EVALUATING HERBICIDES IN SUGAR-CANE CULTIVATION

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The final testing of an herbicide or herbicide-mixture, in order to determine whether it will find a place in general field practice, is a constantly recurring problem in weed control research. Experimental work of this nature has to be carried out both in plant and ratoon canes under different conditions of soil and climate so as to cover the greatest range of weed species.

The evaluation of the toxicity of an herbicide as described by Woodford must proceed in 3 stages. It is essential to determine the toxicity of the herbicide firstly to the crop, secondly to the weed, and thirdly to the crop and weed in association. In References p. 555.
Evaluation of herbicides with crop and weeds

This paper, only problems concerning the evaluation of herbicides with crop and weeds growing together will be dealt with, on the assumption that the toxicity of the herbicide to the crop and weeds has been already determined in preliminary experiments. At the final phase of the testing procedure, it must be emphasized that it is the economic possibilities of selected herbicides which have to be assessed.

Information on this aspect of weed control research in sugar-cane literature is inadequate. The present contribution is an attempt towards reaching a better understanding of the methods underlying the execution of such experiments in order to achieve more uniformity in the compilation and presentation of data.

Methods used in Mauritius during the last 5 years are reviewed and discussed under the following headings:

1. Plot size and lay-out.
2. Assessment of weed population.
3. Assessment of mortality.
5. Effects on cane yield and sucrose content.

1. Plot size and lay-out

Apart from certain annuals which have a gregarious habit and some perennials which may occur in pure stands, the distribution of weed species in a cane field is generally scattered. The plot size selected should, therefore, be sufficiently large to be representative of species present and also to satisfy cane yield data requirements. Experimental work based on information derived from the studies of Evans on the best shape and size of plot for field experiments with sugar-cane, showed that the most convenient plot size for the evaluation of herbicides in cane fields is about 1/40 acre with 4 cane rows. In ratoon crops, when every alternate interline is covered with trash, as is the case in Mauritius, plot size should be increased to about 1/20 acre with 8 cane rows.

The lay-out should be a randomized block design with at least 4 replications. In such trials, the herbicides under test should be compared to standard formulations in use at the usual rates of application. It is also important that the herbicides should be tested at 3 doses: that which has given the best results in preliminary work, a higher and a lower dose. Such a procedure allows the experimenter to find out both the maximum dose which can be used without yield reduction and the effect of a minimum dose on the weed population. Results obtained thus give an assessment of the economic possibilities of the new chemicals. It must also be pointed out that, when such experiments are carried out in postemergence of the weeds, that is, in weedy crops, both clean and weedy plots should be included in the experimental design, as indicated by Fryer, in order to obtain the upper and lower limits of yield against which the yield of herbicide-treated plots can be compared.

2. Weed assessment

Very little information is available in sugar-cane literature concerning methods for estimating weed population of cane fields in herbicidal work. Of those that have been used the following may be mentioned: separation and weighing, percentage area, and frequency-abundance. The merits and limitations of these methods are discussed below.
(a) The separation and weighing method

A grid of known dimensions is thrown a number of times at random on the experimental plot. Weed species within it are cut, separated into main groups of plants and then into individual species. The green or dry weight of each species is determined and expressed as a percentage of the total green or dry weight.

CLEASBY\(^4\) makes use of this method for weed estimates but does not separate the plants into individual species. He classifies them into 3 main groups, counts the number of weeds present in each group, and weighs them separately. To relate number to weight, he introduced a ‘weed factor’ which is obtained by multiplying the number of weeds by their green weight and taking the square root. Weed factors are then related to the visual appearance of the plot to facilitate their interpretation.

The separation and weighing method is fairly reliable, but its limitations lie in the fact that each sample has to be separated into its constituent species, an operation which is both tedious and time consuming. If simplified, as suggested by CLEASBY, it would seem that very little information is obtained on the toxicity of the herbicides to individual weed species. This point deserves consideration. A treatment may have proved excellent in one trial because of the absence of a particular species, but unsatisfactory in another trial because of the dominance of another species. Data obtained from a weed estimate should give information on ‘total effects’ as well as on ‘individual effects’ of the herbicides on the weed population. Further, the way in which annuals and perennials are affected by the treatment is worthwhile recording separately. Information of this nature will be of great value as it will assist the experimenter in solving many of the discrepancies with which such experiments are often beset.

(b) The percentage area method

This method consists in placing a small quadrat a certain number of times in a plot and estimating visually the proportion covered by each species. The area covered by the vegetation plus bare ground should make up to 100.

This technique has been used in Mauritius mainly in small plot trials where accurate data are required on the toxicity of herbicides to different weeds. Its use, however, at this final stage of testing is not advisable because it is too tedious and time consuming.

(c) The frequency-abundance method

This technique is often used for the assessment of weed population in weed control work. It consists mainly of visual estimates, and their interpretation in terms of numerical values which are related to a rating scale. Although this method may lack the precision of quantitative methods, yet the ease with which it is operated makes it a useful tool. As WILLARD\(^4\) points out, visual ratings in weed control experiments do not necessarily mean that the results are less accurate or less satisfactory than methods which profess to be quantitative. Any experimental technique which involves a good deal of time spent in field work and statistical analyses, obviously implies a small number of experiments. As a result, data obtained generally fail to cover the range necessary to assess the economic possibilities of the herbicides on a field application basis.

This method is sufficiently reliable for weed assessment in cane fields, more

References p. 555.
particularly if observations are made by independent workers and the average data recorded. Although frequency-abundance has its limitations, it should be emphasized that in field trials of this kind one has to decide between 2 factors: (i) establishment of a large number of experiments, distributed over different climatic zones and soil types; or (ii) limiting the number and distribution of the experiments, but using a more precise method in the estimation of weed population. In adopting the frequency-abundance technique, it is assumed that any loss in accuracy of weed estimates in individual trials is compensated by a greater number of repetitions over a larger area. This technique has been used in Mauritius for the last 5 years, and has proved of value in the assessment of weed population. The rating scale adopted has been the following:

<table>
<thead>
<tr>
<th>Classes</th>
<th>No. of points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very abundant</td>
<td>8</td>
</tr>
<tr>
<td>Abundant</td>
<td>7</td>
</tr>
<tr>
<td>Common</td>
<td>6</td>
</tr>
<tr>
<td>Frequent</td>
<td>5</td>
</tr>
<tr>
<td>Fairly frequent</td>
<td>4</td>
</tr>
<tr>
<td>Occasional</td>
<td>3</td>
</tr>
<tr>
<td>Rare</td>
<td>2</td>
</tr>
<tr>
<td>Very rare</td>
<td>1</td>
</tr>
</tbody>
</table>

The classes of the rating scale have been restricted to 8 in order that differences between the limits of the scale be clear and readily observable. Experimental data are recorded by 2 observers who are unaware of the treatment given to the plot when scoring. A preliminary list of weed species is made by each observer in individual plots followed by a scoring for abundance while walking slowly up and down the interlines. The 2 observers then compare their results, and in case of disagreement, they score anew until some compromise is reached as to the number of marks allotted. Final results are expressed in percentage of control. One of the advantages of this method is that "individual" as well as "total" effects of the herbicides on the weeds are recorded. In the case of persistent herbicides, such as the substituted ureas, it allows the experimenter to follow the biological shift of species with respect to treatment effects. In addition, the relative abundance of species being scored separately, effects on annuals and perennials, grasses and broad-leaved weeds, are readily obtained. One of the disadvantages of this method lies in the fact that complete dominance of 1 species in a plot appreciably lowers scoring of that plot. A note should be made of such cases for further consideration when the results are pooled and the average taken.

The frequency-abundance method is quick and easy, and gives useful results in weed control experiments, provided a sufficient number of trials be laid down over a representative area.

3. Assessment of weed mortality

In weed control work, mortality is generally assessed by the method of awarding points according to the degree of damage sustained. Different rating scales have been used by different workers, and in Mauritius the one which has proved the most convenient is the following:
The adoption of 8 classes in the rating scale has been found necessary in order that differences between classes be readily observed in the field.

It must be pointed out, however, that the use of this method alone would not give information on the overall effects of the herbicides on the weeds, since the relative abundance of the different species are not accounted for. What is really wanted from such experiments is the "overall" killing effect of the herbicides on the weed population present in the plots, in order to be in a position to evaluate their economic possibilities in general field practice.

A technique, in which the killing effect of the herbicides is related to the relative abundance of the different weed species in experimental plots, has been worked out and applied in herbicidal work in Mauritius. Briefly it may be summarized thus:

(a) One to 3 days prior to spraying, weed assessment of the plots is made, the abundance of each species being recorded separately.

(b) About 3 to 5 weeks after spraying, weed mortality is assessed, the extent of damage sustained by each species in the plot being recorded separately.

In order to evaluate the overall effect of the herbicides studied, the following calculations are made:

(i) The "mortality-abundance rating" of individual species is first determined as shown in the following example:

\[
\text{Mortality} = 3 \\
\text{100\% kill} = 8 \\
\text{Abundance} = 6
\]

\[
\text{Mortality-abundance rating} = \frac{\text{mortality}}{100\% \text{kill}} \times \text{abundance} = \frac{3}{8} \times 6 = 2.25
\]

Mortality and abundance values are obtained from assessment data sheets and the 100\% kill figure is the value given to total kill in the mortality rating scale adopted. The reasons that have led to this calculation need some explanation. In dividing mortality values by 100\% kill rating, the extent to which the herbicide has affected the species in relation to the total effect it could have exerted on the weed, is obtained. When this ratio is multiplied by abundance, the measure in which that effect is apportioned with respect to the relative abundance of the species in the plot, is obtained.

(ii) The second step in the calculation is to find out the "overall effect" of the herbicides with respect to the different species present in relation to their abundance in the plot. This is obtained by dividing the sum of "mortality-abundance" ratings of
the species present by the sum of their "abundance" and multiplying by 100. In other words, it means calculating total mortality as a percentage of total abundance of the different species constituting the weed population of the plot. This is better explained by reference to an example given in Table I, in which a few species only have been listed.

**Table I**

<table>
<thead>
<tr>
<th>Weed species</th>
<th>Abundance</th>
<th>Mortality</th>
<th>Mortality-abundance rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species A</td>
<td>6</td>
<td>3</td>
<td>2.25</td>
</tr>
<tr>
<td>Species B</td>
<td>3</td>
<td>5</td>
<td>1.90</td>
</tr>
<tr>
<td>Species C</td>
<td>2</td>
<td>1</td>
<td>0.25</td>
</tr>
<tr>
<td>Species D</td>
<td>1</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>Species E</td>
<td>4</td>
<td>6</td>
<td>3.00</td>
</tr>
<tr>
<td>Species F</td>
<td>5</td>
<td>8</td>
<td>5.00</td>
</tr>
</tbody>
</table>

Total 21 Total 12.40

"Overall effect" is worked out thus:

\[
\text{Overall effect} = \frac{\text{Total "mortality-abundance rating"}}{\text{Total "abundance"}} \times 100
\]

which works in this case to

\[
\frac{12.4}{21.0} \times 100 = 59\%
\]

This figure 59% gives the overall effects of the herbicide in relation to the abundance of species present, expressed on a percentage basis. Average "overall effects" for a particular treatment, when compared to those obtained for standard formulations in use, gives a measure of appraising the economic possibilities of the herbicide.

4. **Assessment of cane injury**

At this final phase in the testing procedure, the aim is mainly to assess cane injury under a varied set of factors in order to determine how the herbicide affects cane growth in field practice. For this assessment, a visual rating is generally adopted, and one that has proved useful and sufficiently reliable is described below.

<table>
<thead>
<tr>
<th>Effects on Crop</th>
<th>No. of Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>No visible effect</td>
<td>0</td>
</tr>
<tr>
<td>Slight scorching effect on leaves</td>
<td>1</td>
</tr>
<tr>
<td>Slight scorching effect, leaves turn yellow</td>
<td>2</td>
</tr>
<tr>
<td>Moderate scorching effect on leaves</td>
<td>3</td>
</tr>
<tr>
<td>Moderate scorching effect on leaves and stem</td>
<td>4</td>
</tr>
<tr>
<td>Severe scorching effects on leaves and stem</td>
<td>5</td>
</tr>
<tr>
<td>Severe scorching effect, death of young shoots</td>
<td>6</td>
</tr>
<tr>
<td>Severe scorching effect, stems: 25% kill</td>
<td>7</td>
</tr>
<tr>
<td>Severe scorching effect, stems: 50% kill</td>
<td>8</td>
</tr>
<tr>
<td>Severe scorching effect, stems: 75% kill</td>
<td>9</td>
</tr>
<tr>
<td>Complete kill</td>
<td>10</td>
</tr>
</tbody>
</table>
5. Effects on cane yield and sucrose content

The lay-out adopted in these field trials allows data to be subjected to statistical analysis for cane yield and sucrose content in the usual manner.

CONCLUSIONS AND SUMMARY

Experimental techniques for the evaluation of herbicides when crop and weeds are growing in association have not been given the attention they deserve in sugar-cane literature. Workers have used different methods with consequent lack of uniformity in the presentation of data. As a result, it is often difficult to appreciate fully the value of such investigations.

The object of the present paper is to emphasize this particular aspect of the problem in describing experimental techniques that have been used successfully in Mauritius during recent years. Their practicability and limitations are discussed. In experimental agriculture, more particularly in weed control research, no technique can claim to be fully satisfactory. The present contribution, therefore, should only be considered as an attempt towards a better understanding of weed control experimentation in sugar-cane.

ACKNOWLEDGEMENTS

The writer is indebted to Dr. P. O. WIEHE, C.B.E., for helpful advice and criticism during the preparation of this paper.

REFERENCES

2. EVANS, H., 1934. Some preliminary data concerning the best shape and size of plot for field experiments with sugar-cane. Bull. 3. Sugar Cane Research Station Mauritius.

DISCUSSIONS

E. BURCH (Hawaii): Is the size or state of growth of the weeds recorded before spraying? What do you use as a check, hand weeding or commercial operation?

R. ANTOINE (Mauritius): The size or state of growth is recorded. There are 2 controls, one which is kept completely free of weeds by hand and another one where the weeds are not controlled at all.

F. J. FLOYD (Jamaica): What precautions are taken to ensure even distribution of herbicides within the 1/40-acre plots.

Mr. ANTOINE: All herbicides in Mauritius are applied by knapsack spray.

N. S. HANSON (Hawaii): I believe that for anyone who is looking for a method of evaluation of herbicides, this paper should be considered. From the standpoint of the relative ease and quickness of evaluation that has been proposed, it falls in line with the type of system that we are using. The grading system is a little different, but I am very much interested in the Frequency Abundance method, used in Mauritius. The main advantage of this system of this sort lies in the time that is spent in running a larger number of tests and quickly evaluating them. It is quicker than picking out the weeds and weighing them or actually counting the weeds. I have had experience with the several systems and I feel that this observation-grading type is the most satisfactory.

H. EVANS (British Guiana): The logarithmic sprayer, which has a means of automatically increasing the dosage of weedicides, has been used in Mauritius. Is it still in use for the preliminary evaluation of herbicides?

Mr. ANTOINE: We are starting experiments with it.