact on marginal probabilities of adopting individual BMPs. Farming in a county with a larger coefficient of variation of target crop yield (a measure of relative yield variability) reduced the probability of frequent adoption of several BMPs. This suggests that yield risk is an important factor discouraging BMP adoption. In contrast, the ratio of a grower's expected yield to the county average yield increased the probability of frequent adoption of BMPs. This suggests that there may be some form of "good manager" effect at work, where growers with higher yields (or at least higher expected yields) than their neighbors tend to adopt more BMPs more frequently. There was no statistically significant relationship between individual growers' frequency of BMP adoption and identification of confirmed cases of weed resistance in the growers' counties, however. These three results are consistent with those of the Poisson count regressions.

Table 4. Effect of Explanatory Variables on Adoption of Individual BMPs

	Regression Type	
Variable	Ordered Probit	Binary Probit
Years of Education	Scout before (+) Clean field (+) Clean equipment (–)	
Years Farming	Control escapes (–)	Control escapes (–)
Total Crop Acres		Supplemental tillage (–)
Percent of Farmland Owned	Clean field (+) Control escapes (+) Supplemental tillage (–)	Scout before (+) Scout after (+) Clean equipment (–)
Percent Roundup Ready Acres	Scout before (+) Clean field (+) New seed (+) Supplemental tillage (–)	Scout before (+) Clean field (+) Supplemental tillage (–)
Percent Yield Difference	Control escapes (+) Clean equipment (+) Different modes (+)	Clean equipment (+)
County Yield CV	Scout before (–) Scout after (–) Control escapes (–) Different modes (–)	Scout before (–) Scout after (–) New seed (–) Different modes (–)
Herfindahl Concentration Index	New seed (+) Label rate (+)	Scout before (–) New seed (+) Different modes (–)
Custom Herbicide Applications	Scout before (–)	Scout before (–)
Resistance in Crop Reporting District	Supplemental tillage (+)	Clean equipment (+)
Resistance in County		
Resistance A Concern	Scout after (–) Supplemental tillage (–)	Clean equipment (–) Supplemental tillage (–)
Raise Livestock		New seed (+)

(+) indicates that the variable had a positive impact on the probability of adopting the BMP more frequently and that the regression coefficient was significant at the 10% level (at least); (–) indicates that the variable had a negative impact on the frequency of BMP adoption, significant at the 10% level (at least).

Growers that planted a greater share of cotton acres to Roundup® or Roundup Ready® Flex varieties scouted for weeds before applying herbicides more frequently and started with a clean field more frequently. Greater reliance on Roundup Ready® varieties was negatively associated with adoption of supplemental tillage to control weeds. This last result is consistent with survey findings that growers were more likely to practice no-till or minimum tillage on their Roundup® or Roundup Ready® Flex acres (Figure 2).

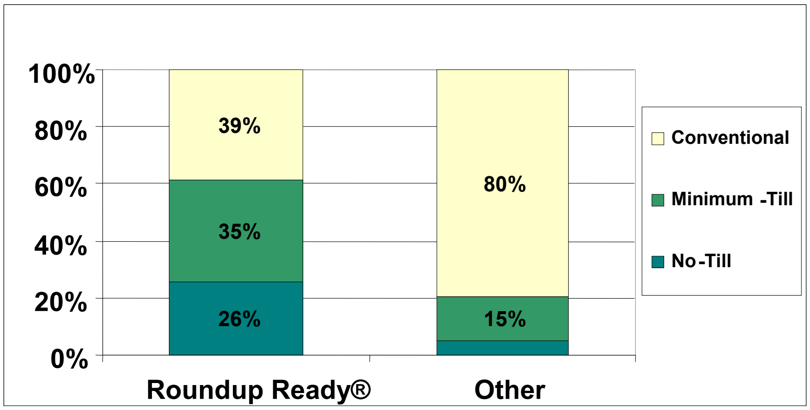

Figure 2. Percent of cotton acres in sample by seed variety and tillage practice

While growers practiced conventional tillage on only 39% of Roundup Ready® acres, they practiced conventional tillage on 80% of other cotton acreage. Growers practiced no-till on 26% of Roundup Ready® acres, but they practiced no-till on only 5% of other acreage.

Conclusions

This study used data from a representative sample of 401 cotton farmers (of 250 acres or more) from the Southern Plains, Delta, and Southeast to examine adoption of ten different best management practices (BMPs) to delay or prevent weed resistance to herbicides. Adoption rates for three BMPs were relatively low, with fewer than 41% growers adopting them often or always. These BMPs were cleaning equipment, using herbicides with different modes of action, and use of supplemental tillage. However, each of the other seven BMPs were practiced often or always by 80% or more of growers. Six of these seven BMPs were always practiced by a majority of growers. In addition, more than 70% of cotton growers always or often adopted seven or more practices (although not necessarily the same seven). In sum, most growers are frequently practicing most BMPs.

The results suggest that extension efforts to increase adoption of weed resistance BMPs can focus on the three infrequently practiced BMPs: cleaning equipment, using herbicides with different modes of action, and supplemental tillage. Regression results suggest growers with less education and more farming experience (perhaps older growers?) were less likely to adopt BMPs frequently. In addition, growers expecting lower yields or who produced in counties with high yield variability were less likely to adopt BMPs frequently. These results suggest extension efforts to increase BMP adoption might consider focusing on marginal production areas.

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