Probability Analysis of Herbicide Response[1]

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Introduction

In many herbicide screening experiments, visual numerical ratings of effectiveness are used to evaluate the relative differences among treatments. The accuracy of these visual estimates of weed control is dependent on the skill and objectivity of the investigator, particularly regarding the assessment of the density and species composition of the sample. Numerous investigators acknowledge the fact that visual estimates of weed control contain errors as high as 20 percentage points, and that valid interpretation of subjective data is difficult unless consistently large differences are apparent.

The results of experimentation conducted at the Great Western Agricultural Experiment Station (3)[3] indicated the need for a statistical method of interpretation of plant-count data obtained from variable-dosage experiments. It was proposed that a suitable statistical method existed which would allow predictions and practical recommendations to be made from variable-dosage data, particularly when small differences were expected. The probit analysis method was examined as a possible tool for the interpretation of dosage-response relationships in weed control. Heretofore, the direct method of variance analysis was applied to variable-dosage data with reservations regarding the validity of the interpretations.

Materials and Methods

Field Procedure

In this study, the method of direct graphical interpretation of the dosage-response relationships of PEBC (n-propyl ethyl-n-butylthiolcarbamate), diallate (2-3-dichloroallyl diisopropylthiolcarbamate) and the mixture, PEBC + diallate, was examined. The introductory studies on probit theory and practice by Finney (2) and Gowing (1) were consulted to formulate method.

A 12 lb/A initial dosage of active ingredient was used for each herbicide, although the PEBC + diallate combination was

[1] Contribution of the Great Western Agricultural Experiment Station, Longmont, Colorado. From a paper given at the Proc. Thirteenth General Meeting, Am. Soc. Sugar Beet Technol., February, 1964.

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[3] Numbers in parentheses refer to literature cited.

applied at the 8 + 4 lb/A dosage. This combination had shown superior broad sprectrum activity without kochia (*Kochia scoparia*) in earlier studies (3) and subsequently (4).

The treatments were applied preplant, soil-incorporated at the 1.5-inch depth on June 13, 1963. A silt loam soil of high fertility, located at Windsor, Colorado, was sampled. Soil temperatures at establishment and at the incorporation depth averaged 72° F. The experiment received 2.75 inches of precipitation during the experimental period which extended until July 8 when the final observations were made.

The treatments were arranged in randomized complete blocks with 3 replications. Plant counts of pigweed (*Amaranthus retroflexus*) and foxtail millet (*Setaria italica*) were made in each treatment and replicate at the initial concentration and at each half-dosage distance of 25 feet. The counts were taken within a wire rectangle which measured 4 inches by 36 inches. Plot size measured 44 inches by 125 feet with the herbicides applied in 7-inch bands to two rows spaced 22 inches apart.

Graphical Probit Analysis

Total control percentages (pigweed + foxtail) were calculated from the observed values at each dosage distance. These percentages were converted to empirical probits as described by Finney (2).

In practice, the expected probits (Y) were plotted against the logarithm of the dosage (X). A straight line or weighted regression line was drawn by eye to fit the control probit on the logarithm of the dosage. This weighted regression line was used to calculate the fitted line by regression analysis. Thereby, the normal sigmoid response curve was transformed to a straight regression line, when the ordinates were measured on a linear scale of probits instead of percentages.

The chi square test was used to test goodness of fit between the theoretical regression line and the actual observations of the relationship between dosage and response. The chi square values were greater than $P = .99$ which indicated a very close fit.

Furthermore, the log LD50 was estimated for each herbicide from the true regression line at probit of control, Y-5 (2). LD50 refers to the lethal dosage which controls 50 percent of the weeds. This statistic was determined because equal increments of dosage may not produce equal increments of response above and below the LD50 position on the curve; response is nonlinear with respect to applied dosage, although the LD50 position is more reliable than response positions at lower or higher dosages.

Results and Discussion

Percentage Response

The experimental data showing the relationship between dosage and response (elimination and competitive absence of weeds) are given in Table 1.

Table 1.—Relationship between dosage of PEBC, diallate and PEBC + diallate and response at each half-dosage distance.

Herbicide	Dosage lb/A	Response number (r)[a]	Percentage control (p^1)[b]
PEBC	12	96	98
	6	95	97
	3	55	56
	1.5	20	20
	.75	5	5
	0	0	0
diallate	12	95	97
	6	66	68
	3	43	44
	1.5	25	25
	.75	12	12
	0	0	0
PEBC + diallate	12	97	99
	6	79	81
	3	66	68
	1.5	39	40
	.75	24	25
	0	0	0

[a] r = Elimination and competitive absence of weeds.
[b] p^1 = Percentage control (100 r/n) after Finney (2).

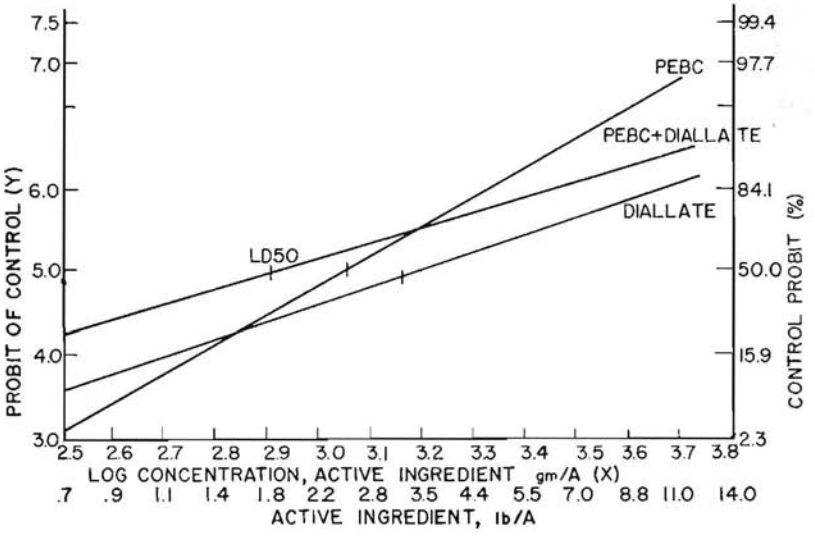
These results show that the total control obtained from the preplant application of PEBC + diallate at 3 lb/A active ingredient was 24 percentage points higher than the control obtained from diallate alone (Table 1). PEBC applied at 3 lb/A alone gave 56 percentage points control when compared to the untreated controls. The untreated controls averaged 95 weed seedlings per square foot or 59 pigweed and 36 foxtail seedlings at the time the observations were made.

Computations from these data (Table 1) showed that the average control for PEBC and diallate alone at the 3 lb/A dosage was 50 percentage points. The 50 percentage point average was 18 percentage points less than the percentage control obtained from PEBC + diallate applied at 2 + 1 lb/A active ingredient, respectively. When results were compared further, the application of 1.5 lb/A of PEBC and 1.5 lb/A of diallate gave 20 and 25 percentage points control, respectively, or a total additive control of 45 percentage points (Table 1). However, the control obtained from a 2:1 combination of PEBC + diallate at the

1.5 lb/A dosage was 40 percentage points. Thus, the additive control obtained from the mixture was 23 percentage points higher at the 3 lb/A dosage than the expected control obtained from single chemicals added at the 1.5 + 1.5 or 3 lb/A dosage (Table 1).

Regression Analysis

The results of the regression analysis of dosage and response are given in Figure 1, shown below.



Examination of the three regression lines shows that PEBC + diallate could be expected to be significantly more effective in weed control than the single herbicides, particularly within the dosage range below 3.9 lb/A active ingredient (Figure 1). At dosages in excess of 3.9 lb/A, PEBC applied alone was more effective, although crop selectivity would limit usage at dosages above the 5 lb/A rate. Diallate was shown to be less effective than PEBC + diallate or PEBC above the 1.75 lb/A rate, but diallate had more effectiveness than PEBC below the 1.75 lb/A dosage of active ingredient (Figure 1). It is known that dosages of diallate between 1.5 to 2 lb/A are sufficient for the control of wild oat (*Avena fatua*).

Calculation and interpolation showed that 84 percentage points control occurred at 4.9, 5.9 and 8.75 lb/A active ingredient

for PEBC, PEBC + diallate and diallate, respectively. In Figure 1, the probit of control (Y) at 5 is equivalent to 50 percentage points of control and (Y) at 6 is equivalent to 84 percentage points.

Inspection of the plotted LD50 positions on individual regression lines shows that the mixture was significantly more effective in the control of weeds than the single chemicals. For instance, the LD50 dosage for PEBC + diallate was 1.75 lb/A while the 50 percentage response point for PEBC and diallate occurred at 2.5 and 3.1 lb/A active ingredient, respectively. These dosage comparisons show that an additive response was obtained by applying PEBC + diallate at dosages up to 3.9 lb/A in combination.

Apparently, these data indicate that PEBC + diallate would be more active under broad spectrum weed conditions and under the equilibria present in some soils than the single chemicals. Conversely, although of significant effectiveness per unit of active ingredient above 2.5 lb/A, PEBC had a relatively narrow activity range under the conditions of the experiment (Figure 1).

These interpretations and inferences were derived from the relative characteristics, slope and position, of the regression lines.

For example, the relatively flat diallate regression line suggests that increased dosages of diallate alone would have less effect on species control than that of PEBC. The line intersection of PEBC with diallate at approximately the LD50 position of the mixture showed that a positive interaction occurred for species and chemicals. On the other hand, parallelism of two regression lines indicates that the chemicals act independently of each other or exhibit proportionate species activity. Likewise, Gowing (1) inferred that parallel dosage-response regression lines were directly comparable perhaps because of similar modes of activity of the chemicals.

Summary and Conclusions

The probit method of statistical analysis after Finney (2) was employed to evaluate the relative effectiveness of three herbicides applied variable-dosage.

The results showed: 1) The herbicide combination, PEBC + diallate, was more effective in weed control than the single chemicals PEBC and diallate within the dosage range from 1.75 to 3.9 lb/A active ingredient; and 2) inspection of the dosage-response regression lines and the LD50 dosages indicated that an additive effect in weed control was obtained from the herbicide combination.

These specific herbicide results gave evidence that the method of probit analysis was adaptable to variable-dosage herbicide studies to define: 1) The significance of small differences; 2) probable dependent or independent activity of a herbicide; 3) relative effectiveness of a herbicide combination; 4) the probable dosage and response relationship of a herbicide; 5) the LD50 value; 6) crop selectivity; and 7) the error of the dosage-response estimate.

Literature Cited

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