Herbicide Application Rates: Risk Premiums with Environmental Implications

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Selected Paper Prepared for presentation at the
Southern Agricultural Economics Association Annual Meetings
Orlando, Florida, February 5-8, 2006

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Abstract:
This paper examines the role of risk aversion in setting herbicide label rates and application rates. Companies establish label rates to be efficacious for a wide range of conditions. The use of reduced rates of herbicide offer the opportunity to increase farm profit and reduce herbicide use, an environmental benefit.

Key Words: herbicide, regulation, insurance, decision making, environment, water quality.

JEL Codes: Q120, Q500

Herbicide Application Rates, Risk Premiums and Environmental Implications

Herbicide labels specify the legal use of the herbicide and the conditions of warranty. If the user follows the label instructions, including appropriate application rates, the herbicide company has certain guarantees regarding weed control and crop injury. Companies establish label rates to be efficacious for a range of conditions rather than for average or ideal conditions. This allows the weed control to be effective in most circumstances and minimizes the risk that weed control fails and the user files a claim.

Individual field weed pressure and the prevalence of factors that affect herbicide efficacy are unknown to the herbicide manufacturer but known to the user at the time of application. The user has better information than the manufacturer (asymmetric information opportunity). Weather conditions, soil conditions, and weed species and stage of development all affect the efficacy of herbicide applications and are better known by the farmer than the manufacturer.

Reduced rates of herbicide, while shown effective by university field trials, might nullify the warranty because the rates may not conform to the label instructions. Farmers with different utility functions and better local information have an opportunity to reduce herbicide rates to increase net income and reduce the total quantity of herbicides released into the environment.

This paper examines the role of risk aversion in setting herbicide label rates and application rates. This is a concept paper containing no data. It is intended to present a model that could be tested and give policy direction, assuming the model is accurate.

Labeled rate, as used in this paper, is the rate given on a herbicide label as providing weed control for the specified weeds. Label rates occasionally contain ranges that differ for specified conditions. For example, atrazine 4L is labeled at 3 pt/acre on coarse soils and 4 pt/acre on medium soils (Kendig and Johnson).

Many studies have shown that reduced rates of herbicides can provide adequate weed control and crop yields in various production systems. Conventional and no-till systems have been evaluated (DeFelice et al.; Johnson et al. 1997,1998). Soil-applied and postemergence herbicides have been evaluated (Devlin et al.; Prostko and Meade). Trials have been done on soybeans (Johnson et al. 1998), grain sorghum (Rosales-Robles, et al.), wheat (Lockhart and Howatt,) and corn (Donald et al.).

Applying reduced rates of herbicides can also be done via zone application by banding low herbicide rates between and over corn rows (less than normal rate but different amounts between vs over corn rows) (Donald, et al.).

Many of these studies have indicated that the use of reduced rates has the potential to increase profitability (Donald, et al.; Rosales-Robles, et al.; Dirks, et al.).

Many of these and other weed control articles indicate that yield is reduced with relatively few weed escapes, depending on the weed. Complete weed control is the objective.

Antidotal evidence indicates that crop producers are hesitant to apply herbicides at reduced rates. This raises the question of “why is the number of farmers that apply reduced rates of herbicides low?” Several possibilities exist. First, farmers may not be aware of the research and merely following the recommendations of their input suppliers. Alternatively, farmers may think that the increased cost of a possible second, rescue, treatment exceeds the reduced cost associated with reduced application rates.

Several sources of risk exist. The initial reduced rate may not give sufficient weed control. Rescue treatments may control weeds but not before a real or perceived reduction in yield occurs. Weather conditions could reduce the opportunity to apply herbicides in rescue treatment. Knowledge of the field and environmental conditions is essential for reducing risk associated with reduced rates of herbicides.

Herbicide performance is affected by weeds infesting the field, rainfall, soil type, temperature and many other environmental factors. Soil applied herbicides are dependent on weed species, percent organic matter and soil texture. (Kendig and Johnson). It is assumed that farmers have knowledge of the weeds infesting the field, soil type, organic matter and soil texture. Their knowledge of these conditions allows them to better determine what rate would be appropriate, if rate efficacy information is available. Labels often mention rates for different types of soils characteristics, such as organic matter, soil texture and pH.

Model

From the literature, it is hypothesized that weed control efficacy increases as quantity of the active ingredient in the herbicide increases until the plateau is reached (see figure 1 panel a). The plateau is hypothesized to be long because of the prevalence of studies indicating the reduced rates of herbicide provide weed control similar to label rates.

Weeds control is for the purpose of increasing yield of the commodity being produced so the weed control efficacy function is transformed into a production function as in figure 1 panel b. Stage II is exhibited until the plateau is reached. While the weed control efficacy function did not reach stage III, the yield production function would.

Excessive herbicides have the ability to injure the crop for which they are labeled (Gunsolus and Curran). Because incomplete weed control has the ability to significantly reduce yields, the production function is kinked near the plateau.

Farmers using herbicides are purchasing weed control events. They purchase a weed control event to insure production unreduced by weed pressure. The weed control event is the labeled rate of herbicide. It will be shown later that the labeled rate or weed control event rate, Q, lies somewhere on the plateau of the production function. The concept that herbicide companies sell weed control events, rather than herbicides per se, is critical to understanding the model.

The herbicide company can set the label rate of the herbicide anywhere on the plateau to achieve max weed control subject to the limits that the label rate has been approved by the federal regulatory agencies. The regulatory agency views documents provided by the company on the impact of the chemical on human health and the environment. Label rates are scrutinized by the regulatory agency for their impact on the environment rather than for their efficacy. The company does not have to prove that the label rate is the lowest rate at which weed control is achieved. The regulatory agency is concerned that the maximum rate permitted does no harm to the environment or human health.

The Herbicide Company Decision

Their objective function is to maximize profit by selling weed control events.

(1) $\Pi = PQ - rX$;

where Π is profit; P is the price of a weed control event; Q = the number of weed control events sold; r is a vector of input costs and X is a vector of inputs. The company sells in an imperfectly competitive market where the quantity of weed control events sold is affected by price of the event and competitor's weed control event products.

(2) $\partial Q / \partial P < 0$

The quantity of herbicide active ingredient, q, necessary for a weed control event, Q, is the relevant question of this paper. If the quantity necessary to provide an effective weed control event lies on the plateau of the production function then $\partial Q / \partial q = 0$.

The impact of q on profit is unknown. Profit decreases as the pounds of active ingredient sold increases because the company is selling weed control events rather than product. More active ingredient per weed control event costs the company more. However, it is hypothesized that the marginal cost of an additional unit of active ingredient approaches zero. The full cost of the herbicide is hypothesized to consist predominantly of research and development, and marketing and distribution expenses. Active ingredient is relatively inexpensive. Therefore, the marginal cost is assumed so small as to have negligible affect the choice of q. Profit could decrease with q, if unsatisfactory weed control results in loss of market or high warranty fulfillment costs.

It is also assumed that the herbicide company is risk averse, having a concave utility function with respect to profit. The uncertainty of the exact specification of the weed efficacy function gives greater uncertainty to Q near the rate where the plateau begins (illustrated by high/low points on figure 1, panel a). Selecting a rate, q, near the left side of the plateau increases the risk of a poor weed control event, Q. Selecting q towards the right side of the plateau gives greater certainty that weed control will be successful under the greatest number of environmental and production scenarios.

Increasing the certainty of Q, reduces the probability that a farmer will have unsatisfactory weed control and file for damages.

However, if the herbicide company sets the label rate too far on the right of the weed efficacy function the risk of herbicide injury increases. (Note: this also increases cost but, as mentioned earlier, the marginal cost is sufficiently low as not to be a determining factor in setting the rate). As the probability of crop injury occurs, the probability that farmers will file for damages increases.

The risk of incomplete control or of crop injury causes the herbicide company to select the label rate somewhere along the plateau. They will try to balance the probabilities and cost of each type of damage to set a rate that minimizes expected costs. If the herbicide company had perfect information of each specific use, it could set the application rate lower. But with imperfect information, the rate is set to accommodate most circumstances.

The Farmer Decision

The farmer is assumed to maximize profit of crops grown. Yield, Y, is a function of q, as illustrated in figure 1, panel b.

(3) $\partial Y / \partial q \geq 0$

Cost also is a function of q. While the cost of ingredients to make q are minor to the company in an imperfectly competitive market, the cost of the weed control, C, is a more important factor to the farmer.

(4) $\partial C / \partial q > 0$.

Selecting rates of herbicide above (below) the label rate will increase (decrease) the weed control cost to the farmer. The farmer has incentive to decrease q while obtaining a good weed control event. The savings associated with reduced rates of herbicide, S, will be the cost of herbicide, H, times the difference between the labeled rate, R_l and the reduced rate, R_r.

(5) $S = H \times (R_l - R_r)$

If q is prior to the plateau, yield responds positively to more q because of greater weed control. If q is on the plateau, yield will not respond to increase q because weed control is complete. Because the company sets the label rate for q on the plateau and because increasing q increases cost to the farmer, a farmer will have no incentive to increase the rate of herbicide beyond R_l. However, there is a range of Q, below the label rate, where the farmer can reduce q without decreasing weed control or yields. Farmers have an economic incentive to reduce herbicide rates in this range.

Two factors indicate that farmers could reduce rates without adversely affecting efficacy. First, published studies indicate that reduced rates are possible without reducing efficacy. The published field trials were done under varying environmental conditions and production systems, indicating that reduced rates can give good weed control without reducing yield. The company apparently has set the labeled rate far enough to the right of the beginning of Q, to permit weed control in many situations at levels lower than the label rate. (Note: trials that do not support reduced rates may not be as likely to be published so the presence of reduced rates studies does not necessarily mean that they work in all situations).

Second, farmers know certain conditions that affect efficacy and can adjust their rates accordingly. Given their knowledge of the size of weeds at spraying, the soil properties of their fields, the environmental conditions affecting herbicide efficacy, they can reduce the quantity of herbicide applied if the conditions indicate good conditions of successful weed control. Local knowledge gives the opportunity for more efficient rate decisions.

Farmer adjusted herbicide rates may fail because of 1) optimism bias where the farmer believes the field conditions to be better than they are, and 2) imperfect, though better than the herbicide company, information regarding the environmental conditions during herbicide uptake by the targeted weeds. Weed control failure could happen with labeled rates but is more likely to happen with reduced rates.

Several costs of weed control when using reduced rates exists. A rescue treatment may be necessary. The rescue treatment would have the cost of application, A, and additional herbicide product, R_2. Rescue treatments may not occur soon enough to prevent yield loss so L_y, yield loss due to delayed treatment, if any becomes a cost. Adverse weather conditions (rain keeping the sprayer out of the field or poor growing conditions reducing adsorption of the product) are the major factors creating untimely events.

(6) $$C = P_r(A + R_2 + L_y) ,$$

where P_r is the probability that a rescue treatment becomes necessary.

Finally, reduced rates may void the warranty of the herbicide company. Some failures are going to occur even with the use of label rates. The reduced rate may not have been the cause of the weed control failure but it means that the farmer, rather than the herbicide company, will bear the cost.

If the farmer is risk neutral, the decision of whether to apply labeled rates or reduced rates would be a simple analysis of savings and cost. If expected savings is greater than expected cost, reduced rates would be preferred by the rational risk neutral decision maker.

The weed science literature suggests that risk neutral decision makers would be using reduced rates of herbicides. Current lack of use of reduced rates of herbicides indicates that the farmer is risk averse, with a concave utility function, regarding herbicide decisions. Applying herbicide at the labeled rate gives a certain outcome – weed control will be satisfactory or the company warranty will cover losses due to failure. Applying herbicide at reduced rates is a risky action – some probability exists of saving the cost of herbicide not needed and some probability exists of having unsatisfactory weed control not covered by the herbicide company warranty.

Figure 2 illustrates the utility associated with the choice. Π_{Rl} is the certain outcome associated with use of labeled rates; Π_{Rr} is the savings that would occur by successfully using reduced rates; Π_{R2} is the expense that would be incurred with unsatisfactory control requiring a rescue treatment. $\overline{\Pi}_R$ is the expected value of the risky action. The difference between Π_{Rl} and $\overline{\Pi}_R$ is the risk premium. The farmer is willing to forego the additional expected value for the certain outcome of using labeled rates.

The presence of a risk premium indicates that more herbicide is being used than would be necessary on the average. Analysis of the risk premium gives an indication of the amount of herbicides that is released into the environment for “insurance, non-weed control” purposes. If the risk premium could be reduced, herbicides released into the environment could be reduced.

Assuming that the utility function of the farmer is fixed, reducing herbicide escape into the environment requires reducing the risk premium by reducing the probability of an unfavorable event or of the cost of the unfavorable event. Several alternatives exist for to reduce the cost of unsatisfactory control to farmers.

First, better information could be supplied by the herbicide companies and university researchers into the factors affecting herbicide efficacy. This information could be used in plant growth models to more precisely determine application rates, reducing the risk of necessary rescue treatments, P_r. This alternative requires that the transactions costs of knowing and using information be reduced. Computer power has reduced the transactions cost and may be approaching a level where individual advisories can be provided to individual farmers.

Because herbicide release into the environment is an externality which the farmer currently does not incur, there have been some projects funded by governments to subsidize the cost of rescue treatments should they be necessary. One project in the Route J watershed of Missouri guaranteed farmers who used ½ rates of atrazine that any necessary subsequent applications would be paid by the state. During 3 years of the project, rescue treatments were never used. Atrazine levels were significantly reduced in the drinking water reservoir and the state incurred no cost associated with additional treatments.

As an alternative to government programs, insurance companies could offer policies that cover loss due to reduced rates. It is hypothesized that the transaction cost and opportunity for moral hazard are too great for such policies to be effective.

Conclusions

Reduced rates of herbicide currently may not be optimal for the farmer for several reasons. First, the chemical is inexpensive and the label rate, though more than necessary for control, is an inexpensive way to insure that subsequent weed control measures are unnecessary. Second, risk averse farmers want the warranty that accompanies the use of herbicides according to the label.

If application rates could be reduced, farm income might rise and the quantity of herbicides released in the environment might be reduced – both desirable outcomes not obtained given the current structure of labeling and warranties. The reduction of transaction costs and concern of government entities to reduce herbicides in water may offer some means of more accurately determining herbicide application rates.

Figure 1. Weed control efficacy function and yield production function

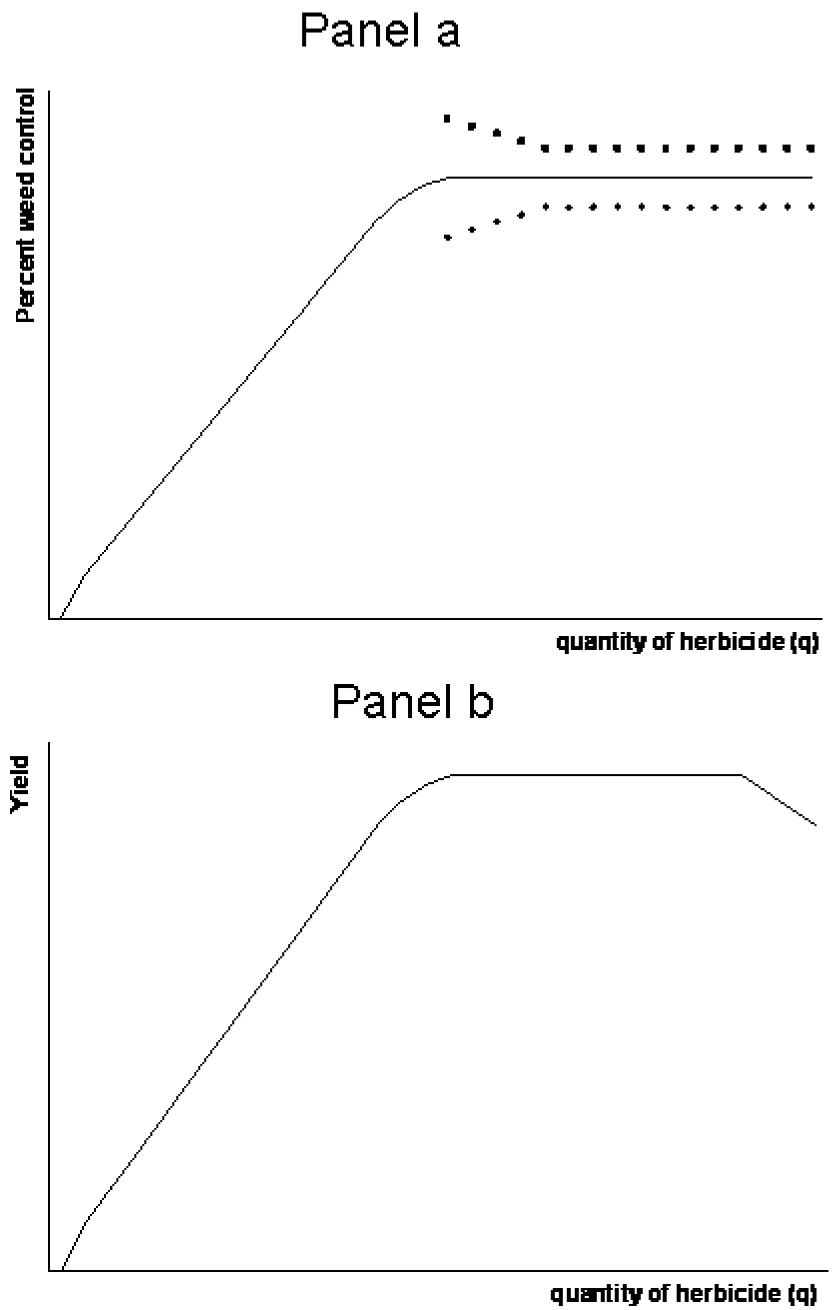
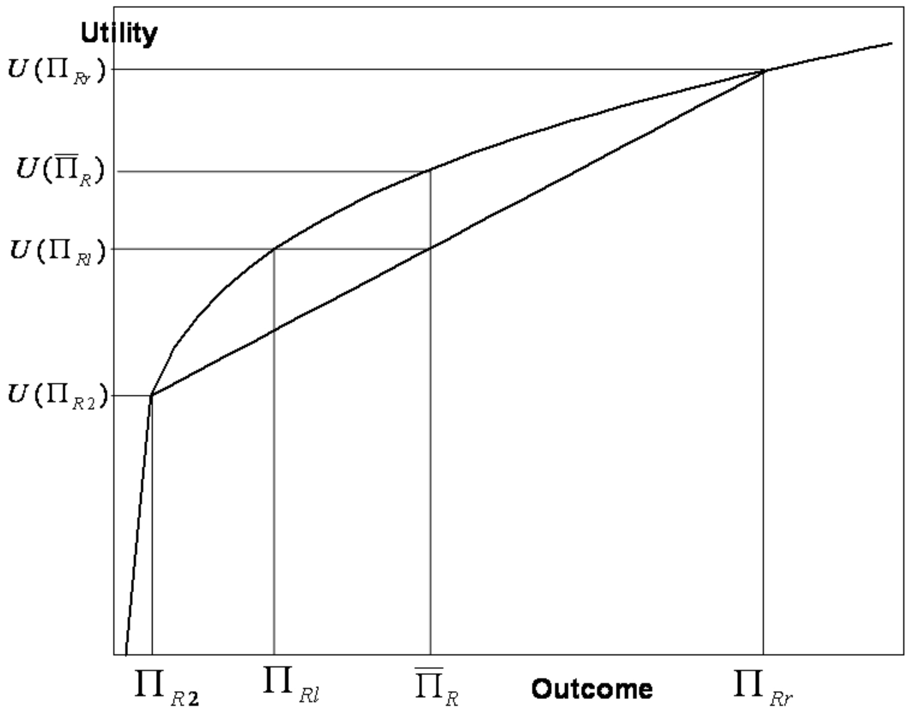


Figure 2. Expected Utility and Risk Premium of Herbicide Rate Decision.



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