The Control of Weeds in Sugar Beet By An Endothal/Propham Mixture Applied at Drilling

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Introduction

Endothal has been used in the United States commercially, for several years with considerable success. It was first introduced to Britain for experimental work in 1954 but Parker (6)[2] reported that it was not sufficiently effective against certain important British weeds. It was noted also by Parker that Endothal was influenced by both soil type and rainfall.

More recently Murant (4) described a combination of Endothal and Propham (IPC) which gave improved over-all kill of weeds. Endothal was poor against *Stellaria media, Sinapis arvensis, Raphanus raphanistrum, Chenopodium album* and *Spergula arvensis,* and only moderate against *Avena fatua.* Propham, while itself not very good against *Matricaria maritima* gave with Endothal, a good control of most of the important weeds (with the exception of Brassica weeds, and *Chenopodium album).*

Murant also noted in this paper that while there was no evidence in the trials reported that the soil type affected Endothal and Propham, previous experience had shown inactivation of both chemicals in black Fen soils. No information was available on the effect of rainfall upon efficiency.

Subsequently it became clear that soils, other than fen soils, affected the efficiency of Endothal and Propham. Murant and Cussans (5) reported 7 trials conducted in 1959 from which it was clear that there was a relationship between activity and the amounts of organic matter and clay in the soils. A factor known as Relative Absorption was devised (= 5x organic matter % and clay %). In these same trials the rainfall was about 1 inch in all cases and no difference which could be attributed to this factor could be seen.

In the same paper 1960 trials are described. In that season an attempt was made to relate the Relative Absorption factor with efficiency but it was found that the rainfall variations overlaid the pattern of responses to such a degree that it was possible only to say that the effect of rainfall was greater than that of soil type.

[1] The Murphy Chemical Company Limited, Wheathampstead, Hertfordshire, England.
[2] Numbers in parentheses refer to literature cited.

The writer's colleagues, Bagnall, et al. (1,2) reported 21 trials with an Endothal/Propham mixture. The data presented showed that rainfall was an important factor in determining the efficiency of the mixture and also that the dose required was influenced by the soil type. The value of the Relative Absorption factor was not borne out, and it was suggested that the chief factors governing rate of use were the clay and coarse sand contents of the soils.

Three rates of the Endothal/Propham mixture were employed. In 13 trials out of 21, little or no rain fell and control was generally poor. In the remaining 8 trials a satisfactory weed control was obtained since a sufficient amount of rain fell upon the soil after application of the herbicide. In these 8 successful trials one or the other of the two lower rates used was adequate for control of weeds with safety to the beet. In the present paper the two rates have been designatd LIGHT Rate (L) and MEDIUM Rate (M) (see below) and in Table 1 and Figure 1 they have been related to the coarse sand and clay percentages in the soils treated. (The soil analysis method used was based on methods reported by Bouyoucos (3) and Tyner (7). It employed a 50 gram soil sample and was designed to record coarse sand at 178 microns and over and clay up to 2 microns. In this paper this method is called the "Standard LONG method").

In Figure 1, lines A-B C-D represent the approximate position on which most soil types lie if plotted in terms of coarse sand and clay. Although the data available to Bagnall, et al. was scanty, it was considered that the division of the main axis A-B in segments, by radii as shown, might well form a useful basis for dividing soils into dosage categories.

In 1961 the writer and his colleagues developed this aspect of the use of the Endothal Propham mixture.

Table 1.—Light and medium rates related to coarse sand and clay percentages in the soils treated.

Trial No.	Mechanical soil analysis					Satisfactory rate of Endothal/Propham
	Coarse sand	Clay	Fine Sand	Silt	Organic matter	
1	48.8	18.2	25.0	8.0	2.61	L
2	31.8	21.6	35.2	11.4	2.51	L - M
3	0.2	11.0	65.6	23.2	2.08	M
4	1.4	7.0	77.2	14.4	3.40	M
5	45.4	8.4	38.8	7.4	3.24	L
6	40.4	9.6	44.6	5.4	1.80	L
7	21.4	22.4	31.2	25.0	3.80	M
8	9.6	24.8	47.4	18.2	3.26	M

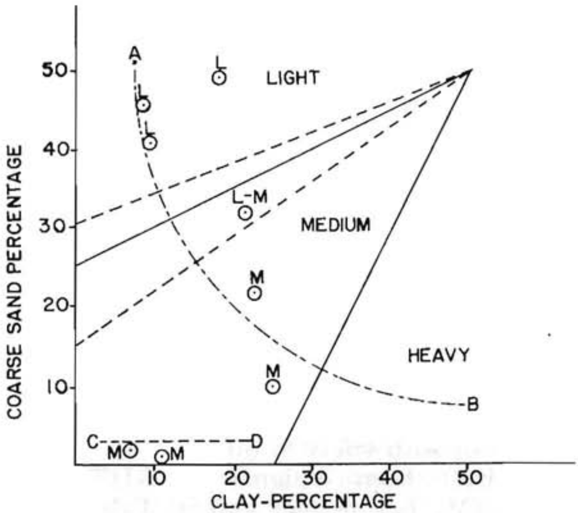

Figure 1.—1960 trials—shows relationship between rates of use of endothal/propham and soil types in terms of course sand and clay.

Materials and Methods

Forty-one trials were successfully carried out with a proprietary preparation of the herbicides, containing 11.4% w/v Endothal (acid equivalent), 8.55% w/v technical Propham. Six rates of use were tested, 3 rates out of the range being used at any one site, the choice depending on the nature of the soil. All soils were analyzed mechanically by the method referred to above, and these values were related to the correct rate of the herbicide (i.e., the rate giving nearest approach to 100% weed kill without adverse effect on the beet). The combined herbicide was applied by hollow cone nozzle in a band directly over the seed row immediately after drilling. Two types of machine were used: a commercial rig, comprising a band sprayer mounted on a precision drill (this method was used both by research staff and commercial growers); and a hand operated device incorporating the same type of nozzle which was pushed along the rows immediately after drilling in the normal way. The nozzles employed were specially developed to apply an even dose of spray across the 7-inch band used. For both machines the following operating data were appropriate: Speed 2 mph; nozzle output 8 fl. oz/minute; pressure 16 lb sq inch: application adjusted to give 7-inch band; and output of 7 gallons per acre, 21-inch row spacing. The formulation described above at dilutions of 1 in 16, 1 in 12, 1 in 8, 1 in 6, 1 in 5, and 1 in 4 give the following rates of use per acre in terms of over-all spraying:

Endothal (Acid equivalent) lb/acre	Propham (technical) lb/acre	Title of rate
1½	1⅛	Extra Light (X/L)
2	1½	Light (L)
3	2¼	Light/Medium (L/M)
4	3	Medium (M)
5	3¾	Medium/Heavy (M/H)
6	4½	Heavy (H)

The titles described have been used for convenience in practice and as they have been found self descriptive they are used here. The titles relate also approximately to the soil type to which they are appropriate.

In addition to the trials, observations on the efficiency and safety of the combined herbicide were made in the 61 cases where it was used commercially, and in these cases also results were related to soil analyses.

Full details of the methods of application, weed and beet counts in the trials will be given in a paper by Caldicott J. J. B. now submitted to 'Weed Research'. The present paper will be confined to the direct relationship between rate of use of the herbicide and the soil type.

Results

Table 2A shows the relationship between the mechanical soil analysis by the Standard Long method and the correct rates of use of the herbicide in the 41 experiments conducted.

Long method results

The results of the Standard LONG method of analysis are plotted in Figure 2. A circular form of graph has been found most appropriate because a) it lengthens the coarse sand axis and thereby tends to separate for pictorial demonstration the different samples and b) because it is found that the curves limiting the different sections are smooth and easily defined when plotted in this form.

It is readily seen that the different rates of use fall smoothly into categories indicating that these rates and the coarse sand and clay factors are clearly and directly related. There tends to be some uncertainty at the higher clay levels, as indicated by trials nos. 37 to 41 where the clay percentages by the Long method are all over 26%. These trials are plotted as problem soils. Field observations indicate that one of the explanations of this situation is the fact that such soils commonly do not form a good seed bed. In England this was particularly common in the spring

Table 2.—Mechanical soil analysis data and herbicide rates for 41 experimental sites.

	A. Standard long method						B. Short method			Dose
Trial No.	Coarse sand %	Clay %	Fine sand %	Silt %	Organic matter %	Theoretical dose	Coarse sand %	Clay %	Theoretical dose	by result
	(1) Soils in which Short and Standard method forecasts agree									
1	0.2	16.6	67.0	16.2	3.91	M	6.5	17.0	M	M
2	0.6	15.8	66.0	17.6	3.52	M	0.8	18.0	M	M
3	1.4	25.4	51.6	21.6	5.25	M	5.9	24.0	M	M
4	2.4	21.0	58.6	18.0	3.09	M	2.3	20.0	M	M
5	2.4	21.4	48.2	28.0	5.61	M	2.6	10.0	M	M
6	7.6	18.8	52.0	22.0	2.75	M	9.2	15.0	M	M
7	8.6	23.8	59.0	8.0	4.5	M	19.2	20.0	M	M
8	12.4	29.0	43.0	15.6	2.3	M	11.0	25.0	. M	M
9	15.0	28.4	40.6	16.0	2.17	M	14.7	33.0	M	M
10	18.0	21.0	43.0	18.0	6.9	M	18.2	18.0	M	M
11	20.2	14.4	47.4	18.0	3.4	L/M - M[1]	18.4	15.0	L/M - M[1]	L/M - M[3]
12	25.6	21.3	32.6	20.0	3.6	L/M	28.6	14.0	L/M	L/M
13	27.0	13.2	45.8	14.0		L/M	25.3	15.0	L/M	L/M
14	28.0	19.2	41.6	11.2	3.8	L/M	28.2	11.0	L/M	L/M
15	29.0	11.0	31.2	18.0	3.8	L - L/M[1]	28.8	20.0	L/M	L - L/M[3]
16	32.0	19.6	36.4	12.0	2.9	L/M	33.3	29.0	L/M	L/M
17	32.2	15.6	39.4	12.8	2.3	L - L/M[1]	40.0	17.0	L	L - L/M[3]
18	32.4	20.0	30.6	17.0	2.2	L	37.7	24.0	L/M	L/M
19	33.2	8.6	51.4	6.8	2.5	L	36.6	15.0	L	L
20	33.2	13.2	28.4	25.2	3.2	L	31.5	12.0	L	L
21	36.9	14.2	40.1	8.8	2.2	L	41.4	18.0	L	L
22	37.0	12.0	41.0	10.0	1.2	L	45.0	11.0	L	L
23	38.0	8.6	46.2	7.2	2.6	L/M	49.0	16.0	L	L
24	38.0	21.8	28.2	12.0	4.4	L	40.3	23.0	L/M	L/M
25	39.4	14.2	32.2	14.2	3.5	L	45.6	17.0	L	L
26	39.8	11.6	45.0	3.6	2.0	L	47.0	7.0	L	L
27	40.6	11.2	44.2	4.0	4.5	L	34.8	5.6	L	L
28	41.8	9.8	44.4	4.0	2.4	L	44.6	18.0	L	L
29	47.4	3.4	31.2	18.0	3.8	XL - L[1]	23.9	3.5	L	L
30	47.4	14.6	30.0	8.0	4.1	L	46.3	12.0	L	L
31	54.4	9.8	33.8	2.0	1.7	XL/L	47.0	11.0	L	L
32	60.0	5.8	26.2	8.0	2.0	X/L	63.0	10.0	X/L	X/L
	(2) Soils in which Short and Standard methods disagree									
33	28.0	17.8	46.2	8.0	2.4	L/M	36.3	11.0	L	L - L/M[3]
34	43.0	18.0	29.0	10.0	4.3	L	47.5	24.0	L/M	L - L/M[3]
35	52.2	13.0	28.8	6.0	1.4	L	48.0	25.0	L/M	L
36	50.2	8.2	35.4	6.2	3.1	L	67.2	8.0	X/L	L
	(3) Heavy Soils which do not respond in usual fashion									
37	11.8	34.4	33.8	20.0	3.7	M	14.9	23.0	M	M/H
38	13.4	27.2	54.0	5.4	3.0	M	15.7	32.0	M	? [2]
39	13.8	26.0	40.2	20.0	3.4	M	14.4	23.0	M	? [2]
40	15.6	29.6	35.8	19.0	4.0	M	17.1	25.0	M	? [2]
41	15.6	35.6	32.2	16.6	7.9	M	18.7	41.0	M	? [2]

[1] Borderline case

[2] All poor at M, M/H and H rates

[3] Both rates described were used and found satisfactory

of 1961 since little or no frost was experienced over the previous winter, with the result that there was no frost mulch. Lack of frost does not affect soils with lower clay and higher sand contents to the same degree. With the exception of these soils therefore the pattern is clear, and the 1961 results confirmed a decision taken previously to restrict commercial usage of the herbicide to medium or lighter than medium soils and to prohibit its use on heavy land and on poor, rough seed beds.

This pattern of relationship was clearly of paramount importance to the future commercial promotion of the herbicide since it offered a means of forecasting correct rates. General practice in the same season (1961) had shown that to be one rate out of true was not serious either from the control or safety point of view. To be two rates out was likely to be serious.

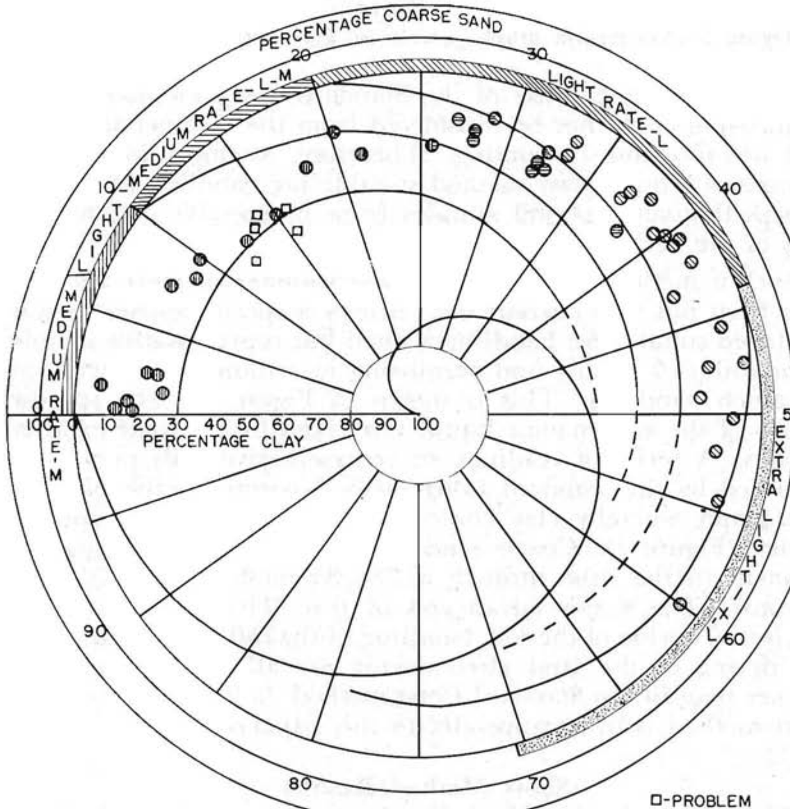

Figure 2.—Graph shows relationship between satisfactory rates of endothal/propham and course sand/clay percentages by standard "long" method.

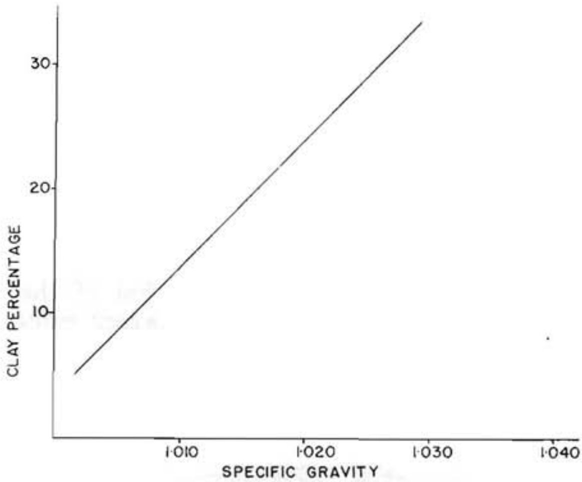

Figure 3.—Conversion graph—gravity to clay percentage.

Unfortunately the use of the Standard Long method of soil examination could not be considered from the commercial angle as it was too time consuming. Therefore, attempts were made to produce a quick easy method suitable for handling hundreds, perhaps thousands of soil samples from prospective commercial users of the herbicide.

Such a method was devised in the summer of 1961 and has since been put into current use. Briefly a special apparatus was developed suitable for handling a small but representative sample of the soil (5.0 grams) and permitting its sedimentation without too much handling. This is shown in Figure 6. The specific gravity of the supernatant liquid was taken by hydrometer after 5 hours. A series of readings on representative soils previously examined by the Standard Long method permitted the plotting of a graph whereby clay content could be read from specific gravity (Figure 3). Coarse sand was determined by sieving the sediment in the tube through a BSS 85 mesh sieve (178 $\pm$ 4 microns). The major advantages of this SHORT method are that initial drying of the soil, handling of the soil in the apparatus, and drying of the sand after sieving are all much easier and quicker than in the Standard Long method (a full report on this Short method is in an appendix to this paper).

Short Method Results

The coarse sand and clay values obtained by this Short method are listed in Table 23 alongside the results for the Long method. These values have been plotted on a graph (Figure 4) with the rates of use divisions as determined in Figure 2 (using

Long method data). It will be seen that the fit is almost as complete as it is in Figure 2. Four exceptions are listed which show a shift of one rate. In two of these, 33 and 34, both Light and Light/Medium rates were found to be satisfactory in practice and this means both Short and Long method forecasts would be accurate. In the cases of 35 and 36 an error of one rate would be made. The Short method forecast rate for trial 35 was in fact used and found to be safe. No data are available on the Short method forecast for trial 36.

The problem clay soils remain in the Medium category, near the upper limit. In practice the probability is that these soils would have responded normally if the seed bed had been good.

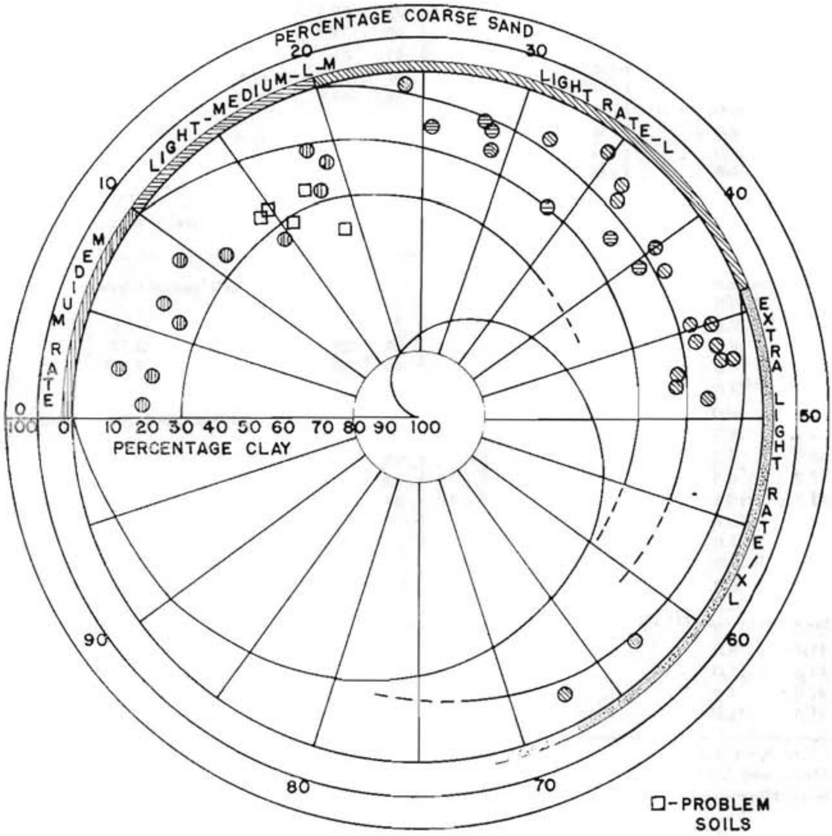

Figure 4.—Graph shows relationship between rates of use of endothal/propham and coarse sand/clay percentages by "short" method.

Table 3.—Soil mechanical analysis data and herbicide rates from 61 commercial sites.

No.	Coarse sand %	Clay %	Theoretical rate	Rate used in practice
A. Theoretical & practical rates identical Satisfactory use of Herbicide				
1	0.81	18.0	M	M
2	1.0	14.0	M	M
3	1.0	10.0	M	M
4	1.09	9.0	M	M
5	1.1	11.0	M	M
6	1.8	10.0	M	M
7	1.9	8.0	M	M
8	2.8	4.0	M	M
9	18.4	11.0	M	M
10	21.6	37.0	L/M	L/M
11	21.7	37.0	M	M
12	22.4	17.0	L/M	L/M
13	22.6	11.0	L/M	L/M
14	22.9	13.0	L/M	L/M
15	23.5	11.0	L/M	L/M
16	23.9	12.0	L/M	L/M
17	25.6	9.0	L/M	L/M
18	25.8	8.0	L/M	L/M
19	25.9	9.0	L/M	L/M
20	26.5	11.0	L/M	L/M
21	26.6	7.0	L	L
22	26.9	10.0	L/M	L/M
23	28.0	18.0	L/M	L/M
24	28.0	14.0	L/M	L/M
25	28.0	9.0	L	L
26	28.8	9.0	L	L
27	29.0	16.0	L/M	L/M
28	30.9	9.0	L	L
29	31.2	4.0	L	L
30	31.5	10.0	L	L
31	31.7	18.0	L/M	L/M
32	32.0	6.0	L	L
33	33.2	6.0	L	L
34	33.9	10.0	L	L
35	34.1	15.0	L - L/M[3]	L/M
36	35.2	11.0	L	L
37	36.9	17.0	L - L/M[3]	L
38	39.0	8.0	L	L
39	39.4	4.0	L	L
40	40.3	13.0	L	L
41	43.6	18.0	L	L
42	44.5	17.0	L	L
43	47.0	7.0	L	L
44	51.9	12.0	L	L
B. Dose applied higher than theoretical				
i) Weed control good—no check to Beet				
45	31.3	10.0	L	L/M
46	36.8	14.0	L	L/M
47	39.5	14.0	L	L/M
48	54.2	10.0	L	L/M
ii) Weed control OK slight check to Beet[1]				
49	30.2	6.0	L	L/M
50	33.8	7.0	L	L/M
51	34.8	10.0	L	L/M
52	38.1	17.0	L	L/M
53	54.9	15.0	L	L/M
54	58.1	7.0	X/L	L
55[2]	67.0	12.0	L	L/M
C. Dose applied Lower than theoretical				
i) Weed control good				
56	0.4	19.0	M	L/M
57	21.6	6.0	L/M	L
58	33.2	17.0	L/M	L
ii) Weed control moderate to poor				
59	1.6	8.0	M	L/M
60	1.8	13.0	M	L
61	23.0	11.0	L/M	X/L

[1] Check only slight and grown out in 7-14 days.
[2] Overdosed by nearly x2 and check on beet severe.
[3] Borderline case.

Commercial Results

The pattern of relationship so far described was very promising and clearly opened the way for the development of a forecasting scheme. A further step was therefore taken. Sixty-one farms where the herbicide had been used commercially in 1961 were visited. In all cases the dosage of herbicide used was decided by the farmer on his own assessment of his soil type. A mechanical analysis was not done in advance of the treatment in any instance. The only requirement here was the assurance that the application had been accurate such that the rate of use to soil type relationship was a true one. After the season the soil from these farms was examined by the Short method and results are listed in Table III. They are plotted on a circular graph in Figure 5. In this instance the clay axis is logarithmic since we are interested only in the lower clay values (below 40%).

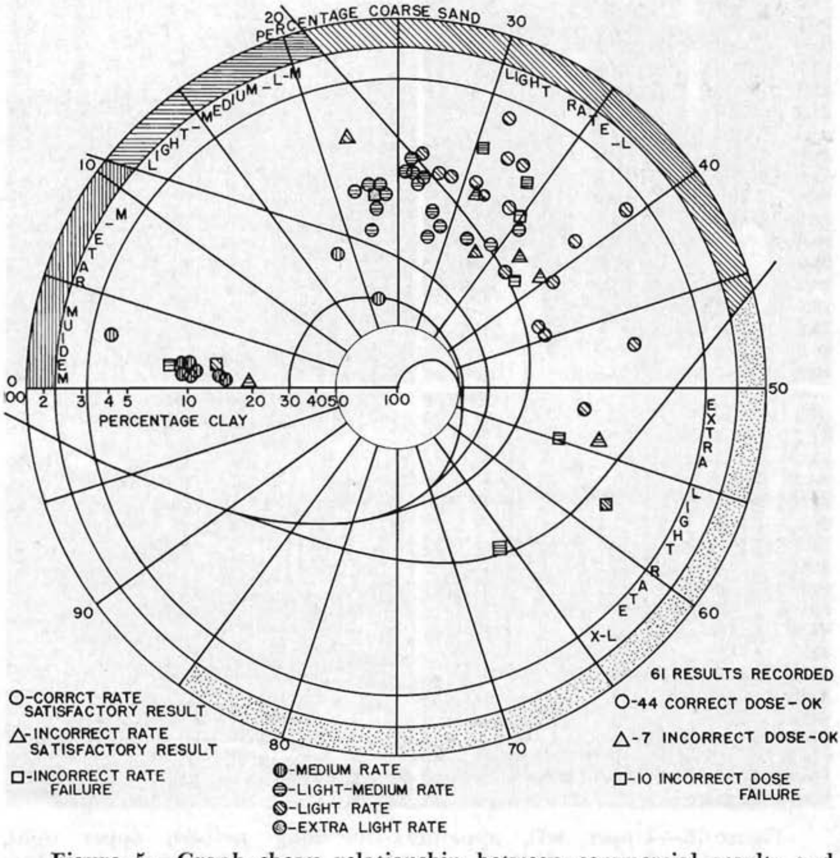

Figure 5.—Graph shows relationship between commercial results and "short" method of soil analysis—1961 results recorded.

Study of Figure 5 will show that the fit here is also good. In most of the instances of use the correct dosage for the soil (by consideration of coarse sand and clay fractions) was chosen and results were satisfactory both in terms of control of weeds, and safety to beet. In several instances however a wrong dosage was employed. In some of these results nevertheless were still satisfactory. In others results were unsatisfactory either as a result of damage, (where too high a rate was used) or through a failure to control the weeds, where too low a dose was used.

It should be pointed out that all the soils studied have a relatively low organic matter content, the highest recorded here being 6.9%. Higher organic contents tend to inactivate the herbicide and nullify the scheme described above. Further there is

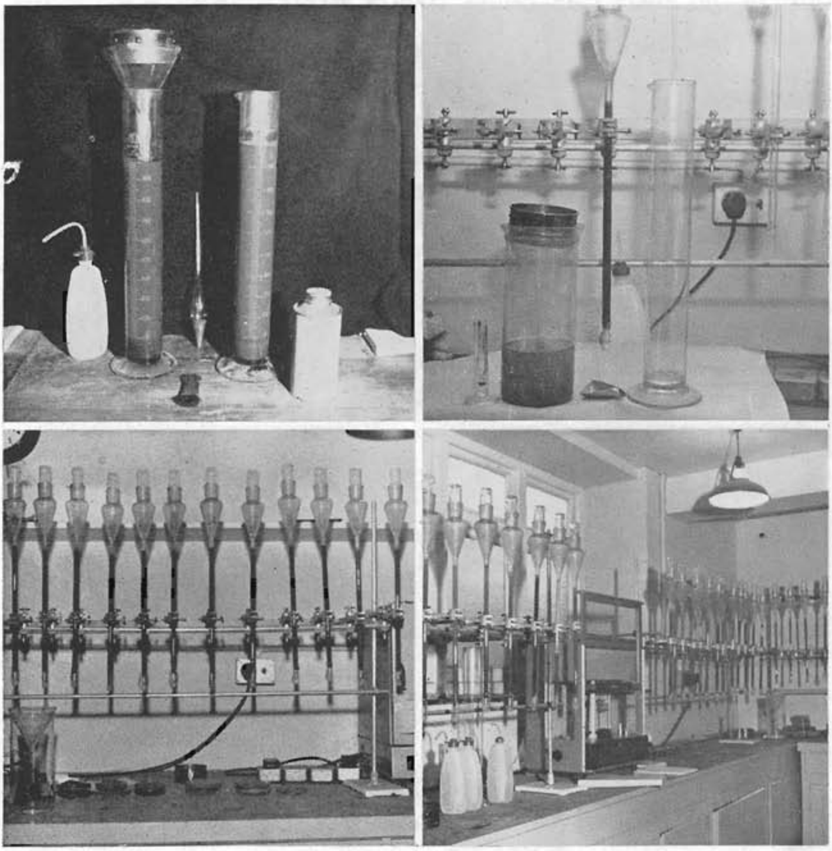

Figure 6.—Upper left, apparatus for long method; upper right, apparatus for short method; lower left and right, apparatus for short method (general view).

an indication that the unusual soils of the Dutch Polders do not respond in the expected pattern. These soils comprise very large proportions of fine sand, and while the theoretical dose by the coarse sand/clay method is often the Medium dose, in practice a Light Medium or even a Light rate is adequate. This situation has not been found with British soils.

Summary

The results presented show that a reliable means of relating the required rate of use of the herbicide to the soil type (in terms of coarse sand and clay) has been evolved. The method is essentially arbitrary in that a range of suitable rates was adopted and the soils have been categorised in terms of this range. Nevertheless a high degree of accuracy in forecasting the required rate is obtained. This, coupled with the fact that an error of one dose from the true is not a serious error suggests that the technique can be used with confidence on a commercial scale. This in fact is being done at present by the writer's Company in preparation for the 1962 growing season.

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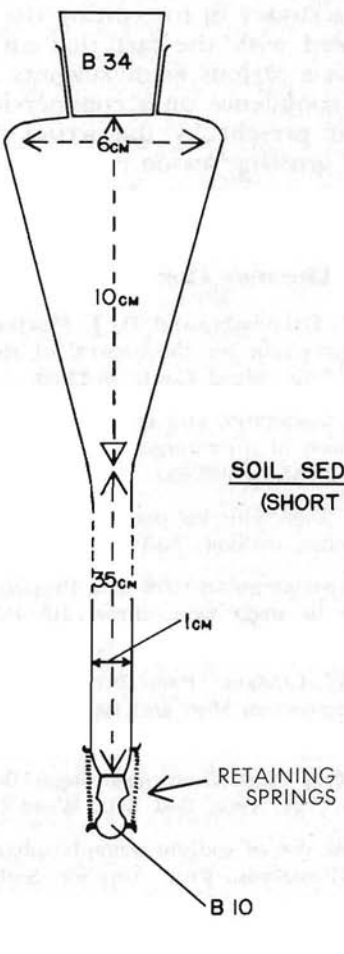
Appendix

The "Short" Method

The sample as received in the laboratory is re-sampled to give a weight of approximately 50 g. Preliminary partial drying of the field sample may be necessary before a true laboratory sample can be taken. This is carried out by infra-red heating. The 50 g. laboratory sample is dried at a temperature not exceeding 130°C. The time varies from 0.5 to 2 hours according to the initial water content of the samples.

The dried sample is broken down with a pestle and mortar in such a way as to disrupt all aggregates but not to reduce the actual particle size. It is then passed through a BSS 10 mesh



SOIL SEDIMENTATION
(SHORT METHOD)

sieve (1676 ± 22 microns and from that part of the sample, which should be at least 95%, weigh 5.00 g into the apparatus (see diagram), via the smaller end, the larger end being stoppered. Add 25 ml of 0.125% Calgon (Sodium Hexametaphosphate) in the same manner, using the solution to wash the soil completely into the reservoir. Replace the smaller stopper and, keeping the slurry in the reservoir, shape with semi-rotary motion for three minutes. Place the apparatus in a clamp in an upright position with the reservoir at the top, and allow to stand for 5 hours ± 10 minutes.

Remove the apparatus from the stand and carefully decant the supernatant liquor without disturbing the silt layer into a 25 ml measuring cylinder and take the gravity at 20°C ± 1°C. Read from the prepared graph the percentage of clay.

Return the apparatus to the stand and wash the total sediment through a BSS 85 mesh sieve (178 ± 4 microns). Wash on the sieve with distilled water and dry at 110°C for 0.25 hours. Weigh and calculate the percentage of coarse sand.

Acknowledgments

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