CHEMICAL WEED CONTROL IN TEA

H. N. Hasselo and S. Sandanam

Weed control in tea Estates has two aspects (Chambers, 1963; "Digitarius" 1963).

(*A*) The need to control weeds in tea.
(*B*) Methods to control weeds.

The second aspect will be considered in detail, particularly with regard to the use of herbicides.

A. The need to control weeds in tea

Weed growth if uncontrolled can be detrimental to tea in three different ways.

(1) Weeds can compete with tea for water, light and nutrients.

(2) They can increase the humidity around the bush thus creating conditions favourable for the incidence of fungal diseases.

(3) They can hinder the field operations such as plucking, spraying, fertilizing.

B. Methods to control weeds

The methods that could be adopted are:

(1) Manual control.
(2) Control by keeping the soil covered.
(3) Chemical control.

(1) *Manual Control* The most common method of weed control in tea Estates is to scrape the weeds off the surface of the soil. This practice has disadvantages such as shortage of labourers, effect on soil erosion and structure.

(2) *Soil Cover* This method of weed control is based upon the idea of creating conditions unfavourable for the germination and growth of weeds.

It includes the practice of growing a cover crop, the use of mulch and the supplying of tea plants, where vacancies occur.

(3) *Chemical Methods* A new development in the control of weeds is the use of chemicals commonly referred to as herbicides. Herbicides must necessarily have the following properties if this method is to be advantageous over the normally adopted method of manual weeding. They must,

(*a*) control the weeds generally occurring on tea lands,

(*b*) not interfere with the growth of tea either directly or indirectly by any adverse effect on the soil microflora and fauna so as to imbalance the soil conditions for maximum crop growth,

(*c*) give prolonged weed control at economic levels of application,

(*d*) not be hazardous to the operator.

Herbicides can be classified in several different ways; for instance into *Selective* and *Non-selective* herbicides.

Selective herbicides are those that affect only a definite group of plants. Examples are 2, 4—D, a hormonal herbicide which controls broad leaved weeds but not grasses, and Dalapon which controls grasses only.

Non-selective herbicides are those that can be effective in controlling all types of weeds *eg* Paraquat (Gramoxone).

Herbicides can also be classified according to their mode of action *viz Contact* herbicides, *Translocated* herbicides, *Residual* herbicides.

Contact herbicides are those that affect herbs or weeds on direct contact between the chemical and any part of the plant *eg* Paraquat.

Translocated herbicides are those which, when applied to one part of the plant, are transported to other parts thereby interfering with the metabolism of the plant and killing it *eg* 2, 4—D, and Dalapon.

Residual herbicides are applied to the soil, are absorbed by the roots and translocated to the shoots thus killing the plant. Residual herbicides must, in order to be effective, remain active in the soil for some time after their application. They normally control seedlings of weeds, *eg* Simazine, Karmex, Atrazine and Atratone.

Thirdly, the herbicides can also be classified according to the stage of development at which the weed population should be sprayed. They are known as *Pre-emergent* herbicides and *Post-emergent* herbicides.

Pre-emergent herbicides should be applied after clean weeding and they only affect the weed seedlings at sprouting, *eg* Simazine, Atrazine, Atratone, Karmex, Prometryne.

Post-emergent herbicides are those that are applied after the emergence of weed seedlings *eg* on standing weeds, *eg* Gramoxone, Phenoxylene plus, Phordene.

Other systems of classification are related to the chemical composition of the herbicides, their chemical and physiological mode of action and so on.

Experiments

In order to test the efficiency of different proprietory herbicides for use on tea land, four exploratory trials (No 1–4) were laid out at St Coombs Estate.

I. Demonstration Trial

In these plots, the herbicides shown in Table 1 were used at three levels of application, *ie* 1, 2 (= 2 × level 1) and 3(=3 × level 1). The amounts are shown in lb/application per acre of the commercial formulation. There were 48 plants per plot approximately. The first application was made on the 7th of February, 1964, the second application on the 25th of March 1964 and the third application on the 6th of June, 1964. Weed control and damage to the tea plants (3 year old—clone TRI 2024 and 2025) were assessed visually. The two clones were not distributed uniformly between the treatments.

II. Painting Trial

Herbicidal solutions prepared in water and of the same concentration as applied to the soil at levels 1 and 2(= 3 × level 1) were painted in a thin film on to the leaves of living tea bushes.

III. Pot Trial

Herbicidal solutions of 2 × and 4 × the standard, *ie* level 1 of Table 1, concentration were applied (8cc/sleeve) to soil of one year old plants (cuttings of clone TRI 2024) growing in polythene sleeves, diameter 6" and height 8", filled with nursery soil. Care was taken that the solutions did not come into contact with the above ground plant parts.

IV. Single plant plots

The same herbicides as shown in Table 1 were carefully applied at two levels 1 and 2 (= 3 × level 1) to the area (8 sq ft) surrounding one plant. One plant represented one treatment or plot there being six replicates. As a check there were two plants, or control plots, in each of the six replicates which were not treated. Between any two treated plants or plots there was an untreated plant which served as a guard plant between two treatments. Each replicate or block consisted of two contour rows of tea plants. The experimental area was situated on a slope with a gradient of 13° and bordered at the top and bottom by a contour drain. The distance between the drains was 54 ft. Block I was situated at the top and Block VI at the bottom. This area was also used to measure soil erosion losses (Hasselo and Sikurajapathy, 1965). The herbicides were sprayed on the 9th of May 1964 and assessments taken on the 8th of July 1964.

TABLE 1.—*Herbicidal Application Rates*

	Dosage lb*/acre/application		
HERBICIDES	level 1	level 2	level 3
Simazine	4	8	12
Atrazine	4	8	12
Atratone	4	8	12
Prometryne	4	8	12
Karmex	2	4	6
Dowpon	3	6	9
Phenoxylene Plus	4	8	12
DH—34	2	4	6
Gramoxone	3	—	9
Phordene	2½	—	7½

*Commercial formulation. *Note:* Phenoxylene plus, DH—34, Phordene and Gramoxone are expressed in pints/acre/application

Results

I. Demonstration Trial

The visual observations made in this trial are given in Table 2.

TABLE 2.—*Phytotoxic effects on tea*

HERBICIDES	Rates of application lb*/acre/ application 1	2	3	Description of toxic effects	Ranking: 1 = slightly phytotoxic. 10 = very phytotoxic
Simazine	4	8	12	No effect	1
DH—34	2	4	6	Mild chlorosis	2
Dowpon	3	6	9	Mild chlorosis	3
Prometryne	4	8	12	Mild chlorosis	4
Atrazine	4	8	12	Mild chlorosis	5
Atratone	4	8	12	Severe chlorosis	6
Karmex	2	4	6	Severe chlorosis	7
Phenoxylene Plus	4	8	12	Curling	8
Phordene	2.5	–	7.5	Curling	9
Gramoxone	3	–	9	Severe scorch	10

Note: Phenoxylene plus, DH—34, Phordene and Gramoxone are expressed in pints/acre/application.

*Commercial formulation.

The phytotoxic effects in this trial (Figures 1 A–D) might have been caused by direct contact, *ie* owing to drift during spraying, or by uptake through the roots or both. These effects were segregated from each other in the painting and pot trials.

II. Painting Trial

Injury to tea leaves due to drift during spraying was assessed by painting diluted herbicidal solutions on to the leaves (Table 3).

TABLE 3.—*Phytotoxic effect of diluted herbicidal solutions painted on to tea leaves*

HERBICIDE	Concentration of solutions lb+/100 gallons level 1	level 2	Description of symptoms	Ranking; 1 = slightly phytotoxic 10 = severely phytotoxic
Simazine	4	12	None	1
Atrazine	4	2	Very mild chlorosis	2
Prometryne	4	12	Mild chlorosis	3
*DH—34	3	9	Mild chlorosis	4
Dowpon	5	15	Mild chlorosis	5
Atratone	4	12	Medium to severe chlorosis	6
Karmex	4	12	Medium to severe chlorosis	7
*Phenoxylene Plus	2.5	7.5	Curling of leaves	8
*Phordene	2.5	7.5	Curling of leaves	9
*Gramoxone	3	9	Severe scorch	10

*Concentration in pints/100 gallons.
+Commercial formulation.

III. Pot Trial

In this trial the herbicidal solutions were applied to the soil.

TABLE 4.—*Phytotoxic effcet of diluted herbicidal solutions applied to the soil*

HERBICIDES	Concentration of solution lb+/100 gal 1	2	Description of symptoms	Ranking 1 = slightly phytotoxic 10 = severely phytotoxic
Phenoxylene Plus	5	10	Not tested	—
*DH—34	6	12	Not tested	—
Prometryne	8	16	Tip scorch, leaves fallen off	3
Dowpon	10	20	Tip scorch, buds stunted & drying	4
*Gramoxone	6	12	Yellowing & falling off of leaves	5
Atratone	8	16	Mild chlorosis and tip scorch	6
Atrazine	8	16	Buds drying off	7
Karmex	8	16	Yellowing, drying, death of shoots	8
*Phordene	5	10	Scorching & death of shoots	9
Simazine	8	16	Scorch, death of shoots	10

*Concentration expressed in pints/100 gals
+Commercial formulation

IV. *Single Plant Plots*

(*a*) *Visual assessment*

The effect of two levels of herbicides on weed control as compared with unsprayed control plots was scored visually and the scorings analysed statistically. No significant effects were obtained in Blocks I and II, which are situated at the upper end of the sloping experimental area. In the remaining 4 Blocks situated lower down the slope weed control in the sprayed plots was significantly better ($P<0.001$) than in the unsprayed plots (Table 5).

It will be seen from Table 5 that the pre-emergent herbicides Karmex, Atratone, Prometryne and Simazine were outstandingly better in the control of weeds. It should be noted that the assessment is based on total weed control and that, therefore, a herbicide like Dowpon, which controls grasses mainly, may be outstanding in its selective control, *ie* of grasses, but not in total weed control, *ie* including broad leaved weeds.

Trebling the application rates, level 2 was significantly better than level 1 by 18%, varying between 0 and 33% for Phenoxylene plus and Atrazine respectively. The results show that the extra weed control obtained at level 2 was appreciably less than for the first dose and, therefore, much less economical, if at all.

(*b*) *Weight of weeds per 1 sq ft*

The weights of shoots and roots of weeds in a quadrat 1 foot square fixed at random, were also recorded (Table 6).

Weed growth in the treated plots was, on the average, significantly less ($P<0.001$) than in the Control plots. Karmex, Atratone, Simazine, Prometryne and Atrazine reduced weed growth to less than 20% in the period under consideration. The effect of an extra double dose (level 2) over level 1 was very small indeed and with the exception of Phenoxylene plus, less than 15% of that achieved with the first dose.

(*c*) *Shoot-root ratio of weeds*

The S/R ratio of weeds *ie* the ratio of the weight of shoots to roots, in the treated plots was compared with that of the control plots and was used as an index of the after-effect of the herbicides (Table 7). The S/R ratio was significantly ($P<0.01$) lower in the treated as compared with the control plots. The variance of "between weedicides" and "levels" was not significant.

Discussion

(*a*) *Effect of herbicides on Weed Control*

The effect of ten different herbicides on overall control, on weights of weeds, 2 months after the first application, and on the shoot/root ratio of weeds has been ranked in Table 8. The average of these three rankings shows that of the ten herbicides tested, Atratone, Karmex, Prometryne, Simazine and Gramoxone in this order, controlled the weeds best and longest.

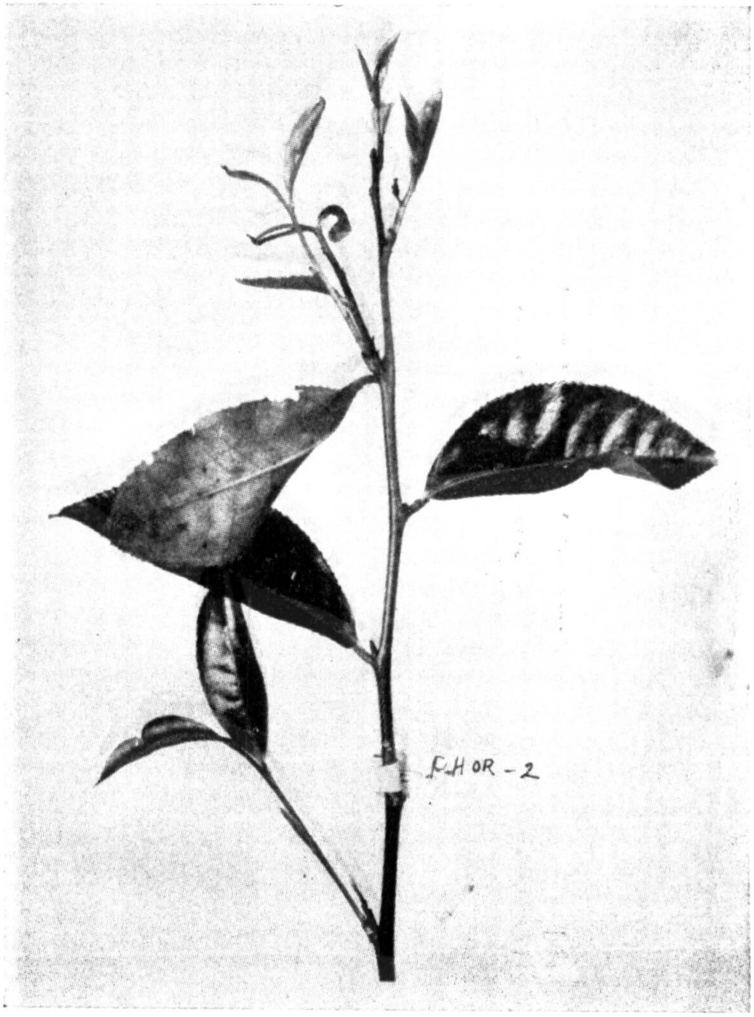

Figure 2B —See Fig 2A. *Note:* bud development *above* label and healthy shoot *below* label.

Figure 2C.—See Fig 2A. *Note:* defoliation of side shoots.

Figure 3.—Effect of herbicidal (selective herbicide) solution applied to two leaves above label.

Note : Growth retardation and defoliation of labelled shoot but unimpeded healthy growth of shoot emerged below treated leaves.

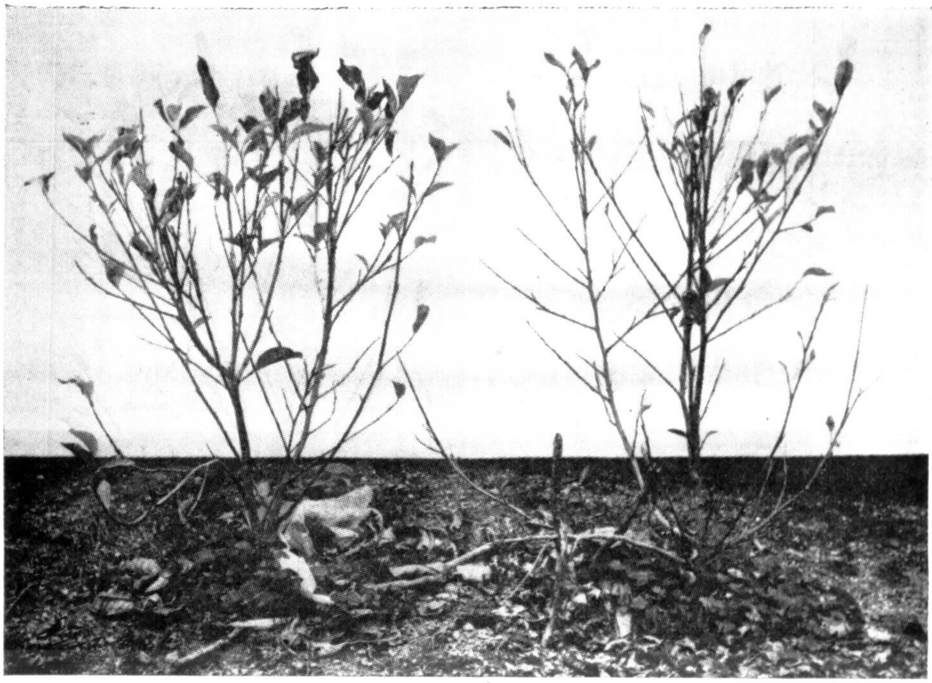

Figure 1A.—Effect of excessive soil applications of pre-emergent herbicides. *Note:* defoliation.

Figure 1B.—See Fig 1A. *Note:* Leaf discolorations: Dark patches were green, grey ones yellow.

Figure 1C.—See Fig 1A and 1B.

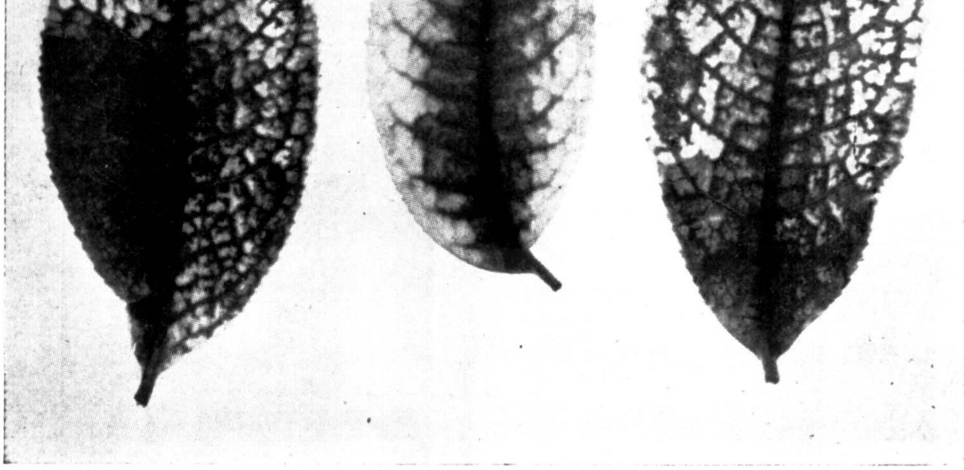

Figure 1D.—See Fig 1A and 1B.

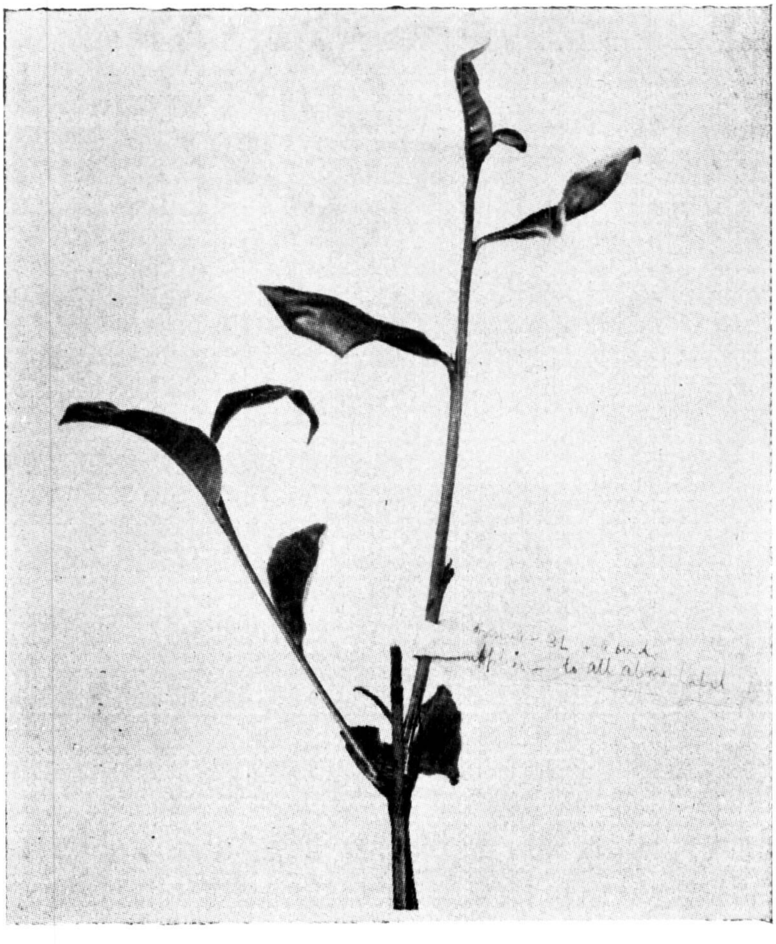

Figure 2A.—Effect of diluted herbicidal (hormone type) solutions applied to two leaves above label These two leaves had dropped off when pictures were taken. *Note:* curling and twisting of leaves *above* label and absence of effect on shoot and leaves *below* label.

TABLE 5—*Visual assessment of Weed Control (Scoring: 1 = poor, 10 = very good control; mean of 4 blocks (Blocks III—VI)*

SCORING	HERBICIDES										Significant Difference
	Karmex	Atratone	Prometryne	Simazine	Dowpon	Gramoxone	Atrazine	Phordene	DH-34	Phenoxylene Plus	
Mean Score of level 1 & 2	8.75 Good to very good	6.75	6.25 Good to fair	6.00	5.75	5.50 Fair	5.25	4.25 Fair to poor	4.00	3.00 Poor	P 0.05 = 1.12 P 0.01 = 1.49 P 0.001 = 1.93
Increase level 2 over level 1 (%)	6%	25%	27%	18%	9%	20%	33%	12%	29%	0%	

TABLE 6—*Shoot + Root weights of weeds (g dry weight/sq ft)*

Weed weight g per sq ft	HERBICIDES										
	Karmex	Atratone	Simazine	Prometryne	Atrazine	Phordene	Gramoxone	DH—34	Phenoxylene plus	Dowpon	Control
Mean weight of level 1 and 2*	0.53	1.25	2.25	2.51	2.69	3.84	4.11	9.76	9.86	11.50	15.77
Control = 100	3	8	14	16	17	24	26	62	63	73	100
Decrease of level 2 over level 1 in % of control	2	5	5	3	1	10	-3	12	28	8	—

*LSD P(5%) = 5.90; P(1%) = 7.80; P(0.1%) = 10.05

TABLE 7.—*Effects of herbicides on Shoot/root ratio of weeds (S/R)*

	Gramoxone	Phordene	Atratone	DH-34	Phenoxylene Plus	Prometryne	Simazine	Dowpon	Atrazine	Karmex	Control
S/R ratio mean of level 1&2	4.9	5.0	5.7	5.7	5.8	5.8	6.0	6.7	7.4	9.2	9.5
% of control	51%	53	60	60	61	61	63	71	78	96	100

TABLE 8.—*Ranking of herbicides in relation to efficacy of weed control (10=poor; 1=good weed control); a=overall control (visual); b=weed growth; c=after-effect on basis of shoot/root ratio.*

Assessment of weed control	Atratone	Karmex	Prometryne	Simazine	Gramoxone	Phordene	Atrazine	DH–34	Dowpon	Phenoxylene Plus
a	2	1	3	4	6	8	7	9	5	10
b	2	1	4	3	7	6	5	8	10	9
c	3	10	6	7	1	2	9	4	8	5
Mean Ranking	1	2	3	4	5	6	7	8	9	10

(*b*) *Effect of toxicity of herbicides*

The rankings of four different assessments *a-d* of the phytotoxic effects of herbicides on tea are given in Table 9.

TABLE 9.—*Phytotoxic effects of herbicides on tea (rankings:—10=serious; 1=little damage); a=overall effect–expt I; b=damage by direct contact (drift during spraying) – expt II; c=damage as a result of uptake by tea roots – expt III; d=after-effect based on shoot/root ratio of weeds* ie *reversed rankings of (c) of Table 8 – of expt IV.*

Assessment of phytotoxicity	HERBICIDES Prometryne	Dowpon	Simazine	Atrazine	DH—34	Karmex	Atratone	Phenoxylene Plus	Gramoxone	Phordene
a	4	3	1	5	2	7	6	8	10	9
b	3	5	1	2	4	7	6	8	10	9
c	3	4	10	7	—	8	6	—	5	9
d	5	3	4	2	7	1	8	6	10	9
Mean Ranking	1	2	3	4	5	6	7	8	9	10

(*c*) *Ranking of herbicides*

Combining the mean rankings of Tables 8 and 9, *ie* in respect of the efficacy of the ten different herbicides in controlling weeds together with their phytotoxic effect on tea, the following ranking is obtained (Table 10).

TABLE 10.—*Ranking of herbicides: mean of weed control and phytotoxic effects; 1=good weed control or/and mildly phytotoxic; 10=poor weed control or/and severely phytotoxic.*

	HERBICIDES Prometryne	Simazine	Karmex	Atratone	Dowpon	Atrazine	DH—34	Gramoxone	Phordene	Phenoxylene Plus
Mean Ranking	1	2	3	4	5	6	7	8	9	10

It will be seen from Tables 8, 9 and 10 that *Prometryne*, a pre-emergent herbicide, gave the best overall results. Its phytotoxic effect on tea was consistently low whilst it controlled weeds satisfactorily even though its effect was not long lasting. This finding does not agree with the observations made in East Africa (1964 ; 1963) where Prometryne was found to be severely phytotoxic when sprayed on tea bushes.

Relatively very good results were also obtained with *Simazine*, a pre-emergent herbicide, though it would seem to be able to cause serious injury under specific conditions (see Table 9 sub c). The latter was thought to be caused by the low organic matter content of 2 % of the nursery soil in experiment III. Phytotoxicity of herbicides in soils has been found to be principally determined by the soil organic matter content (Homburg & Mariouw Smit 1964 ; Sheets 1964 ; Dubey and Freeman 1964). In these circumstances the danger of phytotoxicity due to soil applications of Simazine might be greater at lower than at higher elevations, where soils contain lower and higher amounts of organic matter respectively.

Karmex, a pre-emergent herbicide, appeared third in the ranking. This was due particularly to its second place in the ranking on weed control (Table 8). However, it appeared to be rather phytotoxic so that great care during application is necessary.

Fourth on the list was *Atratone*, a pre-emergent herbicide capable also of affecting standing weed seedlings to some extent. It produced the best and most consistent results in respect of weed control. It was, however, equally consistent in its phytotoxic effect which was well above average (Table 9).

The fifth place was for *Dowpon* mainly because of its, on average, low phytotoxicity. As Dowpon is a selective herbicide it is not surprising that it does not show up well in the total weed control ranking.

The ranking of *Atrazine*, a pre-emergent herbicide, was similar to that of Dowpon. It is average both in respect of weed control and phytotoxicity. The improved control obtained from larger application rates (Table 5) warrants further tests to be made with this chemical.

As *DH-34* is a herbicide still in its experimental stage, no further information on its specific characteristics can be given.

The effect of *Gramoxone*, (a contact non-selective weedkiller) is similar to that of *Phordene*, a hormone herbicide, both being consistently phytotoxic in the four different types of assessments made (Table 9 a-d). Weed control was average. This was, in respect of Gramoxone, due to the fact that weed control was not persistent, it being of short duration (approx 2 weeks). The immediate control by Gramoxone was very good.

The low ranking of *Phenoxylene plus*, a hormone herbicide, was due to its very poor control of weeds and toxicity to tea.

(*d*) *Soil erosion and efficacy of chemical weed control*

Soil erosion in experiment IV was found to be appreciable (Hasselo & Sikurajapathy 1965). It was estimated to amount to a layer of 0.16 inch approximately in the period between the application of herbicides and the assessment of their effect on weed control some 2 months later. It was reported earlier that no significant effect of herbicides as compared with the control was obtained on the basis of visual scorings in the uppermost two Blocks Nos I and II (Table 5). The efficacy of weed control in Blocks III, IV, V and VI, situated lower down the slope in this order, is shown in Figure 4. The mean weight of weeds collected at each of the two levels of herbicidal application in Blocks I (top of the trial area) to VI (bottom of slope) is shown in Figure 5.

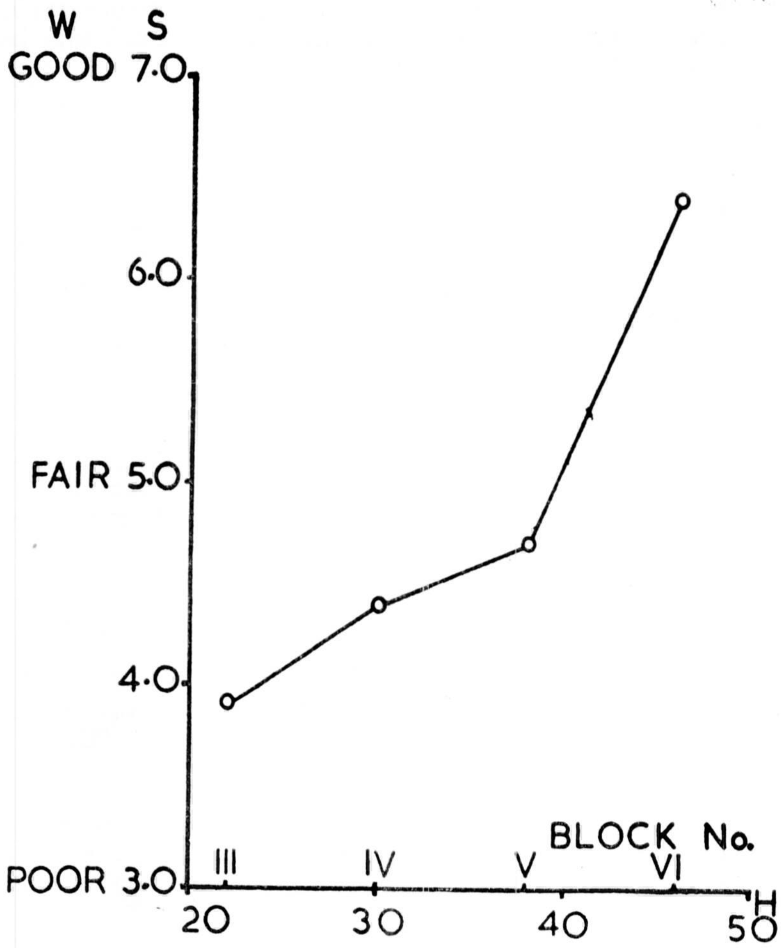

Figure 4.—The effect of position on slope (H in feet down the slope) of Blocks III—VI on efficacy of weed control (W) in these Blocks (S=10=very good; 1=very poor control). See also Table 5.

It will be seen from Figures 4 and 5 that weed control and weed growth were much poorer and more prolific respectively in the eroded upper blocks, particularly at the lower level of application. The downward trend in Figure 5 is significant at $P < 0.05$ ($b_{WH} = -0.26$) and is the resultant of a succession of downward and upward trends. It reflects the successive phases of erosion and accumulation, erosion taking place at the downslope side of a row of tea bushes planted on the contour and accumulation on the side facing upwards (Hasselo, 1964).

Apparently, too much of the applied herbicides had been washed downwards with the soil eroded from the upper blocks and too little left so as to control weed growth significantly. On the other hand, accumulation of soil and herbicides will occur on less steep parts (lower down) on a slope, improving weed control there but also increasing the danger of phytotoxicity to tea. It should be emphasized here that the trends shown in Figure 4 and 5 were due to erosion and not to leaching of herbicides. Firstly, because in the period under consideration there could not have been any appreciable leaching as the subsoil was still dry and, secondly, because leaching of herbicides is considered to be of minor importance among the factors which inactivate herbiaides in the soil (Quastel, 1963).

It will also be seen from Figure 5 that the, on average, better weed control at level 2 as compared with level 1 was mainly due to better control in the eroded upper blocks (I, II and III).

Average weight of weeds in the control plots (Fig 5) amounted to 14 g per square foot. Hence, weed control in the treated as compared with the untreated control plots amounted to 58% in Block I. It increased going down the slope by 5% per block to 83% in Block VI, or a difference of 25% between blocks I and VI. As the distance between these two blocks was 40 ft, weed control improved by 1.9% per yard down the slope. It is of interest to note that a figure of 1½ to 2% was also obtained in studies on the effect of "position on slope" on productivity of tea land (Hasselo, 1964).

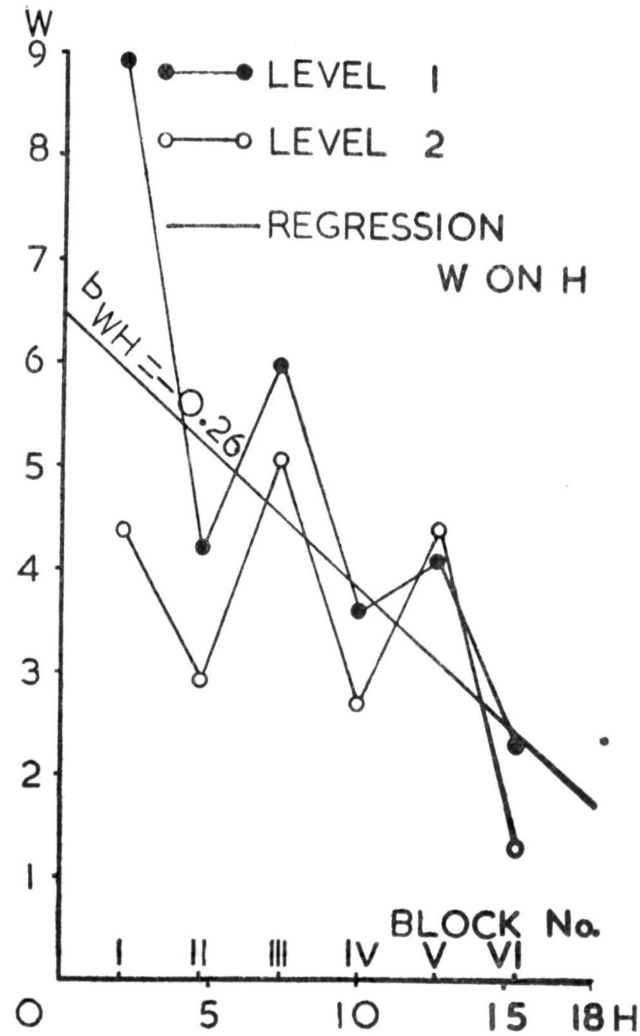

Figure 5.—The relation between position on slope (H in yards down the slope) of Blocks I—VI and mean shoot weight of weeds (W in g dry weight per square foot per Block) at two levels of herbicidal application, each level representing the mean of ten different herbicides.

Summary

Ten different herbicides were assessed on their phytotoxicity to weeds and tea. All of them reduced the growth of weeds but also caused phytotoxic symptoms in tea (Figures 1, 2 & 3).

The results of different assessments of phytotoxicity are given in Tables 2 to 7 and are summarized in Tables 8, 9 and 10. In Table 10 the different herbicidal effects are averaged and ranked in relation to each other.

It was shown that soil erosion could greatly reduce the efficiency of chemical weed control. On the other hand, herbicidal toxicity to tea might readily occur in places where sprayed soils accumulate after erosion or on soils with low organic matter contents. In view of the latter, lower rates of herbicidal applications might be effective and indeed be necessary, in order to reduce toxic effects on tea, in tea grown at lower elevations, where soils generally contain less organic matter.

The increase in efficiency of chemical weed control going down a slope was due to soil erosion rather than to leaching of herbicides. This efficiency gradient appeared to be of the same magnitude as that of the soil productivity gradients observed on sloping tea land.

The results did not allow conclusions to be drawn on the long term herbicidal effects on tea nor on the economics of chemical versus other methods of weed control.

Acknowledgements

The authors wish to thank Mr. P. Kanapathipillai for the statistical analysis, Mr. M. Sikurajapathy for his part in the field work and Mr S. M. Kandasamy for drawing the graphs.

References

Chambers, G. M., (1963) The problem of weed control in tea. *World Crops*, **15** : 363-368.

"Digitarius" (1963) Tea without weeds. *Tea, J. of Tea Boards of East Africa*, **3** : 24-34.

Dubey, H. D., Freeman, J. F., (1964) Influence of soil properties and microbial activity on the phytotoxicity of linuron and diphenamid. *Soil*, **97** : 334-340.

Hasselo, H. N., (1964) Productivity gradients on sloping tea land in Ceylon. *Tea Quart.* **35** : 207-216.

Hasselo, H. N., Sikurajapathy, M. (1965) Estimation of losses and erodibility of tea soils during the replanting period. *J Agric Soc of Ceylon*, **2** : (in press).

Homburgh, K., Mariouw Smit, F. (1964) Ueber die Persistenz zweier neuartiger Methoxyharnstoffpraparate im Boden. Lecture given in Amsterdam, Holland.

Quastel, J. H., (1963) Microbial activities of soil as they effect plant nutrition. Plant Physiology Vol III : Inorganic nutrition of Plants : 671-756. Academic Press, New York and London.

Sheets, T. Y. (1964) Metabolism of herbicides. Review of disappearance of substituted urea herbicides from soil. *Agric. Food Chem.*, **12** : 30-33.

Wilson, K. C., (1964) and (1963). *Ann. Rep. Tea Res. Inst. of East Africa for 1963 and 1962.*