AN ABSTRACT OF THE THESIS OF

LANE EDWARD COULSTON for the MASTER OF SCIENCE
(Name) (Degree)

in AGRICULTURAL ECONOMICS presented on [illegible]
(Major) (Date)

Title: AN ECONOMIC ANALYSIS OF ALTERNATIVE HERBICIDE PRACTICES



Abstract approved: John A. Edwards



There is a critical lack of economic information in the area of chemical weed control. This paper is intended to stimulate study in this area. The objective is to develop a method of economic analysis of alternative herbicide practices.

The data used were taken from a Druchamp winter wheat trial conducted on the Hyslop Agronomy Research Station at Oregon State University in 1966. Diuron and linuron were used at four dosage levels at pre and postemergence.

Production functions for the four herbicide treatments were determined for all alternatives. Price ratios of herbicide and wheat were used to determine points of profit maximization. Limits were established for levels of profitable herbicide use. Within these limits, alternatives may be selected depending on the prevailing price ratio conditions.

The results from this analysis are in no way indications of recommended herbicide practice due to the experimental data used. One practice however, was found to be superior to all other alternatives in this problem analysis.

In the concluding remarks, the values and limitations of this approach are discussed. The principal weakness is a lack of adequate information to be used by economic analyses.

A discussion is included of economic aspects of herbicide use that have not been fully investigated. Suggestions are made for topics of future economic study that would be valuable contributions to the field of chemical weed control.

# An Economic Analysis of Alternative Herbicide Practices

by

Lane Edward Coulston

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1969

APPROVED:

Redacted for Privacy

Associate Professor of Agricultural Economics
in charge of major

Redacted for Privacy

Head of Department of Agricultural Economics

Redacted for Privacy

Dean of Graduate School

Date thesis is presented August 29, 1968

Typed by Donna L. Olson for Lane E. Coulston

ACKNOWLEDGEMENTS

My sincere appreciation to Dr. John A. Edwards for his guidance and encouragement in developing this thesis. His critical review of this manuscript has been invaluable.

To Dr. William R. Furtick for his foresight, enthusiasm and stimulation that encouraged me to undertake this study.

To Dr. Emery N. Castle for review of this manuscript and guidance in my graduate program.

To Dr. Arnold P. Appleby for review of this manuscript.

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

# AN ECONOMIC ANALYSIS OF ALTERNATIVE HERBICIDE PRACTICES

## CHAPTER I

## INTRODUCTION

Weeds are plants that are growing out of place. Actual crop losses result from the intrusion of these undesirable plants. Plant competition is the natural force where plants compete for available space, light, nutrients and soil moisture. Weed species detract from the potential growth of the crop. Competition between crops and weeds is most severe when competing plants are similar in vegetative habits and demands upon available resources.

Weeds possess many characteristics of establishment and growth that make them difficult to control or eradicate. They have competitive advantage as they are capable of rapid establishment and early growth. Weeds respond quickly to available soil moisture and nutrients. Studies have shown that crop yield reductions from weed competition occur during the first several weeks of growth and their presence after this time is practically negligible in reducing yield.

After seedling establishment in annual crops, a substantial number of weed species are capable of withstanding cultivation control practices. These remaining weeds present a problem of reinfestation with the production of an abundance of weed seeds. Weeds are difficult to control because of their widely adapted mechanisms for seed longevity and establishment. Weed seeds are capable of lying dormant in the soil for many years. All viable seeds do not germinate in any one year. Under present tillage practices, stirring and turning the soil brings seeds to the surface, where they obtain favorable conditions for germination and establishment.

The longevity and establishment of weed seeds is perhaps the most fundamental and most complicated problem in weed control. Because of variations in weed species, climatic conditions and cultural practices, the potential loss from weeds is ever present.

## Economic Losses

Determination of the economic losses is not an easy task. The actual loss in potential or the additional costs incurred in agriculture production is at best an estimation because of a lack of adequate data.

The most obvious direct loss from weeds is a yield reduction arising from plant competition with the crop. The presence of weeds at time of harvest may increase the costs of harvest and in some cases actually reduce the quality of the final product. Costs of production are increased. Labor and cultivation requirements rise. The presence of weeds in pasture lands reduce the carrying capacity and accounts for a reduction in livestock production. Weeds clog waterways for irrigation. Insects and diseases are harbored by weeds and are responsible for crop losses. Weeds also affect land value (Ennis, 1967).

## Demand for Herbicides

The control of weeds is basic to agriculture production. Since the discovery and introduction of 2,4-D after World War II, the field of chemical weed control has grown rapidly. Agriculturists are concerned with less costly and more efficient methods of controlling weeds. In recent years, herbicides have acquired wide scale acceptance in the United States. As a result of this acceptance, more and better herbicides are being demanded in all areas of agriculture and crop production.

The agricultural production land in the United States is only a small portion of land throughout the world involved in providing for the world's population. The importance of weed control in relation to other agricultural pursuits has been slow to be recognized in many areas, especially the less developed nations. Weeds are considered a problem in all production areas but their impact on production is not fully realized. These areas involve most of the world's population and nearly all of the areas where food is critically short.

The advancement of this new technology is critical to supplying food for the world's population. At present the Agency for International Development (AID) estimates indicate 60% of the world's population is suffering from malnutrition, principally protein deficiency. It should be evident that increases in food production have lagged behind population growth rates. The problem of maldistribution of the food supply is evidenced by areas of poverty and hunger. Many of these areas have the potential for feeding their population.

The rapid growth of the chemical weed control in the United States and Europe has created a serious demand for staff and personnel to support the needs of sales, research and development. The growing concern for increased agriculture production in areas where food shortage is a problem has increased the need for qualified personnel. The total number of people in universities, government and industry who try to service this enormously varied and complex field, in relation to the economic importance, is pitifully small. The main effort is being made in the areas of research in order that the benefits and facilities of chemical weed control might reach and benefit as many as possible in agriculture throughout the world.

The majority of the literature reviewed for this paper was taken principally to obtain a cross section of the efforts being made in the area of economic studies of weed control. Papers presented in various regional weed control conference proceedings are based on preliminary studies comparing yield differences and costs of herbicide and application. Many of these papers were presented with intention of dramatizing the extreme losses due to weeds and to motivate farmers to increase the total farm use of herbicides.

From available information sources, there is no evidence of intensive studies of the economics of weed control by agriculture economists in this country. There have been studies in this area conducted by several British economists. Hillebrandt, in abstracts from the "Journal of Agriculture Economics", has discussed the economic theory involved in studies of pesticide use. Gwyn presented a paper before the British Weed Control Conference discussing production functions and dosage response curves. In this paper he also outlined the type of experimentation and data necessary to establish the maximum and economic optimum points of production.

Various attempts have been made to estimate losses by region, state, and for the United States. These estimates range from \$3.5 to \$5 billion annually on a national basis. These figures, as given by Knake, are combined figures of values of net yield at current agriculture prices plus the cost of herbicide and application. These estimates, while impressive are not valid figures expressed in production potential and the existing demands for agriculture commodities. The increase in agriculture production, as represented in these figures at current prices, may have a considerable impact on the marketing of these inelastic commodities. A marked increase in agriculture production, could represent a serious depression in prices in one country. There is presently a great demand for food outside the United States but the question arises as to the economics of moving this production into the needy areas. If increases in demand by increasing population in the United States, for example, keep pace with the increasing adoption of herbicide use, the suggested imbalance may not occur.

These potential loss figures are questionable as to accurate measurement of the effects of weeds alone. Many other crop loss factors such as plant disease, insects and nematodes may have some interacting influences. It is presently very difficult to arrive at reliable values of agriculture losses from weeds.

## Cultural Practices

The introduction of chemical weed control involves changes in many traditional practices. The row spacing of many crops is determined by the type of implement, animal or mechanical operation that must be accomodated for weed control. Present row spacing and plant densities are questionable as to optimum yield potentials. As better control methods develop, there is a trend toward closer row spacing, precision planting and higher plant populations per unit area (Ennis, 1967).

In the small grain crops and especially in corn production in the midwestern United States, there have been dramatic changes in cultural practices involving minimum tillage and cultivation. These crops are now capable of being grown with the use of chemical seed-bed preparation and a minimum amount of cultivation.

## Agriculture Society

An example of a large acreage crop markedly affected by the introduction of herbicides is cotton. Hand labor has been traditionally employed for the weeding and harvest of the crop. Methods of mechanical harvest could not be implemented until a chemical was discovered to control the weeds in cotton. The impact here was on the labor requirements. One practice could not be implemented without the other. The labor force would have been too expensive to retain for only one job. Mechanical harvest and chemical weed control are strongly complementary in this situation.

Changes in cultural practices may have more than a direct net yield effect on agriculture production. Many practices, besides being labor saving, may represent substantial reductions in machinery costs. Indirect associated costs of other supporting items and services may be reduced. The agriculturist is interested in reducing production costs both fixed and variable.

What may appear to be reduction in demand and consumption for certain items on the farm may reappear in demand and consumption for other goods and services. Changes in demands may show up in other sectors of the economy. As a result of new practices and new technology, production in agriculture is expected to increase its contribution to the total growth and development of the economy. Cost reduction on the farm may reappear in other sectors as an effect of savings on the farm and investment in other sectors of the economy.

Discussing labor demands in agriculture is not new. As production efficiency increases, more people are forced to move off the farm. As farm laborers are replaced by new advances in technology, the unemployed move to the cities in search of new employment. Undoubtedly, many of the social and political problems with which the nations are faced today can be traced back to the changing situations in agriculture.

The western world has been dealing with these social problems for many years. The impact that chemical weed control has on labor displacement here is now of little serious consequence. In nations where weed control is a limiting factor in the development of agriculture, growth and change in the agriculture society will be greater as a result of this introduction.

## Structure of Paper

Although competition from weeds has been recognized by farmers since the beginning of agriculture, it has only been since World War II that a concentrated effort has been made to thoroughly determine the importance of weed control in agriculture production. As a new generation of weed control personnel has arisen to take their place among the many diverse agriculture specialists, they have found that weeds are a much more important factor limiting food production and utilization of new technologies than has been previously recognized by agriculture authorities.

It is with this interest in mind that I have selected the topic of an economic analysis and evaluation of alternative herbicide applications for my thesis problem.

The second chapter of this paper deals with the setting of the economic stage. The economic theory to be used is production economics as it applies to agriculture production. Within this framework will be treated marginal physical products as a function of an agriculture input. Applying monetary value to this function, value of marginal products and optimum and maximum points of production will be established.

Chapter three will involve the introduction of weeds and herbicides into the production economics theory presented previously. This will involve the presentation of a statistical problem analysis and the results taken from the analysis.

Comparisons of the herbicide practice analyzed in chapter three will be made in chapter four. Graphic illustrations will be used to analyze the herbicide practice found to be most economical within the limitations of the experimental data.

Finally, the last chapter will be an interpretation of the case study as a whole. Limitations as well as the strengths and weaknesses of the problem analysis will be discussed.

# CHAPTER II

## PRODUCTION ECONOMIC THEORY

Basic to the entire development of this paper is the agriculture production function. The concern is for the relationship between the input of an agricultural variable and the resulting yield of an agriculture output.

The yield of an annual crop is a variable function of a number of variable inputs. In order to study this relationship, all other inputs that normally contribute to production will be held constant. The change in yield is measured as unit increments are added. This relationship can be seen in Figure 1.

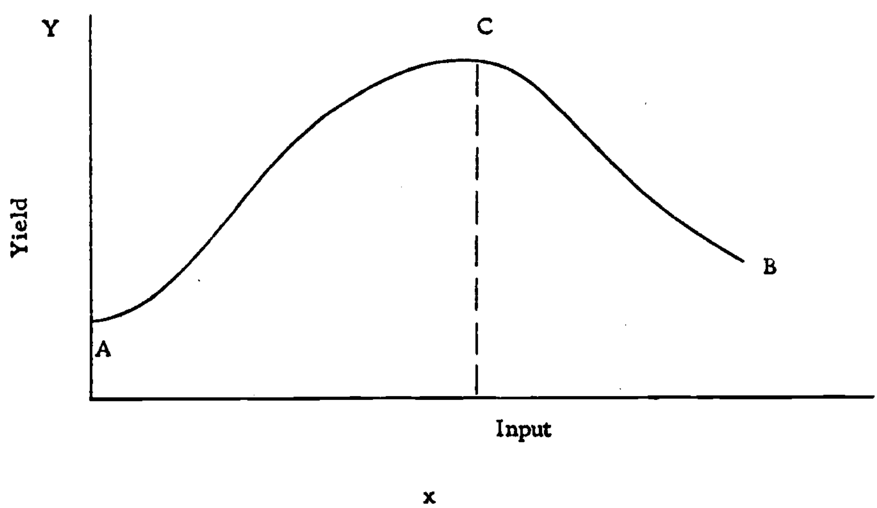


Figure 1. Total Product Curve

Yield is registered along the Y axis and the variable input on the X axis. From the yield response of no input at point A, through point B, the yield is expressed first to a maximum at point C, thereafter declining from such level of input where any additional amount of input results in a decrease in production. This curve from A through B is the total product curve.

Another important relationship is the marginal product curve, MP. This curve, Figure 2, establishes the effect of changes in output for each successive increment of input. The total product curve may increase first at an increasing rate followed by an increase at a decreasing rate, to a point of maximum production, C.

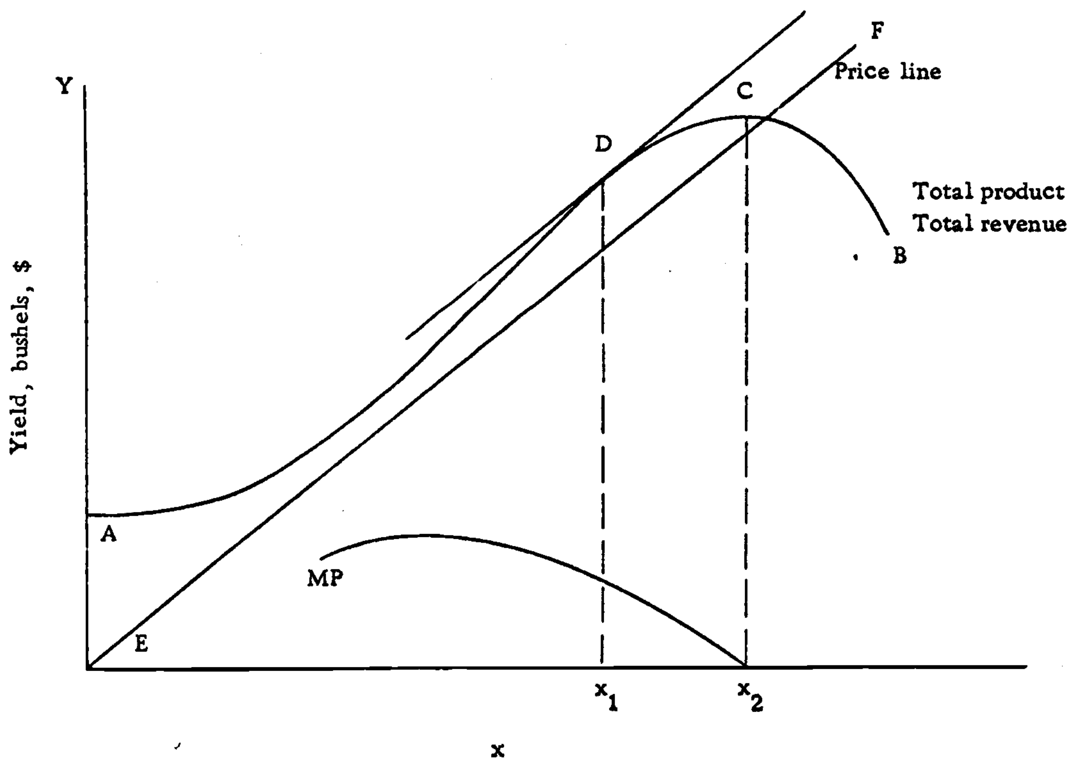


**Figure 2. Optimum and Maximum Production.**

As production increases at a decreasing rate, marginal product is declining. Point C is where the marginal product is equal to zero. Any addition of input beyond this point is a negative marginal product, as yield is decreasing.

In order to study these functions from an economic viewpoint, the total product curve must be transformed into a monetary expression. A price assigned to the product gives a total revenue curve the same shape at the total product curve. The net effect of an increase in total output is a fall in price of the product, but under the micro conditions studied of the individual firm, changes in volume of output have no appreciable effect on the total supply. It may therefore be assumed that the price schedule of an individual farmer is unaffected by changes in his level of production. Consequently, the total revenue curve, Figure 2, will be the identical shape of the dosage response curve.

As the marginal product is expressed in physical units of yield, the application of product price gives a similar relationship or the value of total product. Marginal product then becomes the value of marginal product or VMP.

The cost schedule of the input used in the production process is assumed to be a linear function. To the individual firm, the cost per unit of input purchased is unaffected by the volume purchased. The cost of input is expressed by the line EF as a constant increasing function through the increasing levels of application rates.

## Maximum and Optimum Production

There are two points of particular interest in Figure 2. One is the point of maximum production. This is indicated at point C, where total product is maximized, where value of total product, VTP, is the greatest. The second point is at point D, the most economical point of production, where profit is maximized. Total profit is expressed by the difference between the total revenue curve and the total cost curve. In this model where the total cost is represented by a single input, the cost curve becomes the price line EF. On the production function, the point of profit maximization is expressed at that point where the total revenue curve is farthest from the price line EF. This value is expressed at that point on the total revenue curve where a line parallel to the price line becomes tangent to the total product curve. At the point of tangency, the slopes of the two curves are equal. This point of tangency, point D, is where the marginal revenue equals the marginal cost of the product. This is the point of optimal production, the point of profit maximization.

The optimal point of input use at $x_1$ is quite distinct from the point at which total revenue is maximized. At any point in excess of C, when more of the input x is used, total production and total revenue are decreasing.

As long as the price of the input is greater than zero, the optimal input will be something less than that resulting in maximum output. Only if the price of input were zero, would the price line EF become horizontal and tangent to the production curve at point C. Thus the maximum and optimum would coincide.

# CHAPTER III

# PROBLEM ANALYSIS

## Introduction

Experimentation with herbicides has not been designed with the intent of extracting information for an economic analysis. The design used in herbicide experiments is such to provide information on toxicity to weeds and levels of herbicide tolerance to desirable crop species.

The herbicide trial chosen for this economic analysis was selected simply because included in it was a wider range of herbicide rates than provided in other available experimental data. Table I contains actual results of field experimentation conducted by the weed control research staff in the Department of Farm Crops at Oregon State University.

For the majority of agronomic crops, the direct effects of herbicide use becomes apparent within the first year. Many indirect residual effects continue after this period. The measurement of the latter becomes complicated to the extent that few accurate and reliable statements concerning these effects can be made. It is for these reasons that this paper will concern itself with the economic analysis of herbicide use on an annually cultivated crop in one year. The objective of this short term analysis is to demonstrate the effectiveness and usefulness of such an analysis on the direct effects of chemical weed control. More precisely, the analysis will compare and evaluate alternative herbicides and methods of application over the period of one year.

Table I. Druchamp Wheat Tolerance Trial - Hyslop Farm. 1965-1966.

| Treatment | Material per acre | Yield bu/acre average* |
|---|---|---|
| Preemergence | | |
| diuron | 0 | 59 |
| | 1.6 | 63 |
| | 2.4 | 62 |
| | 3.2 | 61 |
| | 4.8 | 44 |
| linuron | 0 | 59 |
| | 1.6 | 68 |
| | 2.4 | 63 |
| | 3.2 | 63 |
| | 4.8 | 58 |
| Postemergence | | |
| diuron | 0 | 59 |
| | 1.6 | 62 |
| | 2.4 | 66 |
| | 3.2 | 65 |
| | 4.8 | 48 |
| linuron | 0 | 59 |
| | 1.6 | 62 |
| | 2.4 | 60 |
| | 3.2 | 64 |
| | 4.8 | 63 |

*Yield average of four replications taken in pounds per acre yield

Presentation of Problem

Two different but closely related herbicides were used in comparison at the same active rates at preemergence and post-emergence treatments. These products on the market are close competitors for the selective control of specific weed problems. Both have the common characteristic that at high rates they injure wheat.

Given the conditions of the yield data, it is clearly seen how the pattern of increasing production to a maximum and eventually decreasing yields, fit the model production function examined previously. The production functions corresponding to the herbicide treatments have been determined and may be expressed graphically. From these functions, the economic optimum may be determined by introducing product and herbicide prices.

The yield response of each herbicide treatment being different, alternatives for maximizing returns are available at any price ratio condition for the two herbicides, considering only the price of herbicide and the cost of application being the same for either. Comparing the economic optimum point of production on each of the four functions at a given price, the most economical treatment may be determined for those conditions. By introduction of variations in prices, i.e., price ratios, any number of alternatives may be established.

The data from the diuron and linuron treatments on winter wheat are barely sufficient for a rough estimation of a production function. Four treatments and an untreated check are actually minimal, as the resulting functions derived from these data are at best an approximation. The yield data may not appear as actual points on the curves of these functions. The curves of the functions offered are those that best fit the arrangement of points from each production function.

Subjecting these data to a multiple regression analysis[1], the following production functions were determined to be the closest approximation for the diuron pre and postemergence treatments respectively:

$$Y = 58.60 + \underset{(4.66)^{2/}}{6.4375\, x_1} - \underset{(-7.17)}{1.9531\, x_1^2} \qquad R^2 = 0.979^{3/}$$

$$Y = 57.9523 + \underset{(2.84)}{7.9462\, x_2} - \underset{(-3.71)}{2.0461\, x_2^2} \qquad R^2 = 0.900$$

---

[1] Computer program, Oregon State University computer center. Account number 75259LANE.

[2] Figures in parenthesis are t values with two degrees of freedom. $t > 4.303$ is significant at 5% level and $t > 9.925$ at 1% level.

[3] $R^2 \geq (0.975)^2$ is significant at 5% level.

These are expressions for yield, $Y$, in terms of physical units, bushels per acre, as a function of herbicide use $x$, in pounds of active material per acre.

If the level of herbicide use is zero, that is $x = 0$, the levels of yield are given as the constants 58.60 and 57.95 bushels per acre. As mentioned previously, the original data may not be represented as actual points in the estimated production function. Referring back to the data in Table I, we find a yield of 59.0 bushels per acre as that yield determined at no herbicide application, $x = 0$.

By taking the first derivative of each function, the marginal physical product or MPP is determined.

$$MPP = 6.4375 - 3.9062\, x_1$$

$$MPP = 7.9462 - 4.0922\, x_2$$

The MPP is that increment of yield obtained by the addition of one unit of herbicide input. The MPP is an important point, crucial to the understanding of an economic analysis. The point of profit maximization is determined by the point where the value of the marginal physical product is equal to the price of the herbicide, i.e., that point where the last increment of input yields no monetary return above its cost. The return in this case is the difference between the value of the physical product obtained by each additional input of $x$, and the cost of the input.

The production functions for linuron pre and postemergence are determined to be the following:

$$Y = 59.8280 + 4.8570\, x_3 - 1.1160\, x_3^2 \qquad R^2 = 0.733$$
$$(1.94) \qquad (-2.26)$$

$$Y = 59.0238 + 1.5892\, x_4 - 1.4880\, x_4^2 \qquad R^2 = 0.614$$
$$(1.01) \qquad (-4.79)$$

The MPP for linuron pre and postemergence are respectively:

$$MPP = 4.8570 - 2.2320\, x_3$$
$$MPP = 1.5892 - 2.9760\, x_4$$

The following chapter will deal with the examination of the value of marginal product curves for all practices and the method employed to select the superior practices.

# CHAPTER IV

# RELATING ECONOMIC EFFECTS

## Value of Marginal Product

The determination of preference for one practice over another is made by examining the value of marginal product curves. The practice indicating the highest profit is chosen.

The MPP multiplied by the price of wheat, Pw, is equal to the value of the marginal product, VMP. By equating the VMP to the price of herbicide input, Px, an equation is determined for the expression of profit maximization at x level of herbicide use, expressed as a function of $Px_1$ and $Px_2$.[4/]

$$x_1 = 1.6480 - 0.2560\,(Px_1/Pw)$$

$$x_2 = 1.9390 - 0.2439\,(Px_2/Pw)$$

The comparison of the points of profit maximization for these two diuron practices, pre and postemergence, can be graphically illustrated showing the range of herbicide use at any price ratio, the price ratios being equal. This is possible as the price of diuron is the same for both pre and postemergence treatments.

---

[4/] Calculation given in Appendix.

The determination of profit is shown in Figure 3.

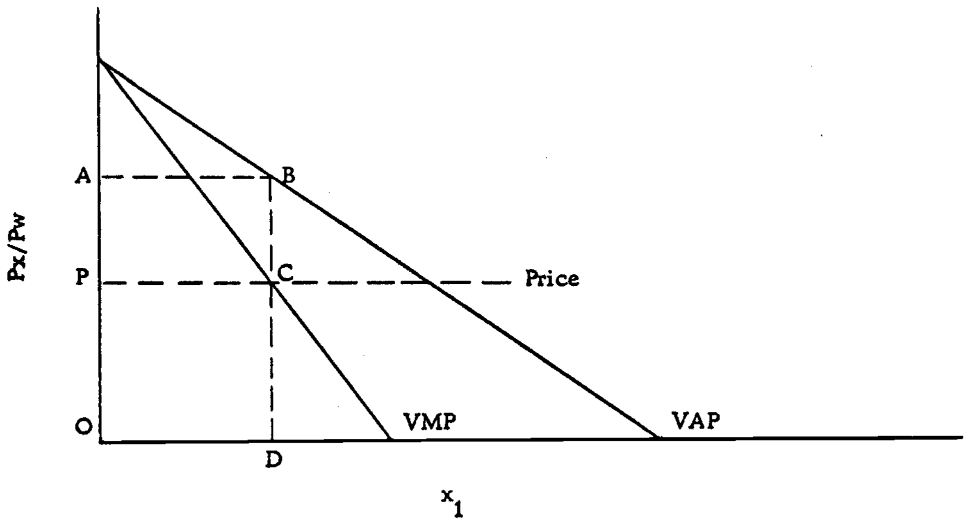


Figure 3. Value of Marginal and Average Product.

The quantity of x is determined where the VMP equals the price, P. In this case, price represents the marginal input cost. Total revenue is represented by ABOD and total cost by the rectangle PCOD. The profit is then represented by the difference or the rectangle ABPC. The comparison of two practices is made by determining the larger area from two VMP curves at the same price condition.

The comparison of the diuron pre and postemergence treatments are seen in Figure 4.

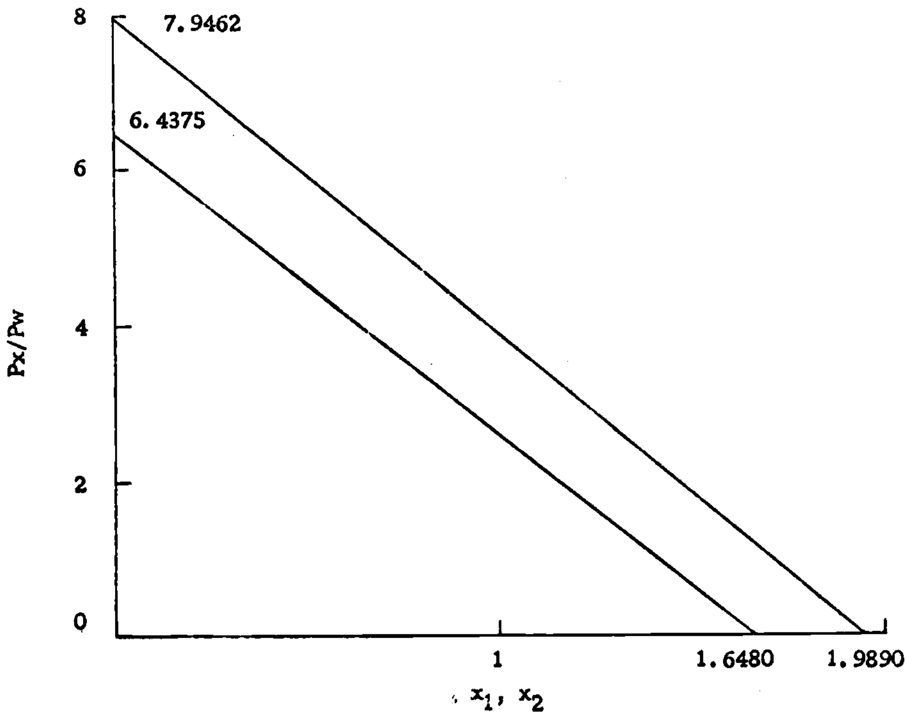


**Figure 4. Value of Marginal Product - Diuron Pre and Post.**

The conclusion of this examination is quite simple. The post-emergence application of diuron, $x_2$, is more profitable than pre-emergence given any price ratio condition being the same for both treatments.

Examining the equations of profit maximization for the pre and postemergence treatments of linuron we have:

$$x_3 = 2.1759 - 0.4479\ (Px_3/Pw)$$

$$x_4 = 0.5487 - 0.3452\ (Px_4/Pw)$$

As was the case for the diuron treatments, one practice of linuron is always better than the other. Linuron preemergence is more profitable under any use and price conditions.

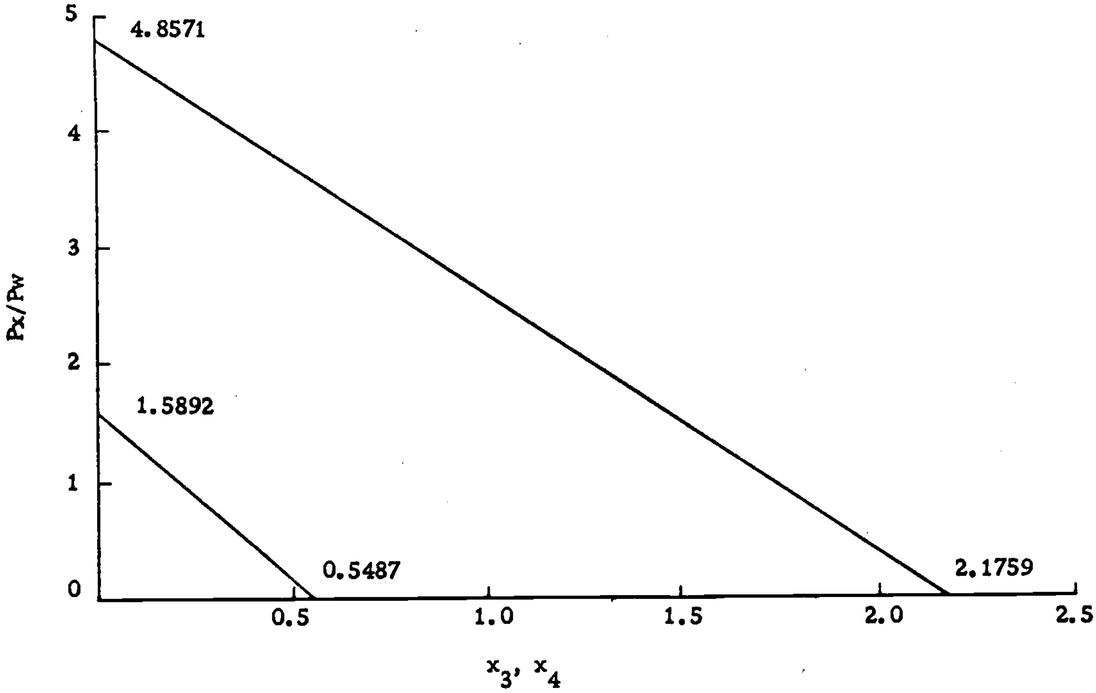


Figure 5. Value of Marginal Product.

Of the four original treatments, one treatment of each chemical has been found better than the other. Diuron preemergence and linuron postemergence would not be used in preference to either diuron post or linuron preemergence within the bounds of this experiment.

In the cases examined, there is no intersection of the VMP curves. In the event that these curves should intersect, the choice of one practice over another may be made in the same manner of determination of profits at a given price.

The difference in time of application between pre and postemergence could possibly have some effect on the price of the chemical over this time interval. In the event that this should occur, the comparison of profits may be conducted in the same manner using the different prices.

The cost of each practice of the same herbicide is taken to be the same. This includes the price of chemical as well as expense of application. Here the price of pre and postemergence treatments is assumed to be the same.

## Comparison of Diuron and Linuron

The problem then remains to compare the range of uses of linuron preemergence and diuron postemergence. These treatments must be compared over the range of no herbicide use, to that point where neither may be used profitably. The actual decision for one or the other, depending on the existing price ratio conditions, will be made on the basis of profit maximization.

The expression of profit is equal to the value of the total product less the cost incurred in the production of this product. More simply, it may be expressed in this analysis as the value of the total product less the cost of herbicide input, assuming all other costs to be fixed.

$$\pi x = Y \cdot Pw - x \cdot Px$$

Profit, $\pi x$ is equal to the total physical product, Y times the price of wheat, Pw, less the level of herbicide input times the price of herbicide, Px.

The original production functions for linuron pre and diuron post were given as:

$$Y = 59.8280 + 4.8571\, x_3 - 1.1160\, x_3^2$$

$$Y = 57.9523 + 7.9462\, x_2 - 2.0461\, x_2^2$$

As mentioned previously, the production functions derived from the multiple regression do not reflect the original check plot data of 59.0 for all treatments. In order to compare the yield production functions on a total profit basis, it is necessary to adjust the yield functions so that both products have the same initial point at no herbicide application. From the experiment, it would be anticipated that no soil or environmental factors would enter in the data to distort these functions. It must be assumed that the check would be the same on any of the plots within the experimental area.

The production function of diuron has been adjusted to coincide with the yield component of the linuron function. The production functions to be used in the remainder of the analysis are:

$$Y = 59.8280 + 4.8571\, x_3 - 1.1160\, x_3^2$$

$$Y = 59.8280 + 7.9462\, x_2 - 2.0461\, x_2^2$$

Taking once again the equations of optimum herbicide rate, for linuron preemergence and diuron postemergence respectively,

$$x_2 = 2.1759 - 0.4479\ (Px_3/Pw)$$

$$x_2 = 1.9390 - 0.2439\ (Px_2/Pw)$$

corresponding rates of herbicide application may be determined for values of selected price ratios.

Table II. Range of Profitable Herbicide Use.

| $Px_3/Pw$ | $x_3$ | $Px_2/Pw$ | $x_2$ |
|---|---|---|---|
| 5.80 | -0.4219 | 8.50 | -0.0342 |
| 4.86 | 0 | 7.95 | 0 |
| 3.70 | 0.5187 | 3.70 | 1.0348 |
| 1.00 | 1.7280 | 1.00 | 1.6951 |
| 0 | 2.1759 | 0 | 1.9390 |

From this, maximum levels of herbicide use are determined. Linuron may not exceed 2.1759 and diuron not above 1.9390 pounds active material per acre. This is then the range within which either herbicide may be used profitably, the exact level being determined by the prevailing price ratio (Figure 6).

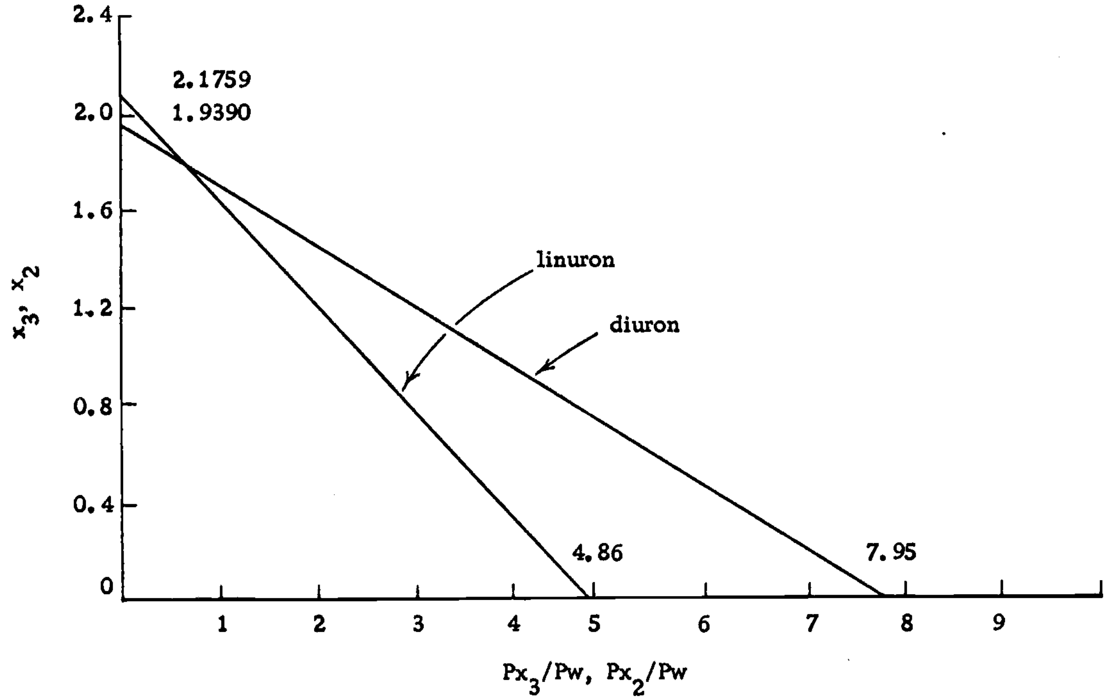


Figure 6. Range of Profitable Herbicide Use.

The price ratio, $Px_3/Pw = 4.86$, corresponds to the lowest attainable point on the production curve for linuron at 59.83 or as indicated here by the level of herbicide use being zero, $x_3 = 0$. Likewise for diuron, when $Px_2/Pw = 7.95$, $x_2 = 0$. This is the corresponding point on the production curve at the yield level attained with no herbicide application.[5/]

---

[5/]These points of herbicide application are expressed as points of the economic optimum under the given price ratio conditions. When $Px/Pw = 0$, that is when the price of herbicide is zero, the maximum that may be economically applied is 2.1759 and 1.9390 pounds active per acre for linuron and diuron respectively. For price ratios greater than 4.86 and 7.95, no herbicide may be economically used.

Taking the levels of herbicide use at profit maximization from the preceeding discussion,

$$x_3 = 2.1759 - 0.4479\,(Px_3/Pw) \quad \text{linuron pre}$$

$$x_2 = 1.9390 - 0.2439\,(Px_2/Pw) \quad \text{diuron post}$$

and by substitution of this level of herbicide use into the equations for the production functions for the two practices,

$$Y_3 = 59.8280 + 4.8571\,x_3 - 1.1160\,x_3^2$$

$$Y_2 = 59.8280 + 7.9462\,x_2 - 2.0461\,x_2^2$$

equations for profit maximization $\pi x$, for both treatments are determined in terms of price of herbicide $Px$, and price of wheat $Pw$.[6/]

$$\pi x_3 = 65.1135\,Pw - 2.1761\,Px_3 + 0.2240\,Px_3^2/Pw$$

$$\pi x_2 = 67.5440\,Pw - 1.9419\,Px_2 + 0.1222\,Px_2^2/Pw$$

Allowing $Pw$ to equal \$1.00, the price ratios of $Px_3/Pw$ and $Px_2/Pw$ may be established by assigning prices of $Px_3$ and

---

[6/] Calculation given in Appendix, page 47.

$Px_2$[7/]. Substituting the price of herbicide into the equations for profit maximization, levels of profit at optimum points of herbicide use for linuron pre and diuron post may be compared graphically.

Table III. Profit as a Function of Herbicide Price.*

| Linuron | | Diuron | |
|---|---|---|---|
| $Px_3$ | $\pi x_3$ | $Px_2$ | $\pi x_2$ |
| 8.00 | 62.04 | 7.95 | 59.82 |
| 5.80 | 60.03 | 6.00 | 60.29 |
| 4.86 | 59.83 | 3.70 | 62.03 |
| 3.70 | 60.13 | 2.00 | 64.15 |
| 1.00 | 63.15 | 1.00 | 65.72 |
| 0 | 65.11 | 0 | 67.54 |

*Prices given for diuron and linuron are present market approximations of \$2.95 and \$2.90 per pound product of 80% and 50% material active respectively. Corresponding prices in pounds active material are diuron @ \$3.70 and linuron @ \$5.80.

Figure 7 illustrates the relationship of the profit $\pi x$, derived from the two herbicide practices to the price ratios of herbicide and wheat. (See Table III)

This graph clearly shows that the linuron treatment is excelled by the diuron treatment at all relevant price ratios. The linuron treatment alone could not be used at a profit for any price ratio

[7/]When $Px_3$ and $Px_2 = 0$, $\pi x_3$ and $\pi x_2$ are expressed in terms of the equations for profit maximization at the highest level of production, that point where total revenue is maximized at 65.11 and 67.54 respectively.

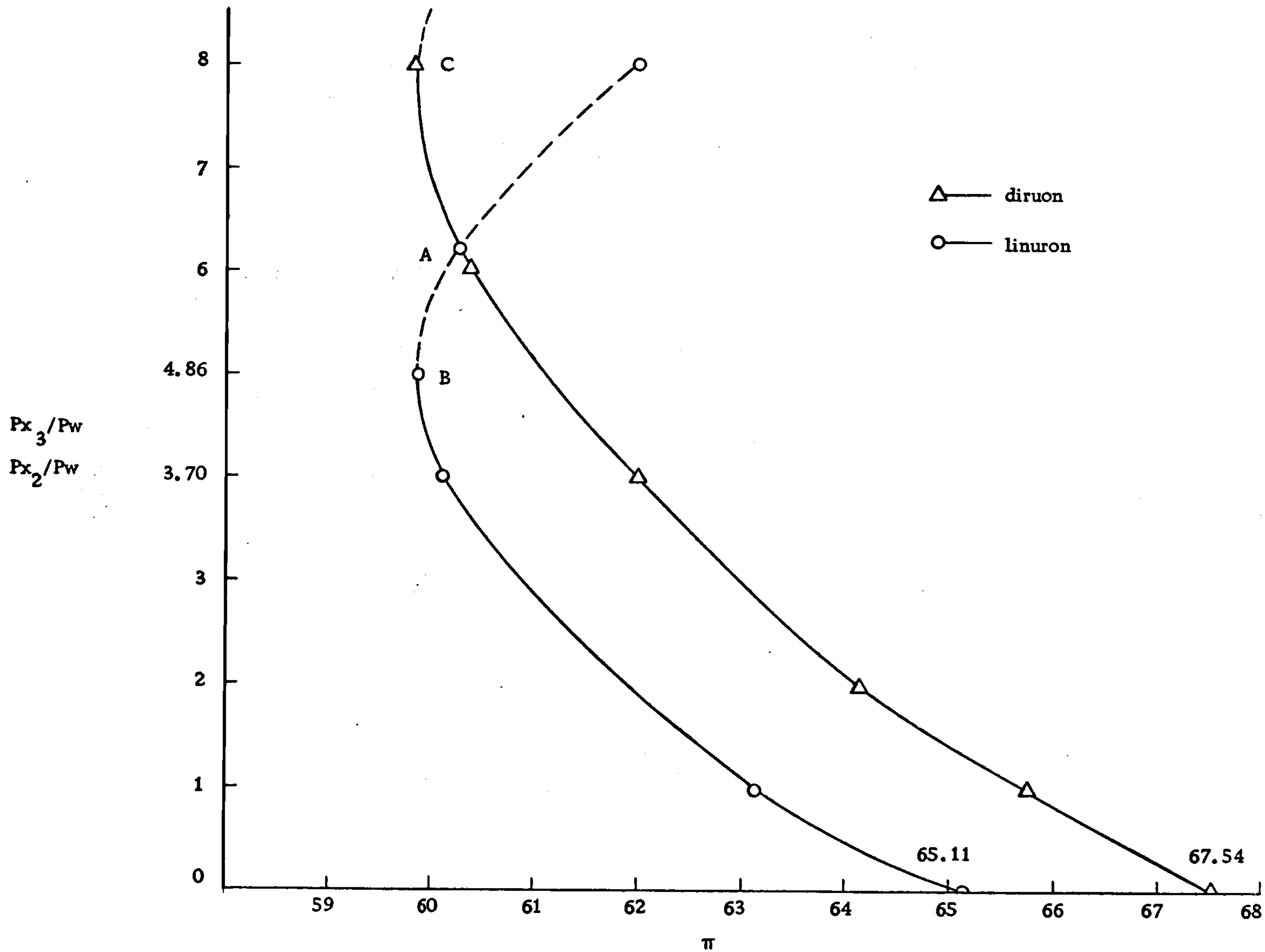


Figure 7. Profit as a Function of Price Ratios.

greater than 4.86 as indicated at point B. The extension of the curve beyond this point is imaginary.

At the same price ratio of 4.86, the diuron treatment may be used profitably. Diuron may be used up to a price ratio of 7.95 and it too becomes imaginary beyond point C. The point of intersection at point A is of no relevance as the curve of the linuron treatment is imaginary at this price ratio condition.

From this analysis, it can be concluded that diuron post-emergence is preferred over all other treatments. It may be profitably used over the range of price ratios from 0 to 7.95

# CHAPTER V

# CONCLUSIONS

## Summary

The objective of this paper has been to develop a method for the comparative analysis of several alternative herbicide practices. Its use is demonstrated to determine the most economical control method. Following the justification for the use and study of herbicides in agriculture production in the first chapter, the proposed procedure of analysis was developed. Chapter II introduced the production economic theory basic to the agriculture production functions employed in the analysis. In Chapter III a specific case problem from actual experimental field data was introduced. This experimental comparison of crop yield data from four alternative herbicide practices, was assigned monetary values to allow for an economic interpretation. These practices were examined over the possible ranges of herbicide price and the price of wheat. The resulting economic comparisons and derived conclusions were graphically presented in Chapter IV.

The conclusions in this chapter discuss the interpretation of results and the strengths and weaknesses of the problem analysis. Uses for these principles and comments on pressing needs for future experimentation and study are discussed as they relate to economic interpretations of the use of herbicides in agriculture.

## Discussion of Results

The experimental data selected were suitable for this analysis. It is a relatively simple comparison considering the alternatives. There are only four treatments, two herbicides with two treatments of each. The herbicides, linuron and diuron, are closely related chemically and their herbicidal properties and action are similar. The relative ease with which the diuron postemergence treatment was selected, facilitates the explanation of this procedure.

After determination of a range over which one practice is the most economical alternative, the economic optimal point of herbicide rate may be determined. The trial used was not selected for this purpose as it is not a good example of the use of these chemicals on winter wheat in the Willamette Valley.

In the Willamette Valley, ryegrass (*Lolium multiflorum*) and wild oat (*Avena fatua*) are serious weed problems in winter wheat production. When these weed problems occur, the level of diuron applied is critical to production and profit levels attainable. Diuron is presently the recommended herbicide practice in this area for control of these weeds.

However in the trial from which these data were taken, neither of these weed species were present. Dramatic differences in yields are not shown from small changes in herbicide application. The following table shows the effect on returns of small changes in herbicide application at a price of diuron that could be expected to prevail in this area. Price of wheat is taken at one dollar per bushel, as has been used throughout in all price ratios.

Table IV. Levels of Profit with use of Diuron.

| X | Y | Px · x* | $\pi$ y |
|---|---|---|---|
| 0 | 59.8280 | 0 | 59.8280 |
| 0.4756 | 63.1444 | 1.7597 | 61.3847 |
| 1.0366 | 65.8665 | 3.8354 | 62.0311 |
| 1.4612 | 67.0704 | 5.4064 | 61.6640 |
| 1.6951 | 67.4183 | 6.2718 | 61.1465 |
| 1.9390 | 67.5430 | 7.1743 | 60.3687 |

*Price of diuron = $3.70 per pound active material

The levels of herbicide use given in the table are the same as used previously and are within the range of diuron use. This range is from 0 to 1.9390 pounds active material per acre, the upper rate is the maximum dosage that could be used profitably under any price ratio conditions.

The yield taken as total revenue, reflects only a slight change in the upper levels of diuron application. The margin between total revenue and variable costs indicates a slight change from zero, rising to a maximum and declining again with slight change in the profit. Marginal returns are not substantially large over this range of diuron rates.

The results of the experimental data and the conclusions drawn from them in this paper are by no means indications or recommendations for farmer practices. The discussion of this particular case study is solely for the expressed purpose of examining an economic situation. The method of analysis is relevant though and could be applied to similar case studies where alternative practices were to be compared.

There are two basic problems in utilizing information of the type given in this paper. The first is the statistical reliability of a biological function. Data from trials such as the one used in this problem analysis serve only as an indication. Even when more data is available for such an analysis, a finite dosage cannot be recommended. There can be determined however, a range of rates within which an economically optimum rate will fall, depending on the existing conditions. The experimental data in this case study, provide a minimum number of input points for the establishment of a reliable production function. More points are desirable. In this case, more rates of herbicide application would increase the reliability of the dosage response curve. This is the primary weakness of this particular problem analysis. Considering other problems of experimental design, reliable projections for herbicide recommendations and economic rates of application cannot be derived from one location. Several locations and replications within each are necessary to minimize local environmental effects and experimental error.

The second problem involved in the utilization of information determined from this problem is the complexity of economic conditions that are arising in the field of chemical weed control. The United States and Europe are experiencing a rapid growth in this area of agriculture technology. In selecting a herbicide practice, farmers are essentially interested in performance consistency. A certain amount of control is expected for a high percentage of applications. This is definitely related to the biological function as a herbicide cannot be expected to demonstrate the same level of performance each year. Farmers look at the cost efficiency of a herbicide practice. Use of a particular herbicide practice is essentially an expression of their willingness to buy dependability.

The major accomplishment of this paper is the introduction of an intensive economic study into the relatively new field of chemical weed control. Little work has been conducted in comparing the alternative practices of weed control, as well as evaluating the use of various chemical practices in economic terms. Early works in economic studies of herbicide use have compared the practice of mechanical weed control to chemical weed control. Studies of this type have been justified when only one chemical was available for use on a particular crop. This is a simple analysis, one prevalent mechanical practice as opposed to one available herbicide. There is a definite need for comparison of alternative practices. A farmer interested in maximizing profits is interested in selecting the herbicide practice that will achieve this goal for him.

## Recommendations for Future Study

The evaluation of economic losses due to weeds can be applied to areas other than agriculture production, as long as the costs of control are compared with all benefits accruing to weed control. This comparison should involve all alternative practices.

Other than agronomic crops, losses due to weeds should be assessed on range lands. This involves the change in productivity of the land as it relates to forage capacity and livestock production. Irrigation canals and other waterways are heavily infested with aquatic weed problems. The cost of cleaning, flow reduction and transpiration losses are all part of economic losses caused by weeds. Weeds also affect maintenance costs of railroads, highways and other public areas. Large expenditures are made for the control of weeds on large industrial sites. Studies have even gone so far as to include economic losses in public health accruing to weeds.

There are other economic questions of herbicide use that have not been fully investigated. One of these concerns the farmer's willingness to pay for herbicides. It appears that the decision of which herbicide and rate to use is based to some degree on other factors than a direct cost benefit relationship. Values are evidently placed on convenience and timing of operation, uses of labor and management and the alternative uses of available resources in farm enterprises. As in all phases of agriculture, there are many economic factors that enter into the decision making process. In the case of herbicide use, all of the economic factors have not been measured.

The need for cost performance studies of herbicides over a long run time period is becoming evident. In crops where a standard herbicide practice has been in use for many years, new weed populations are being cultivated. In these cases, what appears to be the most economical practice on an annual basis, may in reality permit certain weed species to increase because they were not removed by the herbicide used. The inexpensive use of 2, 4-D for example, has been a desirable practice in many crops. Grasses and particularly hardy perennials, not easily controlled by 2, 4-D are given an advantage in increasing their population. The economics of control of these problems, after a weed build-up, were not considered when what appeared to be the most economical practice was chosen.

Problems such as this are becoming more apparent and there is a definite need for study in this area.

In addition to the existing need for economic evaluations of current herbicide practices, new trends and developments in chemical weed control are adding to the complexity of these economic evaluations. The developments forseen are principally concerned with drastic price changes in three major groups of herbicides. Within the next three years the phenyl ureas, triazines and carbamates will begin to lose their patent coverages. When this happens, prices of these herbicides will fall substantially, perhaps as much as half the current price. As a result of price changes, the economic dosages will permit higher use rates and better weed control at the same or possibly a reduction in total cost.

Every year more and more new herbicides are granted registration and released on the market. The number added each year to currently used herbicides is increasing the growers' alternatives. Research is presently being initiated on a large scale to investigate the possibilities of herbicide mixtures. These mixtures are combinations of proportions of herbicides designed to achieve more complete control of the entire weed spectrum. The alternatives will be great.

In the future, a grower will have basically three economic choices for determining the optimal herbicide application. The first is the opportunity of increased dosages, as herbicides no longer protected by patents are reduced in price. The second alternative is a new, high cost, herbicide protected by patent. This would probably be expensive relative to the control it would achieve. The third possibility is a herbicide mixture, utilizing a combination of low cost herbicide with a possibly more effective new herbicide at a low rate. The predictions for the future in chemical weed control are complex, perhaps to such a degree that a farmer will be unable to make the evaluation of the most economical alternative by himself.

The type of information that will be needed for grower use will have to be supplied by someone trained and experienced in making these analyses. The sophistication of herbicide use, the wide variety of chemical alternatives and the complexity of the economic situations require intensive study in this area. There is a real need for increased attention to the economics of chemical weed control in order that professional advisors can provide this information to the growers.

It is necessary that the economist and agronomist work together to solve these problems. One of the functions of economists in agriculture is to assess whether or not the practices the agriculture scientist has shown to be technically feasible are economically justifiable. In order that the economist evaluate the practices of weed control, adequate data must be supplied with the cooperation of the agronomist.

In agriculture production, the required data are of two types. First, in experimental design, there must be a wide range of herbicide rates. This is necessary to provide accurate information for the corresponding production function so that a valid economic interpretation of the physical results can be obtained. The second requirement is a complete account of the benefits of weed control from herbicide use to which the economist can apply monetary values. Due to the complexity of economic conditions, many areas of herbicide use need urgent attention. The more prominent points are, study in areas of agriculture other than agronomic crops, the understanding of a grower's willingness to pay for herbicides, cost performance studies of alternative practices and an investigation of the alternatives arising from price changes and herbicide mixtures. Only if these data are adequately available can any investigation into the economic aspects of herbicide use be undertaken, by relating its cost to the job it does.

# BIBLIOGRAPHY

Cole, H. and G. H. Berggren. Economic importance of herbicides. Farm Economics (Pennsylvania State University), April 1966, p. 1-4.

Davis, C. Economics of chemical weed control. Crop Comments 19(7): 1-3. 1966.

Decker, G. C. Justification for the use of pesticides in agriculture. Proceedings of the 20th North Central Weed Control Conference 21: 1-5. 1964.

Ennis, W. B. Economic aspects of crop losses caused by weeds. FAO Symposium on Crop Losses, Rome, October 1967. p. 127-145.

Fischer, L. A. Pest control - An economic approach. Economic Planning 1(2): 8-9. 1965.

Friedman, Milton. Price theory; a provisional text. Chicago, Aldine. 1962. 285p.

Furtick, W. R. The importance of weed control in tropical and sub-tropical agriculture. Corvallis, Oregon State University, Farm Crops Dept. 1967. 11 numb. leaves. (Duplicated)

__________ National and international needs for weed science, a challenge for WSA. Presidential address. Weeds 15: 291-295. 1967.

Gwyn, James. Economic aspects of herbicide use. Proceedings of the British Weed Control Conference 3: 702-709. 1966.

Heady, Earl O. and John L. Dillon. Agriculture production functions. Ames, Iowa State University, 1961. 667p.

Hillebrandt, P. M. The economic theory of the use of pesticides. Part I. Journal of Agriculture Economics 13: 464-472. 1961.

__________ The economic theory of the use of pesticides. Part II. Journal of Agriculture Economics 14: 52-61. 1961.

Hillebrandt, P. M. The economics of the use of selective weed-killers. Farm Economist (Oxford) 9:209-224. 1959.

Hoffman, G. O. Economics of chemical weed control. Proceedings of the Southern Weed Control Conference 14:347-352. 1961.

King, Lawrence J. Weeds of the world. New York, Interscience. 1966. 526p.

Myrick, D. C. Cost of weeds and economics of control. Proceedings of the Western Weed Conference 14:10-16. 1954.

__________ Economic studies of weed problems and control. Proceedings of the California Weed Conference 8:10-17. 1956.

Shaw, W. C. Weed Science - Revolution in agriculture technology. Weeds 12:153-162. 1964.

Strickland, A. H. Some problems in the economic integration of crop loss control. Proceedings of the Fourth British Insecticide and Fungicide Conference 2:478-492. 1967.

# APPENDIX

# APPENDIX

## Herbicide Levels for Profit Maximization

$$MPP = \frac{dTP}{dx} = b + 2cx$$

$$Pw \cdot MPP = VMPP$$

when $MPP = Px$

$$Px = (Pw)\ (b) - Pw\ (2cx)$$

$$x = \frac{b}{2c} + \frac{1}{2c}\left(\frac{Px}{Pw}\right)$$

| | | |
|---|---|---|
| Diuron | Pre | $x_1 = 1.6480 - 0.2560\ (Px_1/Pw)$ |
| | Post | $x_2 = 1.9390 - 0.2439\ (Px_2/Pw)$ |
| Linuron | Pre | $x_3 = 2.1759 - 0.4479\ (Px_3/Pw)$ |
| | Post | $x_4 = 0.5487 - 0.3452\ (Px_4/Pw)$ |

Determination of Total Profit Maximization

$$\pi x = Y(Pw) - x(Px)$$

when $Y = 59.8280 + 4.8571\,x - 1.1160\,x^2$

$$x = 2.1759 - 0.4479\,(Px/Pw)$$

$\pi x$ for Linuron Pre

$$\pi x = (Y)(Pw) - (x)(Px)$$

$$\pi x = (59.8280 + 4.8571\,x_3 - 1.1160\,x_3^2)(Pw) - (Px_3)(2.1759 - 0.4479\,[Px_3/Pw])$$

$$\pi x = 65.1135\,Pw - 2.1761\,Px_3 + 0.2240\,Px_3^2/Pw$$

$\pi x$ for Diuron Post

$$\pi x = 59.8280 + 7.9462\,x_2 - 2.0461\,x_2^2\,(Pw) - (Px_2)(1.9390 - 0.2439\,[Px_2/Pw])$$

$$\pi x = 67.5440\,Pw - 1.9419\,Px_2 + 0.1222\,Px_2^2/Pw$$