DO HERBICIDES REDUCE INCOME VARIABILITY FROM AGRONOMIC CROPS?

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Summary. It is generally perceived that increased application of herbicides leads to reduced riskiness of cropping. In this paper it is shown that while higher rates do lead to lower variability of herbicide efficacy and weed density, they can lead to greater variability of income. This is due to variability in factors such as phytotoxicity, grain pricesand the weed-free yield. For control of ryegrass with diclofop-methyl in Western Australia, it is shown that price and yield uncertainty are the most important causes of income variability and that weeds and herbicides make only a small contribution to income variability.

INTRODUCTION

There is ample evidence that most farmers, both in Australia and elsewhere, are "risk averse" (2, 4, 5, 8, 10) . Risk aversion, in this context, means a preference for stability and certainty of income (1). Risk averse individuals are prepared to sacrifice some expected income in order to reduce the variance of their income.

Herbicides and other pesticides are generally perceived to be inputs which reduce risk (e.g. 7, 13, 15). Some farmers attempt to reduce income variability by applying more chemical than would be necessary to maximise profits. However the variability of a number of factors is affected by application of herbicide. Pannell (12) has shown that for some of these factors, herbicide application increases variability, casting doubt on the effectiveness of high herbicide dosages as a means of reducing income variability.

Variable or uncertain factors in the herbicide/weed/crop/economics system include:- the effectiveness of a given dose of herbicide, the number of weeds actually present in the crop, the competitiveness of the weeds,- the degree of phytotoxicity of herbicide on the crop,- the yield potential of the crop, and the price received for output.

One aim of this paper is to estimate, for a particular example, the contribution of each of these factors to overall income variability. The other aim is to determine whether under the combined impact of all these sources of variability, herbicide application increases or decreases variability of income. The example is control of annual ryegrass, *Lolium rigidum*, in wheat by post-emergence application of diclofop-methyl (Hoegrass). Some assumptions of the analysis are specific to heavy soil at Merredin in Western Australia's eastern wheatbelt.

METHODS

The model. Crop yield (Y) is represented using the following general form.

(1) $$Y = Z.[1 - D(W)].[1 - X(H)]$$

where Z is production with no weeds present, D is the damage function representing the proportion of production lost at weed density W, and X is a function giving the proportion of yield lost through phytotoxicity from herbicide dose H. The hyperbolic functional form suggested by Cousens(6) is used for D(W) and a linear function is estimated for X(H). W is a function of V, the pre-treatment weed density, and K(H), the proportion of weeds killed at herbicide rate H.

(3) $$W = V.[1 - K(H)]$$

The kill function, K(H), is represented here by a logistic function (9). Parameters and detailed functional forms for D(W), X(H) and K(H) are taken from Pannell (12) who estimated the model for diclofop-methyl application to ryegrass in wheat.

Profit (T) is given by

(4) $T = P.Y - C.H - A - F$

where P is output price, C is herbicide cost, A is herbicide application cost (which is independent of the application rate, H) and F represents costs from all other inputs. In the following analysis it is assumed that P = $150/tonne (net on farm), C = $48/kg a.i., A = $2.50/ha and F = $63/ha.

The variable factors. For each of the uncertain or variable factors listed in the Introduction it was necessary to estimate the level of variability likely to be encountered for the example problem. This was done as follows.

Herbicide efficacy. In field trial data it can be difficult to distinguish between variation in final weed density due to variation in weed kill and that which is due to variation in the pre-treatment weed density. For this analysis the coefficient of variation [c.v.(%)] of weed mortality wassubjectively estimated based on field trial data and anecdotal evidence. The assumed c.v.(%) of final weed density was 20% at 50% survival.

Weed competitiveness. Field trial data indicated that the c.v.(%) of yield due to differences in weed competitiveness was approximately 10% at zero herbicide applied.

Weed-free yield. The distribution of weed-free yields was estimated using a simulation model of wheat growth/water balance. This was solved repeatedly for heavy soil at Merredin using data from 1912 to 1987. The resultant distribution of yields had a mean of 1.17 tonnes/ha and a standard error of 0.47 tonnes/ha.

Pre-treatment weed density. Weed density varies over time, between crops and within a crop. Even if the weed density is estimated by sample counts, some uncertainty remains about its actual value. For this analysis the variance of weed density was estimated from replicates of chemical company trials. The estimated c.v.(%) was 20%. The mean pre-treatment weed density was assumed to be 300 plants/square m. This value was chosen arbitrarilyfor illustrative purposes. In practice the mean value could be between zero and a thousand or more plants/square m.

Phytotoxicity. The proportion of yield lost at a diclofop-methyl rate of 0.375 kg a.i./ha was estimated from 14 field trials in Western Australia between 1983 and 1988 as having a mean of 0.054 and a c.v.(%) of 90%.

Wheat price. The c.v.(%) of wheat price was estimated from residuals of aregression of wheat prices over recent years against time. The estimatedc.v.(%) was 20%.

Procedure. The model given above was used to calculate the relationship between herbicide rate and net profits per hectare (excluding fixed costs and family labour costs). Initially it was assumed that none of the above factors was variable. Then the mean and standard error of profit perhectare was calculated for a range of herbicide rates with one factor at a time being treated as variable or stochastic. This indicated the magnitude of the individual contribution of each factor to overall income variability. Finally the model was solved with variability included for all factors simultaneously.

RESULTS AND DISCUSSION

Table 1 shows the net profit for a range of herbicide dosages with no variability included in the model. For this particular example, profit is maximised at a herbicide rate of approximately 0.3 kg a.i./ha.

Table 1. Net profits at different herbicide dosages ($/ha).

Rate of diclofop-methyl (kg a.i./ha)	0.0	0.1	0.2	0.3	0.4
Net profits ($/ha)	38	51	75	81	78

Table 2 shows the standard error of profit/ha with different factors assumed to be stochastic. Except for the results labelled "All", factors other than the one being examined are treated as certain and deterministic.

Table 2. Standard error of net profits at different herbicide dosages with different factors treated as stochastic ($/ha).

Stochastic	Rate of diclofop-methyl (kg a.i./ha)				
factor	0.0	0.1	0.2	0.3	0.4
Nil	0.0	0.0	0.0	0.0	0.0
Herbicide efficacy	0.0	5.1	5.2	2.4	0.97
Initial weed density	3.6	6.5	3.4	0.87	0.18
Weed competitiveness	11.0	11.0	6.6	2.5	0.89
Phytotoxicity	0.0	1.7	4.2	6.9	9.4
Wheat grain price	23.0	27.0	34.0	36.0	37.0
Weed-free crop yield	48.0	59.0	66.0	67.0	66.0
All	53.0	68.0	77.0	77.0	76.0

It is striking that the major sources of income variability are wheat price and weed-free crop yield. Factors more directly related to the herbicide and weed (herbicide effectiveness, initial weed density, weed competitiveness and phytotoxicity) make only a small contribution to overall variability of income.

The low level of income variability due to variability in herbicide efficacy may be surprising. Fig. 1 shows why it occurs. If a low rate of herbicide is applied, the mean weed density is high, leading to relatively high yield loss. However the high variability of weed density at this low herbicide rate does not result in high variability of yield (and thus income) due to the shape of the yield loss function. On the other hand if a high herbicide rate is used, the mean and variance of weed density are greatly reduced. While this reduces the mean yield loss, the variance of yield loss is not necessarily reduced at all due to the steepness of the yield loss function at low weed densities.

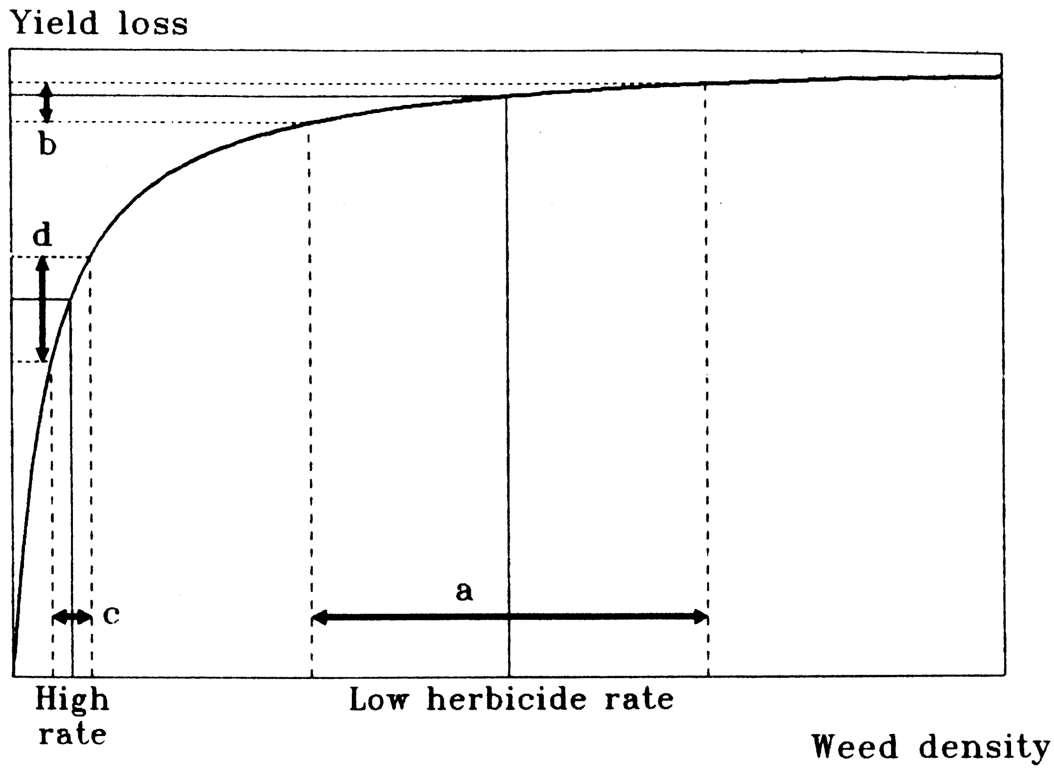

Figure 1. High variability of weed density at low herbicide rate (a) does not lead to high variability of yield loss (b). Increasing the herbicide rate reduces variability of weed density (c) but not of yield loss (d).

It should be noted that although income variability is insensitive to variability in herbicide efficacy, this does not imply that the optimal herbicide dose is insensitive to herbicide efficacy. In fact Pannell (12) found that herbicide efficacy is the variable to which the optimal herbicide dose is most sensitive.

Of the six variable factors examined, three are associated with lower income variation at higher herbicide rates (herbicide effectiveness, initial weed density, weed competitiveness) and three result in higher income variation at higher rates (phytotoxicity, wheat grain price, weed-free yield). Thenet result is that at rates above 0.1 kg/ha, income variability is almost unaffected by changes in the herbicide rate (see bottom line of Table 2).

Why, then, have herbicides and pesticides generally been perceived as risk reducing inputs both by farmers and by academic agricultural economists? I suggest that there are different reasons for these two groups. For farmers the main focus is on herbicide efficacy. They correctly perceive that at lower rates, herbicide performance is more variable so they view higher dosages as being less risky. However they may not perceive the greater riskiness of higher dosages due to the factors such as phytotoxicity and wheat price variability. This is not surprising due to the easy visibility of a herbicide failure, whereas a 10% yield loss through phytotoxicity, for example, may go completely undetected.

Agricultural economists have also been guilty of taking too narrow a view of the problem. In almost all published studies on the risky aspects of pesticide use, attention has been focused on uncertainty about the weed or pest density (e.g. 3, 7, 11, 14). This focus has resulted in the view that pesticides reduce income variability. There has previously been no published study analysing the effect of a pesticide on riskiness of income given variability in phytotoxicity, crop price or pest-free yield.

It is concluded that, at least for this example problem, the herbicide should not be considered as a risk reducing input since its overall impact on risk is small and, if anything, positive. The relevance of this conclusion to different herbicides, weeds and environments will vary. The extent of yield variability will depend on the particular environment and the crop being considered. The degree of phytotoxicity and its variability depends on the herbicide used and the crop species. Grain prices are generally variable, although for some crops in some countries producers are sheltered from price variation by various price support schemes. Nevertheless it seems likely that for most weed control problems in crops, one or more of these factors will at least reduce if not eliminate the risk-reducing properties of herbicides.

This is not to say that there are not important economic benefits to be gained from herbicide use; table 1 shows how herbicide can increase expected profits. However it seems that the additional benefits of herbicides as an "insurance policy" can be illusory.

It has been shown that reducing herbicide rates below label recommended doses can be profitable (12). Results presented here mean that arguments against rate cutting based on assertions that it increases risk may be invalid and must be examined critically.

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