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Rabo AgFocus

Nature Finds a Way: The Rising Cost of Herbicide Resistant Weeds in the U.S.

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Contents

The increasing prevalence of weeds with resistance to one or more herbicides, including glyphosate, is increasing the cost of row crop production in the US. Soybeans and cotton are the most susceptible of these crops as they have fewer chemical options for controlling key weeds which are developing resistance to multiple herbicides.

While chemical herbicides will remain the primary control mechanism of choice, tillage is likely to increase. Glyphosate will continue to be an important platform for weed control; however, a variety of modes of action will need to be made available in order to supply much more robust soybean weed management programs. Concurrently, new seed products will be required to increase chemical diversity while allowing farmers to continue low tillage practices. In addition, a widespread return to older chemistries to add diversity to herbicide rotations is likely.

Corn planting is likely to increase in the Midwest and eastern Corn Belt in the near-to-medium term as soybean production margins decline relative to those of corn.

Introduction

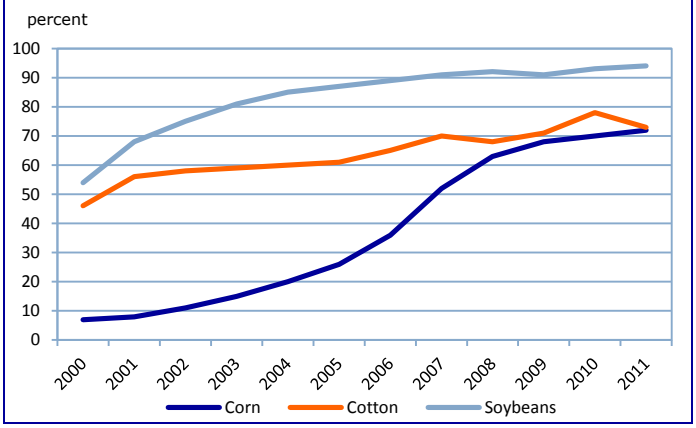
In 1996, agricultural production practices were altered substantially with the introduction of soybeans which were resistant to the active herbicide ingredient glyphosate, sold by Monsanto under the trade name Roundup™. This allowed farmers to plant soybeans and spray Roundup for complete weed control, even on a post-emergence basis. Rapid adoption of the new technology was driven by cost savings from the reduced total herbicide applications and the significant convenience gained from a one-size-fits-all weed management program.

As a result of the unprecedented effectiveness of the new technology, soybean production became more profitable and expanded from 25 percent to 32 percent of the total major crop plantings in the United States (US) within five years. Although over time profitability decreased as the cost of the seed specifically engineered to resist glyphosate rose, farmers have been able to better control a wide spectrum of weeds for no more cost than previous methods. Consequently, the value of soybean production as a rotation crop and, depending on the region, as a replacement crop for wheat and cotton increased.

By the mid-2000s, over 90 percent of soybeans planted in the US were glyphosate resistant (*see Figure 1*). Due in part to the new ease of weed control, production practices that minimized tillage became increasingly prevalent. As a result, many producers moved to two post-emergence applications of the herbicide each season. In cases where pre-emergence application was used, glyphosate was frequently the herbicide of choice. In many cases, glyphosate was even effective enough to allow farmers to apply lower rates than the label recommendations.

Within five years of the introduction of widespread annual application of glyphosate, a weed population with resistance to the herbicide began to be identified. Introduction of glyphosate-resistant corn and cotton in the early 2000s exacerbated the problem by expanding resistance selection from continuous soybean fields to fields where rotation was occurring. The geographically wide area of glyphosate utilization across different crops saw

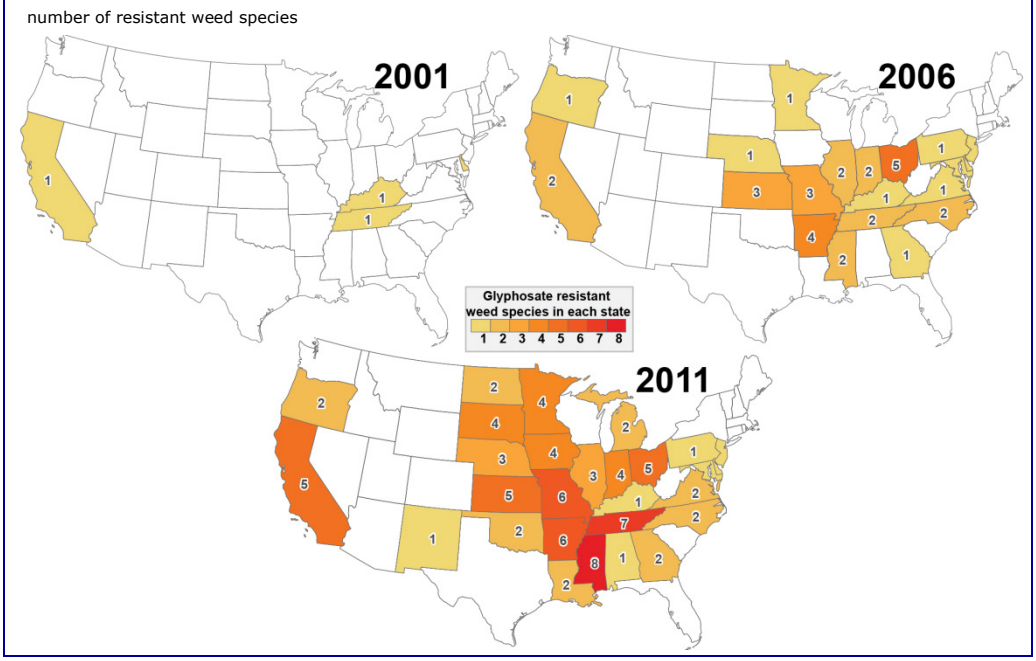
Figure 1: Share of Glyphosate-Resistant Plantings in Selected Crops , 2000-2011



Source: USDA, 2011

an increase in weeds resistant to glyphosate. Some of these weeds had already developed resistance to one or more other herbicides or modes of action[1]. By 2011, 13 weed species with resistance to glyphosate had been identified in the US, with over 85 confirmed biotype observations in 28 states. Of the confirmed biotype observations, 15 percent were resistant to more than one mode of action (MOA) (*see Figures 2 and 3*).

Figure 2: Spread of Glyphosate-Resistant Weeds, 2001 vs. 2006 vs.2011



Source: International Survey of Herbicide Resistant Weeds; Rabobank, 2012

As pressure from weed resistance grows in the US, farmers will seek new solutions for management programs. A likely first step will be an increase in corn planting which will lead to increased demand for related inputs such as nitrogen, and corn-specific chemicals. Crop protection providers should also anticipate increased demand for corn-related herbicides.

Additionally, a movement to increase diversity in soybean weed management programs will likely present an opportunity to revitalize demand for older herbicide chemistry. Seed genetics companies will see strong demand for soybean varieties with resistance to multiple families of herbicide. Furthermore, a greater need for precision management of weeds is likely to elevate demand for chemical storage and application equipment.

Increased corn-on-corn rotations could have a knock-on effect by reducing yield potential and thus US production capacity. Furthermore, soybean farmers are likely to incur additional expense in time, equipment and application costs to implement weed management programs. The sustained increases in global demand for soybeans will

[1] Multiple resistance occurs when a weed type become resistant to more than one herbicide classification (mode of action class). Cross resistance occurs when weed types develop resistance within the herbicide classification.

therefore continue to push planting on new ground to the western (lower yielding) regions of the US, and to South America.

Figure 3: Number of Glyphosate-Resistant Species in the US

Common Name	Confirmed Biotypes	Number of Bio types with Multiple Resistance
Horseweed	23	2
Palmer Amaranth*	14	3
Common Waterhemp*	12	3
Giant Ragweed	12	2
Common Ragweed	8	1
Italian Ryegrass	4	1
Johnsongrass	3	0
Kochia	3	0
Annual Bluegrass	2	0
Goosegrass	2	0
Hairy Fleabane	2	1
Jungle rice	1	0
Rigid Ryegrass	1	0

Source: International Survey of Herbicide Resistant Weeds; Rabobank, 2012
*Current driver weed

Resistant Weed Problem Not New to US

The reduced yields and increased production costs associated with these resistant weeds have grown rapidly across the southern US and are expected to significantly increase as far north as central Illinois and southern Iowa in 2012. The University of Tennessee's Department of Plant Sciences estimates the yield impact of resistant weeds on soybean production at up to 17 percent. For farmers in the southern US, including the delta region, the total cost of these weeds is estimated in the tens of millions of dollars.

Over the past three years, researchers' reports of resistant weeds in the northern Corn Belt area—from North Dakota through Indiana and Ohio—have intensified. Within the next three years, expansion of glyphosate-resistant weeds is likely to be explosive, with resistance to other herbicide groups growing in the process. The most likely result of this expansion will be forced changes in farming practices and culture, which will ultimately increase the cost of US crop production as well as offer opportunities for new seed and chemical technology.

While farmers are beginning to utilize preventative measures due to education and incentive efforts from researchers and the industry, significant work remains to stop the spread of challenging weeds. Based on farmer and weed scientist interviews, resistance problems often occur in a few fields with more relaxed management standards before spreading. Thus, understanding local conditions and implementing preventative measures will increase in importance.

The Corn Belt Impact Likely to be Felt as Early as 2012

Nationally, the expansion of glyphosate-resistant weeds and the development of weeds with multiple resistances is reaching a mass critical enough to accelerate widespread changes in chemicals used in weed management programs beginning in 2012. Additional cost and loss of convenience from producing soybeans also portend an increase in US corn production area over the medium term. The need for more intensive management is also likely to drive increased farm-level equipment sales as farmers work to implement weed management through storage and application of chemicals, and look to increase spot tillage.

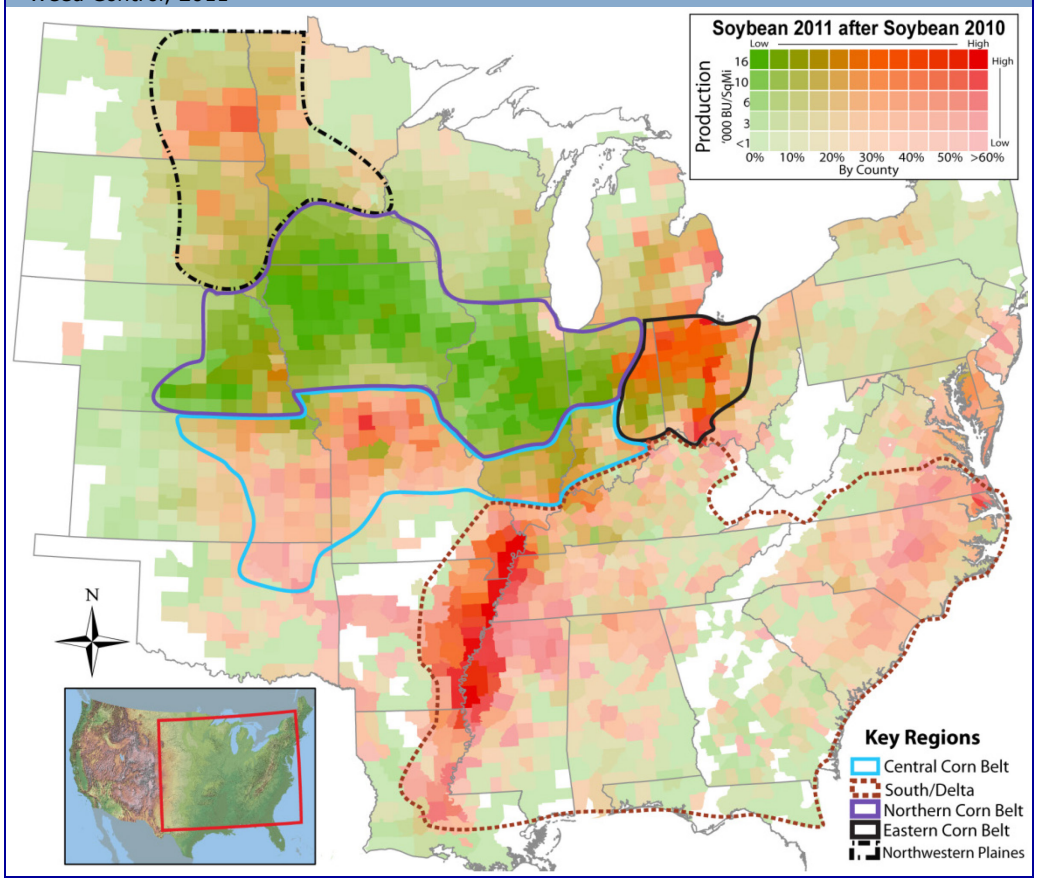
Region Determining Factor for Farmer Attitudes and Probable Courses of Action

Based on Rabobank's farmer focus groups' analysis, there are three broad classifications of farmer attitudes regarding herbicide resistant weeds in the US. In general, these attitudes correlate with levels of exposure to glyphosate-resistant weeds. Due to the spread pattern of driver weeds[2], such as water hemp, the attitudes tend to be geographically correlated with the density of soybean following soybean production (*see Figure 4*). Farmer attitudes

[2] The term driver weed refers to a species which is adapted for large areas and thus has the most potential to stimulate changes in management programs.

for dealing with herbicide resistant weeds can generally be segmented along the production culture lines from the North to the South. These attitudes, as well as the predominant production culture of the geography, will likely dictate the timing, magnitude and ultimately the courses of action farmers take to enhance weed management practices.

Figure 4: Heavy Soybean Production Culture Correlation with Attitude towards Herbicide-Resistant Weed Control, 2011



Source: USDA-NASS Cropland Data Layer, Rabobank, 2012

Northern Corn Belt Farmers Likely to Increase Corn Rotation as First Step to Manage Resistant Weeds

While many soybean producers have limited themselves to one weed management option in glyphosate, a more complex set of herbicide options have been more broadly deployed by corn producers. According to the Weed Science Association of America, no new herbicide chemistry has been introduced for use in any crop for the past 20 years. However, products from multiple families of herbicide (classified by MOA) have been made available for corn production. Consequently, resistance to glyphosate was much more likely to develop in agricultural production cultures with exposure to heavy soybean production year after year. While corn-rotation-dominated geographies have had fewer problems to date, resistant weed populations are expanding at an alarming rate. In 2009, a survey of water hemp populations across the state of Iowa revealed that one third was not adequately controlled by glyphosate. Over the next two to three years the problem is expected to intensify significantly.

In the northern Corn Belt, where resistant weeds have not been identified with enough frequency to be considered a population, farmers tend towards preventative measures. In this region, the increase in corn–on-corn rotation is a natural response to threats from glyphosate-resistant weeds[3]. However, the need to alter heavy use of glyphosate in corn production as well as soybean production will add costs to both crops. A preventative approach to herbicide resistant weeds in the northern Corn Belt is estimated to cost USD 10 to USD 15 per acre for corn and USD 5 to USD 10 per acre for soybeans. On a per bushel basis, this would translate into a USc 4 to USc 10 increase in the price required for soybeans to break even with corn[4].

Due to the lack of significant pressure for controlling resistant weeds, changes in management practices are likely to be much slower in the more northern parts of the Corn

[3] Farmers in south central Illinois and northern Missouri indicate that an increase of 10-15 percent in corn production would be considered a good approach to better weed management.

[4] Assuming a 180 bushel per acre corn yield and 55 bushel per acre yield for soybeans

Belt. Farmers and crop consultants are expressing concern that until the problem becomes more serious, the majority of producers will continue to utilize the short term, cost effective approach of widespread post-emergence application of glyphosate.

The timing of needed action is likely to be sooner than most anticipate. Weed populations grow at a logarithmic rate, which means the population is not recognized until it is already a serious problem. With reports of small populations of weeds which did not die after 2011 glyphosate applications from as far north as Wisconsin and northern Iowa, the next three years are likely to see a substantial increase in preventative activity. Farmers in this region indicated a preference for increasing corn–on-corn rotation as a way to increase the number of herbicide options available for weed control.

Eastern Corn Belt and Northern Plains Taking Action in 2012

The eastern Corn Belt states of Indiana and Ohio, where soybean after soybean production is more prominent, have also begun to encounter more glyphosate resistance in weeds. An increase in corn rotation is being encouraged in these areas as an immediate solution to the problem. New technologies which combine glyphosate resistance with active ingredients from other MOA, such as growth inhibitors, are likely to be readily adopted throughout the Corn Belt where there is less conflict with other more sensitive crops.

A recent survey reported by BASF indicated that farmers in the northern Plains states were strongly considering changes in weed management programs. The majority of those planning to make changes were adding chemicals to herbicide applications as well as adding a pre-emergence application with residual weed control capability.

Herbicide Resistance to Increase Continuous Corn Production In the Central to Southern Corn Belt

The central Corn Belt, including Kansas, northern to central Missouri and central to southern Illinois, is beginning to experience enough resistance, particularly from species such as water hemp and rye grass, to drive a preventative action attitude. In these areas, farmers are concerned that 2012 could become a break-out year for herbicide resistant weeds.

Four common approaches to weed control were reported by farmer focus groups in this region: enhancing chemical applications by introducing a pre-emergence application with residual control; spraying glyphosate at earlier stages of plant growth to ensure low survival rates; increased corn production on 10 percent to 15 percent of soils to help control existing weed problems; introducing some spot tillage on previously no-till land where weeds have survived to later stages. In every case, cultivation was considered the option of last resort, especially for historically no-till soybean farmers.

In addition to the loss of convenience created by glyphosate-resistant soybeans, increased cost of production lessens the competitiveness of soybean production in this region. The cost of controlling resistant weeds in soybeans in this central region was estimated by farmers to be approximately USD 30 per acre more than the glyphosate program[5].

Areas Already Experiencing Resistant Weeds Anxious to Adopt New Solutions

From southern Illinois through Tennessee down the Mississippi Delta and along the East Coast, glyphosate-resistant weeds are an on-going problem. Extremely hardy weeds with multiple resistances, such as Palmer amaranth, require increasingly intense management practices. Every tool available is currently being used in this region, including hand cultivation crews which manually cut and hoe patches of persistent weeds.

The appetite to adopt new technology is very strong in this region. Many farmers have already either included or switched to the chemistry of glufosinate, which was made widely available to soybean producers in 2009 (USD 24.6 million in glufosinate sales in 2010, compared to USD 318 million in 2010 glyphosate sales[6]). However, chemicals from the growth regulator family, such as Dicamba and 2,4-D, will have hurdles in parts of the south (generally from Tennessee southward) due to drift impacts on other regionally produced crops such as cotton.

The additional cost of producing soybeans after resistant weeds have heavily infested production areas is estimated to be USD 40 to USD 45 per acre more than the simple glyphosate program. Consequently, production of corn and other rotation crops, such as

[5] Much of the additional cost is due to the addition of herbicides to weed management programs. Once resistant weeds had begun to appear, farmers reported the need to add at least two additional herbicides at the cost of USD 15 per acres each. Thus the total additive cost of controlling resistant weeds is USD 30 per acre.
[6] Source AMIS Global.

grain sorghum, is likely to replace some soybean production as a part of recommended weed management practices.

Glyphosate Remains Important Platform but More Options Needed Long Term

Although some varieties of weed are developing specific resistance to glyphosate, the herbicide will remain an important part of US weed management programs. As weeds continue to adapt and develop multiple resistances, a much more robust management attitude must emerge. In many cases, glyphosate continues to be perceived by farmers as a very effective weed management tool and farmers predominantly report the desire to enhance their glyphosate program through the inclusion of new chemistry as opposed to completely replacing the herbicide.

The lack of strong chemical alternative options to glyphosate has generated demand for additional post-emergence herbicide chemistry to be made available for soybean production. Pending regulatory approval, in 2014 to 2015, new soybean genetics based on a glyphosate platform with a dual resistance to active growth regulator ingredients (2,4-D and Dicamba) are expected to be released on the market. These technologies are likely to find wide demand, especially in the central to southern Corn Belt. However, concerns over the impact of growth regulators on other crops combined with the potential for more rapid development of multiple resistances will continue to drive demand for additional solutions. In addition, concern from the environmental community over the introduction of 2,4-D to a larger area may restrain the total volume potential for this herbicide.

The major concern of weed scientists in the northern Corn Belt is the development of weeds with resistance to multiple classifications of herbicides[7]. Over time, continued intensive use of glyphosate, in some cases as the sole herbicide, has added glyphosate resistance to weed populations which were already developing resistance to several MOA. In many locations, including the Midwest, resistance to acetolactate synthase (ALS) inhibitors is already common. Over the past three years, new weed biotypes with resistance to hydroxyphenylpyruvate dioxygenase (HPPD) inhibitors, protoporphyrinogen oxidase (PPO) inhibitors and, in 2011, growth regulators[8], have been discovered in corn and soybean fields. While the populations appeared to be contained at the time, the unprecedented widespread pattern of glyphosate use allows weeds with resistance to multiple herbicides to become more common.

As weed pressure increases, true diversity in both chemical and production weed management programs will be required. Farmers will be driven to more intensive weed management programs which will include frequent rotation of herbicide classifications, effective crop rotation and increased tillage. While industry and academic weed scientists expect glyphosate to remain a key part of the herbicide arsenal, a mix of chemistries which span several MOA will be required for each herbicide application. Opportunities for the adoption of new seed genetics with resistance to multiple herbicides are likely to increase in the future.

Long Term Threat of Multiple Resistance Creates Need for New Use of Old Chemistry

The introduction of soybean genetics which are resistant to Dicamba and 2,4-D, will likely be well received by producers. However, weed scientists believe[9] this development does not add true diversity to the weed management programs. Both chemistries are classified in the same MOA, which has the potential to develop weeds with resistance in much the same way as glyphosate. Furthermore, the continued utilization of glyphosate in the same weed management programs threatens to encourage a weed population with resistance to both modes. Thus, the chemistry which is currently important in corn production could become marginalized for all row crops.

To enhance diversity enough to avoid neutralizing the already limited chemistry available for soybeans and corn, many additional MOA will need to be introduced for soybeans. In addition, each application of herbicides to any row crop will eventually need to include more than one effective[10] MOA. Spot application of mixed chemistries is also viewed as an alternative. In this case, farmers are willing to sacrifice part of their crop to ensure that the resistant population is controlled.

[7] Herbicides are classified into nine modes of action based on the varying physiological effect they have on weeds.
[8] Specific resistance to 2,4-D, which is in the same mode of action classification as Dicamba, confirmed from a 2010 Nebraska water hemp population.
[9] See Owen and Hartzler, 2012 Herbicide Guide For Iowa Corn and Soybean Production, http://www.weeds.iastate.edu/reference/wc9412.pdf
[10] Modes of action which do not already have resistant bio types in the field.

With no new chemistry currently being developed, the crop protection industry is turning to existing active ingredients for solutions. Farmers in Iowa and Illinois reported using a non-glyphosate pre-emergence herbicide for the first time in 15 years, on the 2012 crop. Soil applied herbicides with residual weed control, such as those from the triazine, dinitroaniline and chloroacetamide families, will likely see renewed demand. Use of older post-emergent active ingredients, such as fomesafen in soybeans and fluometuron in cotton, has already increased significantly over the past five years.

Increased Cost Will Require Higher Commodity Prices to Drive Production

Rabobank estimates the current breakeven for soybeans compared to corn-on-corn in the central Illinois area to be between 2.25 to 2.35 times the price for corn. The additional cost of USD 30 per acre will increase the economic requirement of producing soybeans to nearly 2.40 to 2.45 times the price for producing corn. Consequently, the cost to control herbicide resistant weeds is likely to solidify and accelerate the trend of increased corn–on-corn rotation throughout the Midwest, or increase the long-term average price of soybeans in the medium term.

Although corn production gains an additional economic advantage over soybean production as a result of glyphosate-resistant weeds, some additional costs will be required to control weeds in corn fields as well. As of 2011, over 70 percent of corn planted in the US was glyphosate resistant. As weeds develop resistance to glyphosate and threaten to become resistant to multiple MOAs, corn producers will need to mix chemicals and rotate them more frequently. The additional cost of preventative programs associated with corn is estimated by farmers and agronomic consultants in the northern Corn Belt to range between USD .055 per bushel to USD .080 per bushel. Additional costs associated with application, storage and handling will also be incurred.

While this is a relatively low cost compared to corn profit margins over the past five years, the impact will be felt as margins inevitably tighten. Farmers express concern over whether or not preventative measures will be sustained under tight margin conditions, preferring instead to pursue short term gains. In this case, the cost of production would likely increase by close to one third, which implies the need for even higher average commodity prices over time.

Need For More Precise Farming Practices to Increase Equipment Demand

As the battle against resistant weeds heats up, farmers are returning to more intensive management practices. The ease and widespread effectiveness of glyphosate allowed farmers to reduce or eliminate practices such as coordinating herbicide application timing through field scouting efforts and spot tilling areas where weeds had survived. Going forward, farmers will be required to manage weeds through timely application of the most effective herbicides. Consequently, increased demand for equipment that will allow farmers to have the flexibility to apply a variety of herbicides (e.g. chemical storage tanks and sprayers) should be expected. In addition, some demand may re-emerge for cultivating equipment as farmers look for ways to keep resistant weeds from surviving to propagate.

As these changes are driving farmers to a more precise approach to weed management, farm equipment manufacturers are likely to find opportunities for enhancing the process of weed management. In the drive to minimize cost and increase efficiency, technology for simultaneously optimizing different inputs, such as equipment, herbicides and fertilizer application, will likely open new market opportunities.

The total increase in demand for cultivating equipment is difficult to determine. Farmers *overwhelmingly indicate that herbicide application is the preferred choice. In no-till cases,* farmers indicate a strong reluctance to return to cultivation. Rather, the preference is a low or no-till approach, which relies on rotating herbicides. Nevertheless, the serious spread of resistant weeds will require a robust approach to integrated weed management of which mechanical options such as cultivating must be a part.

A Return to Conventional Soybean Seed not Likely

The increased cost of additional herbicides may tempt farmers to return to less expensive non GMO seed. A wide-scale movement in this direction is unlikely for the following three reasons. First, little has been done to develop widely adaptable new technology in conventional seed. While some genetics companies have maintained conventional breeding

programs, most of the available seed is regional. Depending on the location, glyphosate-resistant seed now yields 5-10 bushels per acre more on average than conventional varieties.

Second, new herbicide-resistance technology will emerge which will continue to advance application options. Seed genetics companies are in the process of introducing genetics with stacked capability to resist multiple herbicide modes of action. Beginning in 2014, additional GM products are likely to be released which will allow more diversity to production systems.

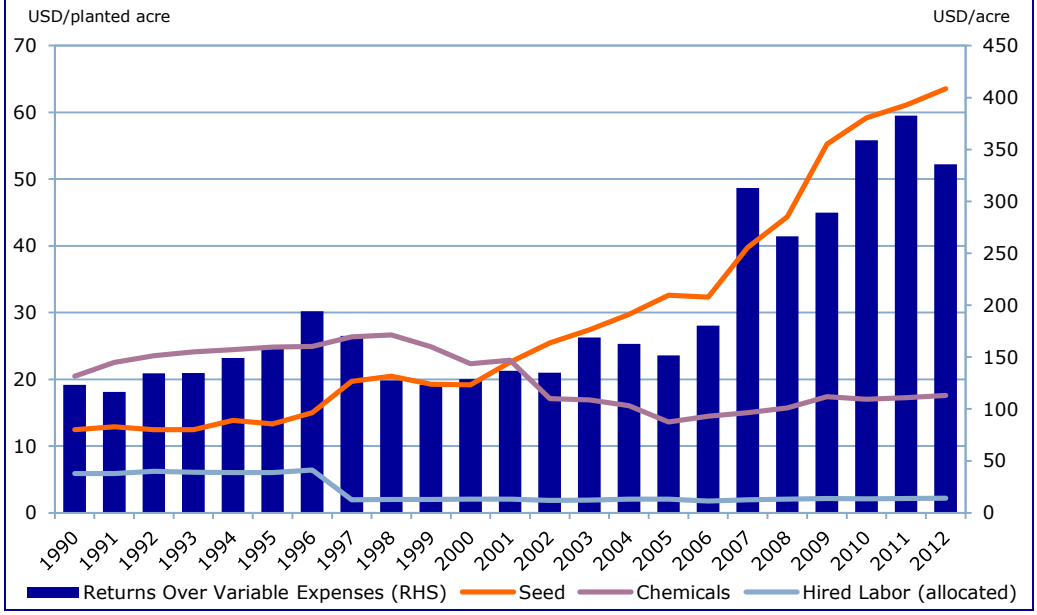
Third, glyphosate-resistant products have encouraged a movement to no-till practices which farmers are reluctant to abandon. Weed management of conventional soybeans requires controlling a wide spectrum of weeds with a limited number of herbicides. Consequently, cultivating through tillage is necessary both to control weeds and to make pre-emergent herbicides more effective. Therefore, a return to a strictly conventional system would be more likely to require expensive and less environmentally friendly tillage.

Lack of an Alternative Likely to Keep Seed Prices High

The increased cost of production is likely to have some effect on farmers' willingness to pay higher prices for GM products. However, with little likelihood of a large scale return to the old alternative of conventional seed, market share should be available for new products which are developed to allow increased diversity without forcing a substantial change in low tillage practices.

The current pricing structure of soybean seed reflects both the increased price of GM technology seen in the early 2000s and the increase in input costs stimulated by the commodity price booms beginning in 2005 (*see Figure 5*). Decreasing profitability driven by increased cost of weed control is likely to put downward pressure on glyphosate resistant seed prices. However, the demand to incorporate new genetic technology with multiple resistance will support prices for new seed products as genetic companies seek to recoup research and development costs.

Figure 5: Selected Soybean Production Cost Relative to Return



Source: Global Insite, Rabobank, 2011