Proc. 9th Brit. Weed Control Conf. 1968

WEED CONTROL IN SUGAR CANE WITH ASULAM

M. J. Tuckett & R. W. E. Ball

May & Baker Limited, Dagenham

Agricultural Research Station, May & Baker Limited, Ongar

Summary In a series of trials in sugar cane in the West Indies, pre- and post-emergence applications of up to 6.5 lb per acre of asulam (methyl 4-aminobenzenesulphonylcarbamate) have given good control of grass weeds, and moderate control of broad leaved species, without damage to plant or ratoon cane. Doses below 3 lb a.i. per acre were insufficient to give adequate control under all conditions. The addition of 2,4-D ester or a mixture of ioxynil octanoate/2,4-D resulted in an improved control of broad leaved species without affecting the selectivity to the crop orimpairing the control of grasses.

INTRODUCTION

The herbicidal properties of the benzenesulphonylcarbamates were first discovered in 1961, (Cottrell and Heywood, 1965) and following field screening experiments in England in 1962, small scale experiments were carried out in a variety of crops in various other countries. Initial work in 1963 in the West Indies with three of these compounds confirmed that asulam was the most active and preliminary results indicated that it was of interest for pre-emergence weed control, particularly of monocotyledons, in sugar cane (Ball et al, 1965).

A series of experiments has been carried out in sugar cane since 1963 to determine the selectivity of asulam under a range of conditions. During the period 1963 - 1966 work was concentrated on applications before the emergence of the weeds, but in the last two years the post-emergence effect of asulam has been investigated, particularly on graminaceous species.

METHODS AND MATERIALS

All the experimental work was carried out in Jamaica and Barbados in commercial crops of both plant and ratoon cane. Two types of trial were laid down namely (a) small plot trials in randomised blocks, with 2 or 3 replicates and a plot size of from 1/64 to 1/40 acre and (b) large scale trials with non-replicated plots of half to one acre in area.

Spraying was carried out in every case by knapsack sprayer, at volume rates of between 20 and 40 gallons per acre. The following formulations of asulam were used:-

NPH 1231 Soluble powder, containing 75% w/w asulam as the potassium salt.
NPH 1232 Wettable powder, containing 80% w/w asulam as acid.
ARD 1301 Aqueous concentrate, containing 60% w/v asulam as the sodium salt.

NPH 1231 was used in the 1963/64 trials, NPH 1232 from 1964 to 1968, and ARD 1301 in some of the 1968 trials.

Weed control was assessed in the pre-emergence trials by estimating the percentage ground cover in 5 or 10 random throws of a 1 foot square quadrat per plot. Separate estimations of ground cover were made for (a) total broad leaved weeds and (b) total grasses, and only rarely were estimates made for individual weed species. In the post-emergence trials, a visual system was used, each individual species being assessed. The scale used was from 0 to 4, 0 representing no control and 4 complete kill.

RESULTS

(a) Pre-emergence trials

The first trials carried out in Jamaica and Barbados in 1963 compared asulam, at doses from 1.5 to 6 lb a.i. per acre, with the most widely used commercial pre-emergence treatment namely 2,4-D ester. The results (Tables 1 and 2) indicated that asulam at a dose of 3.0 lb a.i. per acre gave excellent control of grasses but only moderate control of broad leaved weeds. In Barbados the period of control of grasses extended to six weeks (when the trials ended) and in Jamaica to nine weeks.

Similar results were obtained at this time in Trinidad (Davies 1966), where asulam at 3 lb a.i. per acre gave good control of mixed weed populations on loam and clay soils, the activity being comparable to Pesco 1815 (a mixture of 2,3,6 - trichlorobenzoic acid and MCPA) at 4 lb a.i. or atrazine at 2½ lb a.i. per acre. However, on light soils, asulam was not as persistent as 4 lb Pesco 1815 although again the overall weed control compared favourably with that of atrazine.

Table 1

<u>Pre-emergence weed control with asulam (Jamaica 1963)</u>
<u>Figures are means for 3 trials</u>

		% Ground cover, weeks after spraying					
		2 weeks		4 weeks		6 weeks	
Treatment	Dose/ac.	Gr.*	B.L.**	Gr.*	B.L.**	Gr.*	B.L.**
asulam	1.5 lb	0	1.7	0.4	4.4	1.2	8.2
"	3.0 lb	0.1	1.2	0.5	2.3	1.9	4.5
"	6.0 lb	0	1.2	0.1	2.5	0.7	3.8
2,4-D ester	14 oz	0.7	1.6	1.3	3.9	7.8	9.0
Control	-	0.6	4.0	2.3	11.9	7.6	17.3

*Gr. = Grasses (Mainly <u>Echinochloa</u>, <u>Panicum</u> spp.)
**B.L. = Broad leaved weeds (Mainly <u>Cyperus</u>, <u>Amaranthus</u>, <u>Cleome</u>, <u>Euphorbia</u>, <u>Mimosa</u> spp.)

Table 2

Pre-emergence weed control with asulam (Barbados 1963)
Figures are results of 1 trial only

		% Ground cover, weeks after spraying					
		5 weeks		7 weeks		9 weeks	
Treatment	Dose/ac.	Gr.*	B.L.**	Gr.*	B.L.**	Gr.*	B.L.**
asulam	1.5 lb	0	8.5	1.2	12.0	1.8	18.5
"	3.0 lb	0	3.6	0	11.6	0.3	23.5
"	6.0 lb	0	5.2	0	11.3	0	16.2
2,4-D ester	14 oz	0	4.3	0.8	8.3	6.5	17.2
Control	-	0	9.9	0	17.3	3.3	24.3

*Gr. = Grasses (Mainly *Sporobolus*, *Echinochloa* spp.)
**B.L. = Broad leaved weeds (Mainly *Cyperus*, *Euphorbia* spp. *Portulaca oleracea*)

In the 1964 and 1965 trials a mixture of asulam with 2,4-D was used, the results being shown in Figures 1 and 2. Very good control of grasses was again achieved, with moderate control of broad leaved species.

No damage to cane was observed in any trial, following pre-crop emergence applications of up to 6.5 lb asulam or 3 lb asulam with 2,4-D.

In some of the trials applications were made after the emergence of the cane, without any apparent damage, and a further series was carried out, in 1966 and 1967, to investigate the selectivity of asulam for post-emergence weed control.

(b) Post-emergence trials

The majority of the trials consisted of simple non-replicated layouts in which asulam alone at 3.0 lb was compared with a mixture containing 3.0 lb asulam, 12 oz 2,4-D ester and 2 oz ioxynil octanoate. The crops varied in growth stage from just emerging to 30" in height and the weeds from the young seedling stage to 6" in height. The control of individual species obtained at 6 sites in Jamaica and Barbados is summarised in Table 3. In none of these trials was any phytotoxicity to the cane noted.

Figure 1 Pre-emergence weed control in Jamaica 1965/66 (Means of 11 trials)

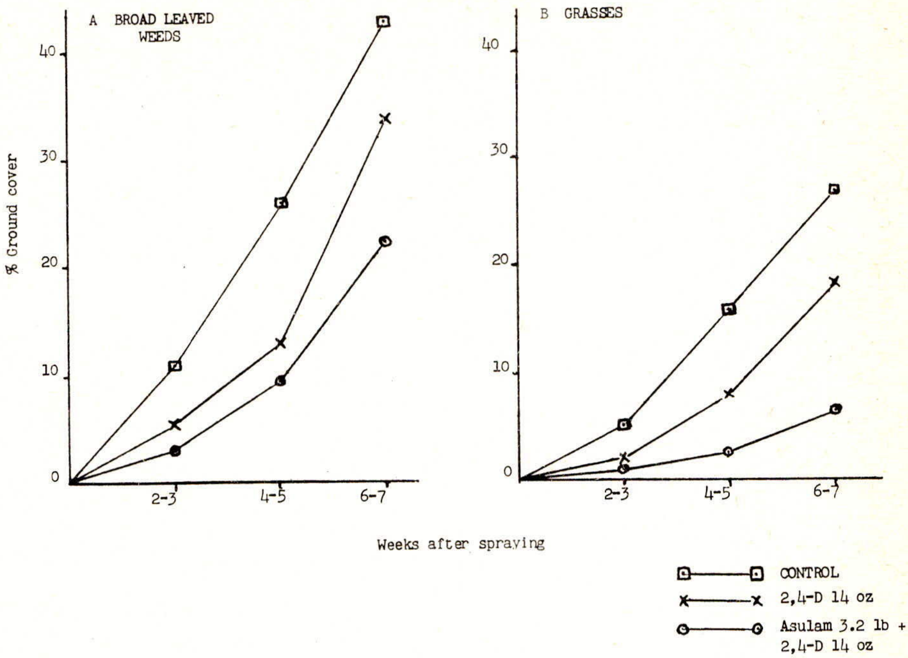


Figure 2 Pre-emergence weed control in Barbados 1965/66 (Means of 5 trials)

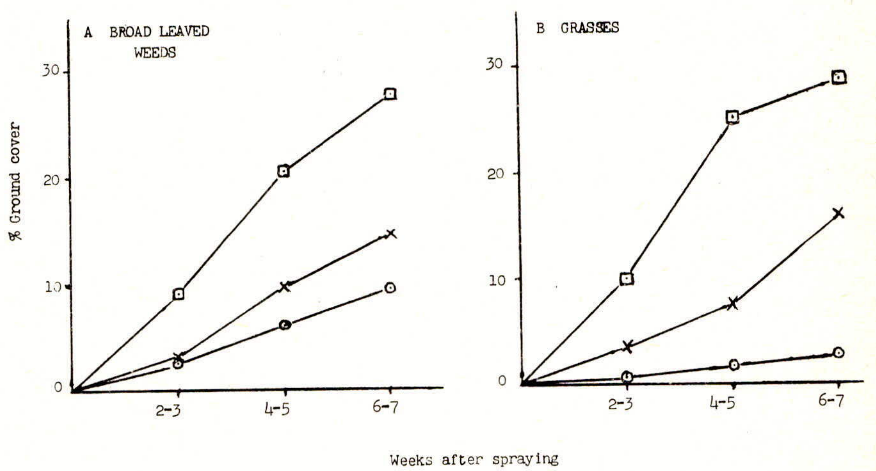


Table 3

Post-emergence weed control with asulam and asulam/ioxynil/2,4-D
Scores* for weed control 4-6 weeks after spraying

Chemical	Asulam						Asulam + 2,4-D + ioxynil					
Dose a.i./acre	3.0 lb						3.0 lb		12 oz		2 oz	
Site No.	1	5	10	11	12	13	1	5	10	11	12	13
Grasses												
Brachiaria eruciformis	-	-	4	4	4	3	-	-	4	4	4	3
Cynodon dactylon	-	-	3	2	2	-	-	-	3	3	-	-
Digitaria sp.	-	4	-	-	-	-	-	4	-	-	-	-
Eleusine indica	-	-	-	-	-	-	-	-	4	-	-	3
Leptochloa filiformis	3	4	-	-	-	-	4	4	-	-	-	-
Panicum fasciculatum	3	4	-	-	-	-	4	4	-	-	-	-
Panicum purpurascens	-	-	4	4	-	-	-	-	4	4	-	-
Sorghum verticilliflorum	-	4	-	-	-	-	-	4	-	-	-	-
Other species												
Anacardium occidentale	1	-	-	-	-	-	3	-	-	-	-	-
Cleome ciliata	-	2	-	-	-	-	-	4	-	-	-	-
Commelina sp.	-	-	-	-	3	-	-	-	-	-	4	4
Cyperus rotundus	2	2	4**	3**	2	2	4	4	4**	4	4	3
Euphorbia sp.	-	1	-	-	-	2	-	4	-	-	4	3
Phyllanthus sp.	-	-	-	-	-	2	-	-	-	-	4	4
Physalis sp.	-	-	-	-	2	-	-	-	-	-	4	-
Portulaca oleracea	-	1	-	-	-	-	-	4	-	-	-	-
Priva lappula	2	-	-	-	-	-	4	-	-	-	-	-

* Scores on scale 0 = No control to 4 = Complete kill
** Some regrowth appearing at 4-5 weeks

DISCUSSION

The data obtained in these trials has confirmed the preliminary results reported earlier (Ball et al 1965). Asulam, at doses of 3.0 lb and above, has given consistently good control of graminaceous species, with both pre- and post-emergence applications. The majority of grasses that have occurred in Barbados and Jamaica were annuals and provided that good spray coverage has been possible, kills have been virtually complete. The main perennial grasses encountered were Panicum purpurascens and Cynodon dactylon. Control of Panicum purpurascens (a stoloniferous species) has been satisfactory, particularly with post emergence applications, but Cynodon dactylon, which has both stolons and rhizomes, has only been checked by asulam at 3.0 lb/acre, and much higher doses (6 lb or more) would appear to be necessary to achieve long term control. It should be noted that the post-emergence affect of asulam alone on grass species is rather slow, especially with the wettable powder (NPH 1232), but the addition of ioxynil octanoate and 2,4-D has resulted in a quicker initial effect on many species.

The initial control of top growth of _Cyperus rotundus_ (nut grass) with post-emergence applications of asulam alone was variable and regrowth was usually rapid. The addition of the 2,4-D/ioxynil mixture gave a more complete control, although regrowth also occurred. This and other species of the _Cyperaceae_ were resistant to pre-emergence applications of asulam.

The control of broad-leaved species by both pre- and post-emergence applications of 3.0 lb asulam alone was less satisfactory, particularly on some members of the _Euphorbiaceae_ and _Portulacaceae_. The addition of 2,4-D has increased the pre-emergence activity on some species and the mixture of asulam with ioxynil octanoate and 2,4-D has markedly improved the post-emergence control of a range of broad-leaved weeds.

One of the outstanding characteristics of asulam is its safety to sugar cane. There has been no evidence of damage with up to 6.5 lb asulam applied pre- or post-emergence. Mixtures of 3 lb asulam with 14 oz 2,4-D or 2 oz ioxynil octanoate and 12 oz 2,4-D ester have been equally well tolerated by the crop. It should be stressed that no attempt was made to direct the spray away from the cane plants in any trial and asulam appears to have a higher margin of selectivity than other grass herbicides in this crop.

Further work is now in progress to confirm this high margin of safety to sugar cane and to obtain further evidence on the range of weeds controlled by mixtures of asulam with other herbicides.

Acknowledgments

We would like to express our thanks to Mr. M. W. Ramsay in Jamaica and Mr. M. A. Gibson in Barbados who carried out the majority of the field work in the asulam trials.

References

Ball, R.W.E. et al (1965) Benzenesulphonylcarbamate Herbicides. Proc. 2nd Symposium on New Herbicides, Paris, 55-56.

Cottrell, H.J. and Heywood, B.J. (1965) Benzenesulphonylcarbamates: New Herbicides. Nature 207, 655.

Davies, W.N.L. (1966) Recent Studies with Pre-emergence Herbicides for Sugar cane in Trinidad. Proc. Br.W.Indies Sug.Technol. 38-44.

Proc. 9th Brit. Weed Control Conf. (1968)

FENAC/ATRAZINE COMBINATIONS FOR SELECTIVE WEED CONTROL IN SUGAR CANE

J. M. Swain and W. J. Burke

Geigy Australia Pty. Ltd., Pendle Hill, N.S.W.2145, Australia

Summary This summary reports the use of a herbicide combination of atrazine and fenac in sugar cane.

It is accepted that the performance of many pre-emergence herbicides is influenced by factors such as soil type, soil moisture, soil tilth, rainfall pattern, and weed species likely to be encountered. Combinations of herbicides are suggested to even out these factors.

In cane production, initially grasses such as Digitaria sanguinalis, Echinochloa crus-galli Beauv., and Panicum maximum Jacq. are the main problems. These are followed by broadleaved weeds such as Ageratum spp., Crotalaria spp., Ipomoea spp., and Xanthium spp. later in the season.

Various weedicides alone and in combination were tested during 1962-63 in all the non-irrigated, sugar growing areas of Queensland. Results indicated synergism with fenac + triazine mixtures. Above 2 lb total active, the triazine + fenac mixture was superior to either chemical singly at the same rate.

Agronomically, grasses were accepted as more serious competitors of sugar cane than broadleaved weeds. They require a greater amount of pre-emergence herbicide for control. With this in mind, atrazine which was second to fenac on grasses and good on broadleaved weeds, was selected as the triazine partner to fenac in a 1 : 1 active ingredient ratio. The distribution and breakdown of each partner herbicide in the soil profile differs and this is a possible explanation for the action of the mixture.

The atrazine/fenac mixture was further tested in 1963-64 under varying soil types and rainfall pattern and its efficiency was confirmed under a wide range of conditions.

INTRODUCTION

Sugar cane production in Australia occurs in a discontinuous strip of 1000 miles along the east coast of Queensland. As can be expected variable conditions of climate and soil type occur. However, the weed and grass problems are similar, in that early in the season i.e. spring and early summer, grasses such as Summer grass (Digitaria sanguinalis), Barnyard grass (Echinochloa crus-galli), Guinea grass (Panicum maximum) are the major problems, whilst as the cane makes a growth and closes in, broadleaved weeds such as Ageratum spp., Crotalaria spp., Ipomoea plebeia become dominant in the late summer/autumn period. Such a continuous weed and grass pressure throughout the growing season requires that any herbicide used for weed control in this crop must be persistent for a period of up to 26 weeks.

In many instances herbicides are more effective on either grasses or broad-leaved weeds and thus when used singly will be inefficient at some point during the growing season.

Preliminary screening trials carried out by the author at Cowra, N.S.W. in 1961/62 showed (Swain) the efficiency of a mixture of fenac (2,3,6-trichlorophenyl acetic acid) + triazine - in particular atrazine (2-chloro-4-ethylamino-6-isopropyl amino-1,3,5-triazine) for the control of annual weeds and grasses over a twelve month period. These were applied to natural pastures containing Eragrostis spp., Lolium spp., Hordeum leporinum, and Arctotheca calendula, and compared with the individual components at equivalent rates.

From these trials it was apparent that these triazines were distributed in the top 1 in. to 2 in. of the soil profile and effectively controlled the shallow germinating plants, whilst the fenac was sufficiently mobile to be present in the 3 in. - 4 in. level of soil, controlling the deeper germinating plants. It has been shown that the breakdown of the triazines occurs towards the surface whilst with time fenac remains more active at lower levels of the soil profile. Thus the distribution and breakdown mechanisms of a fenac + triazine mixture in the soil are such that theoretically a product combining these two groups of chemical should give a complete broad spectrum weedicide (Weiss). Fenac generally is regarded as being more active on grasses than triazines and observations made indicate that in the sugar areas of Queensland grasses germinate at greater depth than the broadleaved weeds.

Recognising the problems associated with the development of a suitable herbicide, for use in sugar areas of Queensland, trials were initiated to establish if a mixture of fenac + atrazine would perform as initial trials and theoretical considerations indicated.

METHOD AND MATERIALS

1962-63 Trials - In November/December 1962 eleven pre-emergence herbicide screening trials were commenced in Queensland cane fields. Eight triazines, other herbicides including 2,4-D as a standard, and fenac, as well as combinations of these, were evaluated. The cane was sprayed within one month before or after the normal final cultivation or lay-by stage. Log plots consisted of single inter-rows, 24 yd long with control areas each end of the sprayed section. Peak dose was 6 lb a.i./ac the rate being halved over six yards for all plots to a minimum of 0.75 lb a.i./ac. Each treatment was replicated three times. Application on the fixed plots was made with a Drake and Fletcher Mistifier Knapsack to plots of 1/80th ac in size. Plot size was selected so that two full inter-rows and three rows of cane were treated.

In both trial types plots were weed free at the time of spraying.

1963-64 Trials - The programme was designed to confirm the choice of fenac and atrazine in a 1 : 1 ratio and to gain more information about the combination. Eighteen trials were established throughout Queensland during December 1963 and applied to fixed plots.

1966 Trials - Five trials were carried out to establish the efficiency of the fenac + atrazine combination in providing weed control from the seedling stage of sugar cane up until it is 'out-of-hand'. Earlier results with fenac alone showed its unreliability especially under conditions of variable soil moisture.

Two of the above trials were designed to simulate commercial application and were laid down by the author using farmer equipment; the other three compared different rates of fenac/atrazine mixture and fenac alone.

Rating System: Field scoring was made on visual assessment on the basis of a 1 to 10 scale: 1 - dense weed cover, 10 = 100% bare ground. For comparison, assessments for a given plot were adjusted so that the mean control scores for the plot were fixed at 1. Scores for 100% control remain at 10.

RESULTS

The graph of logarithmic trials results (see Fig. 1) shows the performance of three outstanding individual chemicals and a mixture of two of these compared to 2,4-D as standard. As expected, 2,4-D failed to give residual control, whereas the other four treatments demonstrated persistence. Fenac was outstanding in this regard. Atrazine alone was superior to simazine (2-chloro-4,6-bisethylamino-1,3,5-triazine). Fenac + simazine in a 1 : 1 ratio was better on grasses than fenac, simazine or atrazine used separately and seemed to indicate a synergistic effect between fenac and triazine. With atrazine alone, results were superior to simazine and it seemed obvious that a combination for further development should comprise fenac + atrazine. Results from the fixed plot trials (See Table I) confirmed the results obtained in the logarithmic plots. Thus from the 1962-63 trials a mixture of 30% fenac and 30% atrazine (now commercially named Domatol 66) was selected for further test.

Table I

1962-63 Fixed Plot Results

Chemical	Rate a.i./acre	Assessment and time of observations... 8 weeks	19 weeks
Fenac	2.0 lb	8.2	9.1
	4.0 lb	8.1	8.8
Fenac + Atrazine	1.5 lb 1.5 lb	8.8	9.5
Fenac + Simazine	1.5 lb 1.5 lb	8.2	9.1

1963-64 results are shown in Table II. Throughout the series the fenac + atrazine mixture consistently gave excellent pre-emergence weed and grass control. Results from all trials showed that the fenac + atrazine combination showed poor post-emergence qualities. The 1 : 1 ratio was therefore confirmed as the basis for the commercial product Domatol 66, using a pre-emergence application rate of 1.8 lb total active ingredient per acre.

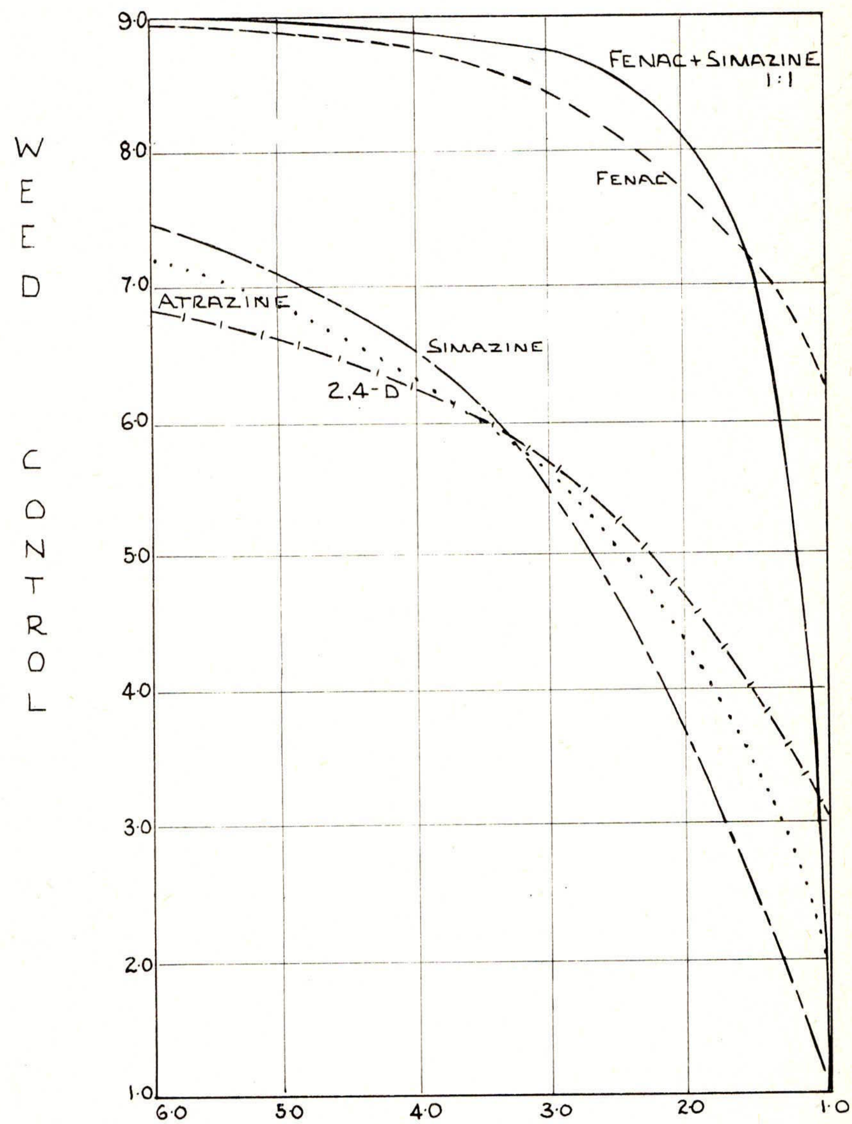
It was shown from the 1966 results that when applied to sugar cane at the seedling stage of growth as distinct from the lay-by stage when the cane is anything from 3 ft or more high, increased rates of fenac + atrazine are required, as against those used when the application is made at the lay-by stage. This is due to the more open cane and high sunlight intensity when application is made to seedling cane.

The effects of soil moisture and the competitive effects of the growing plant are also important when application is made at this time, as better results are obtained in the row where the plants are growing than those obtained in the inter-row, even for grasses which arethe main problem species present. The combination of fenac + atrazine at 2.4 lb active ingredient per acre provided more efficient and reliable weed control than did fenac alone at 3 lb active ingredient, even though grasses are

2. 1962-63 TRIALS

CONTROL OF GRASSES AFTER 15 WEEKS

FIG. 1.



the major problem at this time (See Table III).

Table II

1963-64 Results

Chemical	Rate a.i./acre	Assessment and time of observations... 9 weeks	17 weeks
Fenac + Atrazine	1.5 + 1.5	9.2	8.8
"	1.0 + 1.0	9.1	8.6
"	0.9 + 0.9	9.1	8.8
"	0.6 + 0.6	8.8	8.3

where mean weed control scores are 1 for unsprayed; 10 for 100% control

Table III

Summary - 1966 Trials Results

Chemical	Rate/acre a.i.	% control after 8 weeks Row	Inter - row
Fenac + atrazine	1.5 lb + 1.5 lb	82% (in 1 trial, 1 rep. gave poor results)	72%
Fenac + atrazine	1.2 lb + 1.2 lb	92%	78%
Fenac + atrazine	0.9 lb + 0.9 lb	86%	62%
Fenac	3.0 lb	92%	73%
Fenac	2.0 lb	77%	57.5%

Results indicate that application to dry soil followed by rain or rain soon after application will give more reliable results than application made to a soil of medium moisture at spraying time.

DISCUSSION

Extensive field trials over two years plus commercial usage, of a product containing 30% fenac and 30% atrazine, applied at 1.8 lb active ingredient per acre to sugar cane which is at the 'out-of-hand' stage, have confirmed the efficiency of such a mixture in controlling weeds regardless of the way the weather influenced the time of germination of the species involved.

Application was made to soils which were well prepared and with ample soil moisture and thus ideal for pre-emergence application, and also on situations where a 2 in to 3 in thick crust had formed. In all areas the soil types or condition at spraying did not affect results.

Application of the product to cane which is in the seedling stage of growth requires 2.4 lb active ingredient to provide satisfactory control of weeds and grasses up to the lay-by stage. The increased rate is necessary at this time because of the absence of competition from the growing cane plant which increases the amount of light intensity available and therefore encourages vigorous weed and grass growth. Germination of weeds and grasses occurs rapidly and it is essential that the chemicals are applied to moist well-prepared soils which allows movement into the weed root zone. This product has been field tested on a wide range of soil types which includes red sands, gray alluvial clays, silty loams and red forest loams.

A wide range of sugar cane varieties and stages of growth have been treated in the trials and commercial application, and no sign of damage in any situation has been reported.

CONCLUSIONS

The mixture of fenac and atrazine in the 1 : 1 ratio will give consistent and reliable weed and grass control in the sugar fields of Australia. It can be applied safely to all varieties of cane and at all stages of growth to provide season-long weed control.

When applied at the seedling stage of growth, 2.4 lb total active ingredient per acre is required, whilst with an application at the 'out-of-hand' stage, 1.8 lb a.i. will provide satisfactory weed control.

The mixture is superior to either compound used separately at equivalent rates.

REFERENCES

SWAIN, J. M. 1962 - Internal report.
WEISS, P. W. 1962 - Personal communication.

Proc. 9th Brit. Weed Control Conf. (1968).

PRE-EMERGENCE WEED CONTROL IN SUGARCANE - STUDIES WITH SOME SUBSTITUTED UREA AND URACIL HERBICIDES

W.N.L. Davies
Tate & Lyle Research Centre, Westerham Road, Keston, Kent
K. Hakim
Tate & Lyle Central Agricultural Research Station, Trinidad, West Indies

Summary Early work with the substituted ureas and uracils in Trinidad concentrated upon the evaluation of monuron, diuron and isocil for pre-emergence weed control in sugarcane. Several other substituted ureas and uracils have been evaluated in Trinidad cane fields in recent years. This paper discusses the results of the more recent experiments.

Noruron and linuron are two of the substituted ureas which performed rather erratically. Unlike some other representatives of their chemical class they caused little or no damage to sugarcane and it is thought that they might be useful as pre-emergence aerial sprays. Fluometuron and metobromuron controlled weeds well in screening trials, but were toxic to plant cane at relatively low dosages.

The substituted uracils, terbacil and EH767, provided excellent weed control, particularly when applied in combinations with diuron. They were toxic to plant cane at rates above 1 lb/acre, but ratoon cane appears to be more tolerant. In contrast to others of the uracils, lenacil showed promise in controlling weeds, and also was non-phytotoxic to plant cane.

INTRODUCTION

It is recognized that the best means of controlling weeds in surgarcane under Trinidad conditions, is to apply pre-emergence herbicides with long residual activity (Lawrie & Vlitos, 1963). As Crafts (1961) has stated, "any successful herbicide used through the soil must be either very low in cost, or very potent", and this statement certainly applies to Trinidad.

Two groups of very potent herbicides have been thoroughly tested in Trinidad cane over the past eight years. These are the substituted ureas and the uracils.

Monuron and diuron were tested as pre-emergence herbicides during 1959. Diuron gave significantly better weed control than monuron. A mixture of 2,4-D amine and diuron (0.63 lb + 2.4 lb a.i./acre) proved as effective as, and cheaper than, diuron alone. Diuron went into suspension more readily when a "Fernamine" 2, 4-D formulation was added, and the suspension appeared to be stable (Lawrie & Neate, 1960).

Isocil, a substituted uracil, gave spectacular weed control in initial tests, but cane was injured at all rates tested (i.e. 3, 6 and 9 lb a.i./acre) tests, several other substituted ureas and uracils have been evaluated over a four year period and the results are presented here.

METHODS AND MATERIALS

The herbicides tested were: (substituted ureas) fluometuron, diuron, linuron, monuron, metobromuron and noruron; (substituted uracils) bromacil, isocil, lenacil, terbacil, EH733 (5-bromo-3-tert-butyl-6-methyluracil), EH 767 (5-bromo-3-(1-ethyl)-propyl)-6-methyluracil), EH 629 and EH 766; (other herbicides) atrazine, propachlor, 2,4-D, dalapon, metoxuron, noruron + atrazine (Herban-X), TBA + MCPA (Pesco 1815), nitralin, TCA, trifluralin, WL 9385 (2-azido-4-ethylamino-6-t-butylamino-1,3,5-triazine) and WL 12637. Pesco 1815 (TBA/MCPA) and atrazine were included in the experiments as "standard treatment". All rates of application are quoted in terms of active ingredient/acre.

The herbicides were applied as pre-emergence sprays. Pre-emergence, as defined in this paper, is the application of herbicide prior to the emergence of both crop and weeds in plant cane, and prior to the emergence of weeds in ratoon cane. Herbicides were applied in water at 20 Imp.gal/acre using hand operated knapsack sprayers fitted with 15006 tee-jet nozzles. The experimental design was randomized blocks with two or four replicates and plot sizes of 1/40 acre.

Weed assessments were made visually at intervals during the course of the experiments. The results are expressed in terms of percentage weed cover. The data were subjected to analysis of variance for determination of L.S.D. values. Rainfall was recorded, and the accumulated rainfall at each scoring date is presented in the tables.

RESULTS

The trials were carried out during 1965 and 1966. Climatically, 1965 was a "normal" year, with rather dry conditions during the first five months. Weather conditions during 1966 were particularly severe. A prolonged drought in the early part of the year was followed by exceptionally heavy rains in June.

(a) The substituted ureas. In trials during 1966, four representative substituted ureas were evaluated.

(i) Metobromuron (Patoran). Metobromuron was tested at 1 lb, 2 lb, and 3 lb/acre. Under the very wet conditions the dominant weeds in the untreated control plots were *Cyperus diffusus*, *Cyperus distans*, *Cyperus surinamensis*, *Fimbristylis miliacea*, *Jussiaea erecta* and *Jussiaea suffruticosa*. Where these weeds were absent, *Lindernia crustacea* and *Mecardonia dianthera* dominated.

Metobromuron provided excellent weed control, at both 2 lb and 3 lb/acre, up to 73 days after application (Table 1). The sedges and both species of *Jussiaea* appeared to be effectively controlled. At these rates, metobromuron caused chlorosis of the cane foliage and some suppression of cane growth.

Table 1

Screening of metobromuron and fluometuron for pre-emergence weed control in sugarcane
Exchange, Devenish 36 on McBean sand to loam

Treatment (lb a.i./acre)	% weed cover after 54 days	73 days
Control	70	100
Metobromuron (1.0)	25	65
Metobromuron (2.0)	10	15
Metobromuron (3.0)	5	20
Fluometuron (1.6)	5	10
Fluometuron (3.2)	5	10
Fluometuron (4.8)	0	15
Atrazine (2.4)	25	35
TBA/MCPA (4.0)	25	30
Accumulated rainfall (in.)	12.82	16.31
L.S.D. (p=0.05)	23	46

(ii) Fluometuron (Cotoran). In the above trial at 1.6 lb, 3.2 lb and 4.8 lb/acre fluometuron provided effective weed control for 73 days, but was phytotoxic to the crop at all these rates (Table 2).

Fluometuron was evaluated also at 4 lb/acre in another trial on McBean sand to loam soil. *Cyperus diffusus*, *C. distans* and *C. surinamensis* together with *Fimbristylis miliacea*. *Jussiaea erecta*, *J. suffruticosa* were the major weeds to be controlled. *Lindernia crustacea* and *Mecardonia dianthera* were also prominent in the places where the larger weeds were absent. Fluometuron controlled these weeds very successfully for 96 days, at which time the observations were discontinued (Table 2). In this trial, also, fluometuron caused chlorosis on cane foliage and also caused some suppression of growth.

Table 2

Evaluation of several experimental herbicides for pre-emergence weed control in sugarcane
Exchange, Devenish 36 on McBean sand to loam

Treatment (lb a.i./acre)		% weed cover after 53 days	73 days	82 days	96 days
Control		65	80	100	100
Nitralin	(4)	10	18	30	40
W.L. 12637	(2)	33	63	80	88
W.L. 12637	(4)	13	38	53	70
Trifluralin	(4)	25	50	78	85
W.L. 9385	(2)	10	13	23	38
W.L. 9385	(4)	5	18	25	38
Fluometuron	(4)	0	5	5	8
Atrazine	(4)	0	8	8	8
TBA/MCPA	(4)	3	10	23	53
Accumulated rainfall (in.)		12.82	16.31	17.77	21.15
L.S.D. (p=0.05)		17	37	30	27

(iii) Noruron (Herban)* Noruron was initially screened in 1961 and gave acceptable weed control (Lawrie, 1961). Further testing from 1962 to 1965 demonstrated that while noruron did not provide outstandingly good pre-emergence weed control, the herbicide was non-toxic to cane at rates as high as 4 lb/acre (Lawrie 1963; Lawrie and Hakim, 1964; Davies 1965; Davies 1966).

In trial on Waterloo loam to clay during 1966, noruron failed to provide effective weed control at 56 days after application (Table 3). The noruron/atrazine mixture (Herban X) gave fair weed control at this time. The standard treatments with diuron +2,4-D, TBA/MCPA + dalapon and atrazine + dalapon all provided good weed control.

(iv) Linuron was evaluated for pre-emergence weed control as the Lorox and Afalon formulations. In 1962 and 1963 Lorox gave better weed control than the standard treatments (TBA/MCPA + dalapon and atrazine + dalapon). Afalon on the other hand, did not provide acceptable control of weeds (Lawrie 1963; Lawrie and Hakin, 1964). During 1964, the performance of the two formulations of linuron was reversed. Lorox did not provide effective weed control on the Arouca soil series or on McBean sand to loam, while Afalon and Afalon + TCA gave good weed control on Golden Grove loam (Davies 1966). In a trial reaped during 1965, a pre-emergence application of Afalon did not appear to depress cane yields (Davies 1966).

Table 3

Evaluation of noruron, noruron/atrazine and linuron for pre-emergence weed control in sugarcane
Perseverance No. 120 on Waterloo loam to clay

Treatment (lb a.i./acre)	% weed cover after 27 days	39 days	56 days
Control	48	75	98
Noruron (2.4)	25	43	65
Noruron (3.2)	25	35	58
Noruron/atrazine (2.0)	13	20	45
Noruron/atrazine (2.4)	25	30	65
Noruron/atrazine (3.2)	15	33	48
Linuron (Afalon) (2.5)	20	38	90
Diuron (3.2) + 2,4-D (0.9)	8	10	25
Linuron (2.0) + TCA (9.4)	18	30	65
Atrazine (2.5) + dalapon (4.25)	8	15	43
TBA/MCPA (4.0) + dalapon (4.25)	8	13	43
Accumulated rainfall (in.)	7.08	9.63	13.68
L.S.D. (p=0.05)	18	25	25

Afalon was tested again during 1966 but, at 2.5 lb/acre, failed to maintain weed control beyond 39 days after its application (Table 3). A mixture of linuron with TCA (2 lb plus 9.4 lb/acre) gave somewhat better results.

(b) The substituted uracils. In a screening trial in 1964, five coded substituted uracils (EH 629, 732, 733, 766 and 767) proved to be very effective herbicides but, at 3 lb and 4 lb/acre, they were severely phytotoxic to plant cane (Davies, 1965). Further trials in ratoon cane during 1965 indicated that the phytotoxicity was less pronounced than in plant cane (Davies, 1966). EH 732 is now marketed as "Sinbar" and has been assigned the common name terbacil, while development of EH 767 continues. Besides these two substituted uracils, a third, lenacil (Venzar), was also evaluated during 1966.

(i) Terbacil (Sinbar). Terbacil was tested at 0.5 lb, and 1.5 lb/acre during 1965 in a trial on the Pasea soil series. The most common weeds in the untreated control plots were *Echinochloa colonum*, *Panicum fasciculatum* and *Rottboellia exaltata*. At 101 days after application excellent weed control was maintained at all rates (Table 4). At 1 lb and 1.5 lb/acre terbacil caused severe chlorosis of the cane foliage and some suppression of growth.

Terbacil was evaluated in 1966 both alone, and in combination with diuron (0.5 lb + 1.6 lb/acre). Due to heavy early rains there was some weed growth in the inter-rows at the time of application. The weed population consisted chiefly of *Fimbristylis miliacea* and *Jussiaea* spp. Under these conditions the terbacil/diuron mixture performed better than terbacil alone. At all three rates, terbacil maintained weed-free conditions along the tops of the rows, but was less effective than terbacil/diuron in controlling the emerged weeds (Table 5).

(ii) EH 767. EH 767 also provided excellent weed control in the trial on the Pasea soil series (Table 4). At the highest rate (1.0 lb/acre) EH 767 caused suppression of cane growth and severe chlorosis of emerged shoots.

Table 4

Evaluation of terbacil and EH 767 for pre-emergence weed control in sugarcane
Orange Grove, Cane from 52W on Pasea soil series

Treatment (lb a.i./acre)	% weed cover after 52 days	65 days	81 days	101 days
Control	33	50	80	90
Propachlor (2.0)	10	25	63	80
Propachlor (4.0)	10	15	35	53
Propachlor (6.0)	10	10	30	50
Terbacil (0.5)	8	10	15	18
Terbacil (1.0)	0	5	8	13
Terbacil (1.5)	3	3	13	18
EH 767 (0.5)	8	10	13	20
EH 767 (1.0)	8	10	13	23
EH 767 (2.0)	3	5	10	10
Diuron (3.2) + 2,4-D (0.9)	3	10	10	25
TBA/MCPA (4.0)	3	10	10	25
Accumulated rainfall (in.)	17.05	18.33	24.64	28.59
L.S.D. (p=0.05)	8	12	17	14

Table 5

Evaluation of terbacil and EH 767 alone and in combination with diuron for pre-emergence weed control in sugarcane
Felicite 11 W4 on Bejucal Heavy clay

Treatment (lb a.i./acre)	% weed cover after 17 days	31 days
Control	23	68
Terbacil (0.5)	18	38
Terbacil (0.75)	15	33
Terbacil (1.0)	18	33
EH 767 (0.5)	20	53
EH 767 (0.75)	18	33
EH 767 (1.0)	20	38
Terbacil (0.5) + diuron (1.6)	10	15
EH 767 (0.5) + diuron (1.6)	10	13
Diuron (2.4) + 2,4-D (0.9)	3	8
Atrazine (2.5)	15	28
TBA/MCPA (4.0)	10	13
Accumulated rainfall (in.)	3.72	8.04
L.S.D. (p=0.05)	6	13

On Bejucal heavy clay, EH 767/diuron (0.5 lb + 1.6 lb/acre) was a very effective pre-emergence treatment (Table 5). EH 767 also appeared to have considerable post-emergence activity on weeds such as *Fimbristylis miliacea* and *Jussiaea* spp.

(iii) Lenacil (Venzar). Lenacil is used for the selective control of annual seedling grass and broadleaf weeds in sugarbeet. It was tested at 2 lb, 3.2 lb and 4 lb/acre in a plant cane screening trial on Talparo clay soil during 1966.

Excellent control of weeds was maintained with lenacil for 81 days, when scorings were discontinued (Table 6).

Table 6

Screening of various herbicides for pre-emergence weed control in sugarcane

Brechin Castle, Enterprise 7 on Talparo clay

Treatment (lb a.i./acre)	% weed cover after 63 days	81 days
Control	90	95
Propachlor (2.0)	55	80
Propachlor (2.6)	65	85
Propachlor (3.2)	45	65
Propachlor (2.0) + atrazine (2.0)	10	10
Propachlor (2.6) + atrazine (2.0)	10	10
Lenacil (2.0)	10	15
Lenacil (3.2)	5	5
Metoxuron (Dosanex) (3.2)	55	80
Metoxuron (4.8)	55	60
Metoxuron (6.4)	50	55
Diuron (2.4) + 2,4-D (0.9)	0	5
Atrazine (2.4)	10	15
TBA/MCPA (4.0)	50	55
Accumulated rainfall (in.)	17.60	23.50
L.S.D. (p=0.05)	49	47

Inspection of the trial at 102 days after application showed that lenacil was still controlling weeds effectively. Unlike the other substituted uracils, lenacil did not appear to be phytotoxic to the crop.

DISCUSSION

The substituted ureas and the substituted uracils are potent weedkillers. For one reason or another the earlier substituted ureas and uracils are not widely used as residual herbicides in Trinidad sugarcane. For instance, diuron, which is an excellent herbicide, is not widely used because it appears to be phytotoxic to B41227, the most widely cultivated variety in Trinidad, when grown as plant cane on phosphate deficient soils (Lawrie and Vlitos, 1963). Isocil provides exceptionally good weed control but is also severely phytotoxic to sugarcane since it lacks selectivity (Bucha et al, 1962).

Of the newer substituted ureas tested, fluometuron and metobromuron have provided excellent weed control in pre-emergence screening trials. However, they appear to damage sugarcane, even at relatively low rates of application. Noruron and linuron have not proved outstanding herbicides for pre-emergence weed control, but neither have they shown phytotoxicity to sugarcane.

The use of fixed wing aircraft in Trinidad to apply pre-emergence herbicides is rapidly increasing. While no useful purpose would be served in continuing trials with noruron and linuron applied with band equipment, it would be valuable to assess the activity of aerial sprays.

Of the substituted uracils, terbacil and EH 767 provided excellent pre-emergence weed control, but were toxic to plant cane at rates above 1 lb/acre. As has been found for isocil and bromacil (Rochecouste, 1967), ratoon cane is more tolerant to terbacil and EH 767 than is plant cane. In ratoons, an initial chlorosis of the leaves disappears within two to three weeks, without any apparent influence on yield. Lenacil has performed well in one trial and its evaluation should be continued. Even at 4 lb/acre, lenacil appears to be harmless to plant cane.

Acknowledgements

The authors gratefully acknowledge the co-operation of the Agricultural Superintendent and members of the field staff of Caroni Limited. Thanks are also due to the Cultivation Manager and field staff of Trinidad Sugar Estates Limited.

References

BUCHA, H.C., CUPERY, W.E., HARROD, J.E., LOUX, H.M. and ELLIS, L.H. (1962) Substituted uracil herbicides. Science 137, 537-538.

CRAFTS, A.S. (1961) The Chemistry and Mode of Action of Herbicides. Interscience, New York. 84-103.

DAVIES, W.N.L. (1965) Evaluation of new herbicides. A. Rep. Tate & Lyle cent. agric. Res. Stn. 1964, 179-216.

DAVIES, W.N.L. (1966) Weed Control. A. Rep. Tate & Lyle cent. agric. Res. Stn. 1965, 67-137.

LAWRIE, I.D. and NEATE, D.J.H. (1960) Weed Control. A. Rep. Caroni Ltd. & Ste. Madeleine Sugar Co. Ltd. cent. agric. Res. Stn. 1959-1960, 69-84.

LAWRIE, I.D. (1961) Weed Control. A. Rep. Caroni Ltd. & Ste Madeleine Sugar Co. Ltd. cent. agric. Res. Stn. 1960-1961, 14-35.

LAWRIE, I.D. (1963) Weed Control. A. Rep. Tate & Lyle cent. agric. Res. Stn. 1961-1962, 95-107.

LAWRIE, I.D. and VLITOS, A.J. (1963) Chemical weed control in sugarcane with special reference to Trinidad. Proc. int. Soc. Sug. Cane Technol. 11, 280-290.

LAWRIE, I.D. and HAKIM, K. (1964) Weed Control. A. Rep. Tate & Lyle cent. agric. Res. Stn. 1963, 40-67.

ROCHECOUSTE, E. (1967) Preliminary observations on the use of the substituted uracils for the control of weeds in sugarcane fields. Proc. int. Soc. Sug. Cane Technol. 12.

Proc. 9th Brit. Weed Control Conf. (1968)

THE USE OF THE BIPYRIDYLS IN SUGAR CANE

G. M. Chambers
Plant Protection Limited, Fernhurst, Haslemere, Surrey

Summary The herbicidal and desiccant activity of the bipyridylium compounds paraquat and diquat was discovered in 1955. This has proved to be a major advance in agricultural chemicals which has paved the way for simple, reliable methods of weed control in many crops, and for new crop production techniques.

Sugar cane is a crop where paraquat is playing an increasing and valuable role for weed control both used alone and in mixture with suitable hormone or residual herbicides. It is proving useful as an efficient replacement of PCP/oil mixtures, or as a supplement to hormone or residual herbicides to provide increased flexibility in use, and improved results.

Paraquat has also become established as a highly effective pre-harvest desiccant to facilitate burning in sugar cane, while diquat is now, following successful experimental usage, developing widespread interest as a chemical method of controlling cane flowering with resultant increases in sugar yield.

INTRODUCTION

The herbicidal and desiccant activity of the bipyridylium compounds paraquat and diquat was discovered in the research laboratories of Imperial Chemical Industries Limited at Jealott's Hill in 1955. This paper will present briefly the ways in which the unique properties of these two compounds are being utilised in sugar cane by permitting improved weed control from more flexible treatments, by increasing the efficiency of harvesting, and by providing a chemical method of controlling undesirable cane flowering.

Properties of Paraquat and Diquat

Paraquat (1,1'-dimethyl-4,4'-bipyridylium^{++}) and diquat (9,10-dihydro-8a,10a-diazoniaphenanthrene^{++}) are fast acting desiccants with some systemic properties and their application to living green foliage is followed by very rapid absorbtion and subsequent death of the treated aerial part of the plant. Because of the rapid uptake by green tissue the herbicidal effect is not affected by rain falling shortly after the application. A further major factor distinguishing these compounds is that, since they are salts of very strong bases, they are immediately adsorbed and inactivated on contact with the clay particles in the soil.

Both paraquat and diquat are effective desiccants but paraquat shows greater activity against grass species than diquat and is also the preferred compound for use as a herbicide in cane or as a pre-harvest desiccant.

Paraquat as a Herbicide in Sugar Cane

These properties enable paraquat to be used as an aid to land preparation in sugar cane, as a post planting but pre-cane emergence treatment and also as a directed inter-row spray. The lack of residual activity after contact with the soil also enables paraquat to be used with safety for weed control along irrigation canals.

The herbicide practices in plant and ratoon cane vary from area to area and according to whether cane trash is burnt at harvest. The problem of weed competition is generally more severe in plant cane since the lack of a developed root system at this stage means that early weed competition will have a greater adverse effect on cane development. Weed control techniques are required only up until closure of the cane canopy after which weed competition is of minimal importance.

In plant cane pre-emergence applications of suitable residual herbicides such as diuron, atrazine, TBA/MCPA, or of 2,4-D may be used at planting and can provide weed control for a variable period, depending upon soil type, climate and weed flora, of 4 to 12 weeks. In ratoon cane when burning of the trash has been carried out, thus leaving bare soil, similar treatments are used.

However, delays can and do occur in the planting and herbicide application schedules, preventing the pre-cane emergence applications being made before heavy weed growth has developed. This situation has prompted an investigation (Manning, 1967) of mixtures of paraquat with diuron, atrazine, TBA/MCPA or 2,4-D and this work has established the following advantages over the use of pre-emergent materials used alone :-

1. The timing of the application of the residual herbicide is no longer of critical importance.

2. The delay in herbicide application may extend the period of effective weed control towards cane closure.

3. A broader spectrum of weed control.

4. Better weed control when conditions render soil-acting herbicides less effective.

5. A greater safety margin in the use of soil-acting herbicides may be achieved by their use at reduced dosage rates.

Weed problems after cane emergence can be considerably reduced where pre-cane emergence treatments have been used, but further control of weeds, particularly in plant cane is generally necessary until cane closure. Weather permitting, this is frequently carried out using inter-row mechanical cultivations, but chemical methods are becoming more widely accepted where it can be demonstrated that they offer more efficient weed control.

A widely used method of inter-row chemical weed control in Trinidad has been that of directed sprays of a herbicidal oil for contact weed control. There are, however, a number of disadvantages associated with the use of oil including the need for protective clothing during application, which is undesirable in a tropical climate, and its unpleasantness in use. Extensive trials have been carried out to compare paraquat with herbicidal oil for inter-row applications and these have established that, beside being far more acceptable to spraying teams, the control of grasses with paraquat at 0.375 lb/a has generally been better than with oil at the normal rate of 27 g.p.a., especially when grass species such as <u>Echinochloa colonum</u>, <u>Leptochloa</u> spp. and <u>Eleusial</u> spp. are established. The addition of 0.9 lb ae/a of 2,4-D amine to the paraquat treatment has provided improved control of broadleaved weeds showing tolerance to paraquat, e.g. <u>Lindernia crustacea</u> and <u>Fimbrystylis miliacea</u>.

Mixtures of paraquat plus suitable residual herbicides have also been shown to have a definite place for inter-row weed control since they combine excellent contact action with lasting residual effect and give increased flexibility in weed control. Mixtures of paraquat at 0.375 lb/a plus atrazine or diuron at 1.5 lb/a have proved particularly effective with the added advantage in the case of diuron that lower product rates can be used with associated greater safety in plant cane. Recent work has also established the value of paraquat plus TBA/2,4-D amine and paraquat plus ioxynil/2,4-D ester mixtures which can provide highly effective economic control of grasses and broadleaved weeds with satisfactory residual action.

It will be evident that the use of any contact herbicides in sugar cane presents the possible problem of phytotoxicity to the crop. This is likely to be of greater importance when the ratio of cane height to weed height is low, and where wind can cause spray drift. Cane is, however, capable of recovering rapidly from the effect of accidental spray contact of paraquat. Trials have been carried out to compare the effect on yield of scorch caused by paraquat applied to the inter-row at 0.5 lb/a with that caused by an application of the established herbicidal oil, where both treatments were applied as in the normal practice. The results of this work, and other studies, have shown that the yield of cane per acre and sugar per acre need not be affected even after fairly severe scorching in the field.

Application technique plays an important part in the efficiency of the treatment and experience has shown that best results with minimum damage to the cane are obtained using low drift floodjet nozzles operating at pressures of 10 - 15 lb sq. in. When knapsack sprayers are used these are best fitted with swan neck lances enabling a directed spray to be made to the inter-row up to the base of the cane.

Paraquat as a Pre-Harvest Desiccant in Sugar Cane

In many sugar cane areas excess trash arriving at the factory during harvesting presents a serious problem. This is due to the economic losses resulting from the transport from the field of waste material, and from the loss of sucrose absorbed by this waste material in the mill. Burning of the cane prior to harvesting is a standard practice in many areas but it is not always possible to obtain a satisfactory burn owing to an abundance of green foliage at harvest time. In these conditions chemical desiccation of the cane prior to burning may provide an effective solution. This technique of pre-harvest desiccation is likely to become of increasing importance as the use of mechanical cutting and loading develops.

Experiments have been conducted throughout the sugar industry to test chemical desiccants for cane and the compounds studied include dalapon, 2,4-D, aminotriazole, CMU, maleic hydrazide and paraquat (Humbert, 1968); of these compounds paraquat has proved to be the most effective yet tested and is now in commercial use as a cane desiccant in a number of countries.

The practice that is adopted is to aerially spray parapuat at 0.5 lb/a with the aim of achieving maximum coverage of the green foliage. Desiccation of the cane is extremely rapid and burning is carried out usually 5 to 9 days after treatment, depending upon weather conditions. This technique has enabled an effective reduction in trash to be achieved and, in addition, can make possible an increased rate of hand cutting.

It is of importance to record that the routine residue analyses that have been carried out in all the areas where this practice of paraquat pre-harvest desiccation has been used have shown that paraquat residues are not detectable in the juice extract (limit of detection 0.01 p.p.m.).

Diquat for Sugar Cane Flower Control

The flowering of sugar cane is a process that may occur in a number of commercially grown varieties in many areas of the world. The presence of these flowers for a long period prior to harvesting of the cane can significantly reduce sugar production, but recent research has shown that diquat can offer, in many areas, an invaluable solution to this problem.

Flowering of sugar cane is a photoperiodic response, but climatic and soil conditions can also play a part in influencing the process. Flowering of commercial varieties of sugar cane does not occur in all cane producing areas of the world and there is, moreover, a variation between different varieties in their propensity to flower. Where flowering does occur, however, this is followed by morphological changes in the plant which, in time, can be very detrimental to the optimum production of sucrose. This is because flowering stops the production of new internodes on the main stem thus reducing its growth potential, it stimulates the growth of the lower yielding side shoots, and it leads to an undesirable increase in fibre content and a consequential reduction in extractable juice. These factors become of increasing significance where the cane remains in flower for prolonged periods prior to harvesting. In some areas, for example, the cane may remain in flower for six months out of a total production cycle of twelve to fifteen months thus limiting its sucrose yield potential, and hence its profitability. Where flowering occurs in the first season of a two-year crop, as may occur for example in Hawaii, this similarly can result in losses of sugar of up to 20% per acre.

Much of the experimental work for the prevention of flowering in sugar cane has been carried out in Hawaii, (Tanimoto and Nickell, 1965), but research workers in other areas of the world have also contributed to the information that is now available. The methods that have been found to be effective in preventing flowering include the following :-

1. Night interruption with light so as to interfere with the stimulus of night length.

2. Lowered temperature.

3. Leaf and spindle trimming.

4. Subjection of plants to moisture stress by water withdrawal.

and

5. The application of certain chemicals.

Of these methods the only commercially practicable solutions are water withdrawal and application of chemicals. Water withdrawal is a technique which is necessarily limited to irrigated areas but even then success cannot be ensured if there is a likelihood of rainfall occurring during the critical period.

Early trials with chemicals showed that maleic hydrazide and later monuron and diuron, when used correctly, were of potential commercial use for flower control. Later trials in which the diquat was included showed this to be the most active compound evaluated, and it gave highly effective control of flowering at a rate of 0.25 lb/a. Results also suggested another very important advantage in that the effective interval over which diquat might be used could be greater than the effective period for other materials previously tested.

Since then other and larger scale trials using diquat have been conducted in a number of countries including Argentina, the Dominican Republic, Guyana, Hawaii, Mexico, Panama, the Philippines and Peru, yielding further valuable information on the effectiveness of diquat for sugar cane flower control. In some of these trials the aerial application of only 0.125 lb/a of diquat has resulted in 100% flower control and led to significant increases in total sugar yield per acre.

The technique consists of an aerial application of diquat at 0.125 - 0.25 lb/a to the upper foliage of the cane just prior to floral initiation. The exact timing of the treatment has to be established in the light of local experience, but in Mexico, for example, this is considered to be during the last week in August and the first week in September.

In the studies that have been carried out increases up to 50 tons cane per acre, on a normal 120 ton per acre crop have been recorded (Humber, Lima and Govea, 1968). These yield increases have been achieved at a cost which is only a small proportion of the value of the additional yield thus making possible, in those areas where the treatment has so far been shown to be effective, a significant increase in the efficiency of sugar production and in the utilisation of resources. If the use of diquat in this way can permit the adoption of previously rejected heavy flowering but high yielding cane varieties this treatment could, in the future, be of even greater value and importance to world sugar production.

REFERENCES

Humbert, R.P., (1968) "The Growing of Sugar Cane" (2nd edition) Elsevier Publishing Company.

Humbert, R.P., Lima, M.G., and Govea, J.S., (1968) "Tassel Control - Progress with 'Reglone' in the Mexican Sugar Industry", Proc. Issct. 13th Congress, Taiwan.

Manning, P.D., (1967) Company internal reports.

Tanimoto, T., and Nickell, L.G., (1965), "Field Control of Sugar Cane Flowering in Hawaii, with Diquat", Issct. 12th Congress Puerto Rico.

Proc. 9th Brit. Weed Control Conf. (1968)

CHEMICAL WEED CONTROL IN BANANAS - A SUMMARY OF EIGHT YEARS' EXPERIMENTS IN THE WEST INDIES

L. Kasasian
Herbicides Agronomist, University of the West Indies, Jamaica
J. Seeyave
Herbicide Agronomist, University of the West Indies, Trinidad

Summary Over 40 experiments (including 10 yield trials) have shown that the best pre-emergence treatments for bananas are diuron and atrazine or where leaching occurs readily linuron and simazine. The most economical post-emergence sprays, onee the leaves of the crop are well clear of the ground have proved to be directed applications by a low drift jet of 2,4-D (amine) plus either dalapon or MSMA depending on the grasses present. For earlier post-emergence use, or where careful application is not possible, the best treatments have been paraquat alone or mixtures of paraquat with diuron. It appears that weed competition affects the yield of bananas mainly by delaying maturity.

The only treatment to kill old banana plants was picloram injected into the shoot but its persistence and toxicity are such that it seems inapplicable where it is desired to replant the area with bananas.

Thirty initial trials were laid down in several islands; it had been hoped to carry several of these through to yield but due to wind damage, inadequate supervision, etc., this only proved possible in the case of two. However, the general picture that emerged clearly showed the most promising treatments were: pre-em. - atrazine and diuron on heavy soils and simazine and linuron on light soils; post-em. - paraquat, dalapon and 2,4-D (amine). The two yield trials showed that yields were reduced significantly only by 3 lb/ac fenac pre-em. (Table 1). Symptoms had been caused sometimes on light soils by pre- or post-emergence applications of atrazine and diuron and also by fenac and TCA (Kasasian, 1964), but it is apparent from Table 1 that these need not necessarily affect the yield adversely. In some of the initial trials, however, the severity of symptoms caused by 3 lb/ac of atrazine and diuron on light soils was such as would almost certainly have affected the yields.

Three further pre-em. trials were carried through to yield in 1964, 1965 and 1967 and the results of these confirm those obtained previously and show that none of the treatments had any significant effect on yield (Table 2). Atrazine and diuron have always given better weed control than simazine and linuron and while all are more or less satisfactory on light soils, none has given consistently satisfactory results on heavy soils, particularly when the rainfall was high. In current pre-em. trials in Dominica and St. Lucia outstanding results have been given by 3 and 6 lb/ac Maloran.

Five of the post-em. experiments carried out between 1963 and 1967 were taken through to yield. The two in Dominica were sprayed when the plants were 4 months old and 5-6 ft tall and that in Grenada

3 months after planting. Unfortunately these trials were inadequately weeded after spraying and so the results reflect the effect of weed competition more than the direct effect of the herbicides on the crop. It was, however, clear that yields were not adversely affected by 2 lb/ac 2,4-D (amine), 5 lb/ac dalapon, 0.5 lb/ac paraquat or 3 lb/ac simazine or linuron each plus either 0.5 lb/ac paraquat or 2 lb/ac 2,4-D.

Table 1

Yield of Robusta bananas, Dominica 1962
(Post-em. sprayed when bananas 4-6 ft tall).

Treatment		Pre-em.	Post-em.
		Yield as % of control	
Diuron 1.5 lb/ac		76.4	95.4
" 3.0 lb/ac		83.1	94.5
Simazine 1.5 lb/ac	) plus 0.5 lb/ac	117.0	109.6
" 3.0	) paraquat	111.2	88.0
Atrazine 1.5 lb/ac	) post-em.	90.3	80.2
" 3.0		119.1	
Fenac 1.5 lb/ac	) plus 0.5 lb/ac	89.0	110.2
" 3.0	) paraquat post-em.	65.5*	110.5
TCA 5 lb/ac		68.9	
" 10 lb/ac		99.6	119.4
" 20 lb/ac		124.1	120.2
" 40 lb/ac			102.1
Dalapon 5 lb/ac			131.4
" 10 lb/ac			127.6
" 20 lb/ac			81.9
Paraquat 0.5 lb/ac			126.5
	L.S.D. 5%	32.2	45.3

Table 2

Pre-em. trials 1964-1967
(Yields as % of control)

Treatment	Grenada Total yield	St.Lucia Average Bunch Wt.	Jamaica Total yield
Simazine 3 lb/ac	113.5	92.3	
" " plus TCA 5 lb/ac	90.3	96.2	Final
Atrazine 3 lb/ac		95.5	results
" " plus TCA 5 lb/ac		96.2	awaited
Diuron 3 lb/ac		87.6	
" " plus TCA 5 lb/ac		95.7	
Linuron 3 lb/ac	79.2	97.0	
" " plus TCA 5 lb/ac	109.2	88.5	
Norea 3 lb/ac		94.5	
" " plus TCA 5 lb/ac		94.5	
TCA 10 lb/ac	111.1		
" 20 lb/ac	87.2		
L.S.D.	28.5	13.0	

The results of the last two post-em. trials are shown in Table 3. The St. Lucia results are given as average bunch wt. only as there was a severe blow-down shortly before the beginning of cutting.

Table 3

Pre-em. trials in St.Lucia and Jamaica
(Yields as % of control)

Treatment	St.Lucia Mean bunch wt.	Jamaica Mean bunch wt.	Jamaica No.nunches Harvested.
Dalapon 5 lb/ac	107.4		
" 7.5 lb/ac		105.6	80
2,4-D (amine) 2 lb/ac	91.2		
" 3 lb/ac		94.7	80
Dalapon plus) 5 lb/ac 2,4-D) 2 lb/ac	102.5		
Dalapon plus) 7.5 lb/ac 2,4-D) 3.0 lb/ac		91.1	100
Paraquat 0.5 lb/ac	97.7		
" " monthly		100.0	100.0
" " 3-monthly		81.9	75
" " monthly first 3 months only		97.3	100
MSMA 2 lb/ac		100.2	92
Pyriclor 1.5 lb/ac		93.8	98
Hoeing monthly		95.6	82
No weeding		84.9	63*
Diuron 1.6 lb/ac plus Paraquat 1.5 lb/ac		98.8	122
Diuron 1.6 lb/ac plus dalapon 2.2 lb/ac plus 2,4-D 1 lb/ac	100.3		
Linuron 1.6 lb/ac plus dalapon 2.2 lb/ac plus 2,4-D 1 lb/ac	100.7		
Simazine 2 lb/ac plus dalapon 2.2 lb/ac plus 2,4-D 1 lb/ac	94.6		
Norea 1.6 lb/ac plus dalapon 2.2 lb/ac plus 2,4-D 1 lb/ac	103.2		
L.S.D. 5%	N.S.	N.S.	26

In current weed competition trials in St. Lucia and Grenada (Table 4) it is clear, as in the Jamaica trial (Table 3), that early weed control is critical.

Table 4

Yield of bananas in the first 12 months after planting.

Clean weeding monthly	856 lb
Cutlassing "	290
" June to November	260
" December to May	54
" June	97
" December	95
" June, Sept., Dec., and March	40

Table 5 summarises the results of a number of recent post-em. trials with a number of other herbicides.

Table 5.

Effect of several post-em. herbicides on the growth of bananas

Treatment	lb/ac a.i.	Number of trials	Effect on crop 0-none; 5-severe
Ametryne	2-3	2	0
Terbacil	1.5	1	0
Ametryne plus Paraquat	1.5 0.25	1	0
Ametryne plus MSMA	1.5 3.0	1	0
Ametryne plus Pyriclor	1.5 0.5	1	0
Pyriclor	0.25-4.0	2	0
TCA plus Paraquat	5-10 0.25	1	0
MSMA plus 2,4-D	2-4 2	3	0-2*
Paraquat plus MSMA	0.25 2.0	1	0
Diquat plus MSMA	0.25 2.0	1	0
Pyriclor plus MSMA	1.0 2.0	1	0
Pyriclor plus 2,4-D	1 2.0	1	4*
MSMA	3	1	2-3*

Atrazine plus) Paraquat)	1 0.25	1	0
Diuron plus) MAMA)	2 g.p.a. Monex	1	0

*injury caused where plants too small to direct all the spray beneath the leaves.

BANANA ERADICATION

Injecting 5 ml of either 2% or 20% a.e. 2,4-D (amine) into cut or uncut banana shoots failed to eradicate the clumps.

In a second experiment 5 ml of the following were injected into standing shoots and cut stems: 2% and 10% picloram, 10% and 50% 2,4-D (amine and ester), 10% and 50% 2,4,5-T, 10% and 20% aminotriazole, 25% and 100% sodium arsenite and 5, 25 and 50 ml/shoot of undiluted paraquat and diquat - only picloram killed the clumps and prevented all regrowth.

In a third trial 5 ml of 0.1-2.0% picloram was injected into cut or uncut shoots. 1% gave complete kill whether the shoots were cut back or not, 0.5% only on cut shoots and 0.25% on neither.

References

KASASIAN, L. (1964) A progress report on chemical weed control in Robusta bananas. PANS (C), 10, 102.

Proc. 9th Brit. Weed Control Conf. (1968)

WEED CONTROL IN SABAH

D. A. Ll. Brown
BAL Estates Sdn. Bhd., Tawau, Sabah

Summary Various combinations and rates of aminotriazole, dalapon, DSMA, MSMA, paraquat, sodium arsenite, sodium chlorate, and 2,4-D (amine) were compared with hand weeding for the control of weeds in abaca (*Musa textilis*). Within six months each treatment had developed a characteristic flora. This was relevant to the selection of herbicides for controlling weeds in rubber and oil palm on the same plantation.

The effect of treatments on abaca was observed. Hand weeding, dalapon, or a sequential application of aminotriazole and paraquat were recommended.

INTRODUCTION

BAL Estates Sdn. Bhd. grows 23,000 ac of the perennial crops, abaca, cocoa, rubber and oil palm, near Tawau in Eastern Malaysia. In 1964 weeding was done by hand or sodium arsenite was used. The rising cost and shortage of labour and the resistance of weeds to the herbicide made changes necessary. In 1965 paraquat was introduced. A trial was laid down in abaca to compare the effects of paraquat, sodium arsenite and DSMA, which was thought to be promising for controlling *Paspalum conjugatum*, resistant to the other two herbicides. It was soon clear that resistant weeds were not going to be successfully controlled by paraquat or sodium arsenite, neither was DSMA likely to prove economic. Another trial was laid down. Both trials were on dark brown clay loams of basaltic origin. Rainfall was well distributed and averaged 87 in. a year.

METHOD AND MATERIALS

The first trial was in old debilitated abaca. Plots were 36 ft. by 36 ft. arranged in a 6 x 6 latin square. The second was in abaca planted five months previously. Plots were 40 ft by 52 ft arranged in four randomized blocks. Treatments are shown in Table 1. Sodium arsenite was applied with a high pressure pump, using a hollow cone jet. All other herbicides were applied with an 078 flood

Formulation used:

aminotriazole	-	'Weedazol TL'
dalapon	-	'Dowpon'
DSMA	-	40% a.i.
MSMA	-	'Ansar 529M'
paraquat	-	'Gramoxone'
sodium chlorate	-	Commercial NaClO3 98% a.i.
sodium arsenite	-	Commercial, 80% As_2O_3 equivalent
2, 4-D	-	'Shell Amine 80'

jet used at low pressure. A wetter, 'Lissapol N', was used at 0.20 to 0.25 fluid oz/gal spray in all treatments except with paraquat in the second trial which then had wetter included in the formulation. Where a sequential spray of paraquat was applied with aminotriazole or with dalapon, this followed fourteen days after application of the other herbicide. In the paraquat treatment in the first trial, the initial monthly round was 0.5 lb a.i. /ac followed ten days later by 0.25 lb. a.i./ac and 0.25 lb. a.i. /ac thereafter.

In the first trial, where the abaca spacing was indistinguishable, 6 ft swathes were marked out and sprayed; while in the second, two swathes of spray were applied between each 10 ft inter-row. With low pressure applications, the volume of herbicide was measured for each plot. Practiced operators under-applied the chemical when first covering the ground and rapidly distributed the small balance over the whole plot. In both trials the herbicide was applied to the mats themselves. Hand weeding was done by scuffling the soil surface with a cutlass.

Effectiveness of the weed control and the principal weeds were noted. There was no special recording of the growth of the abaca in the first trial, except for a count of number of suckers six months after start of treatment; while in the subsequent trial the abaca was recorded in detail quarterly. Length and width of the first fully opened leaf of the tallest stem of each mat was recorded, to give a measure of leaf area. Total number of suckers and stems was recorded and height of all stems, where the lowest active leaf was no longer a sword leaf, was measured from the ground to the junction of the petiole of the first fully open leaf with the unopened leaves. Girth of stems was measured 3 ft. from the ground. A soil pit, 3 ft square and 2 ft deep, was dug in each plot in the middle of one of the 10 ft inter-rows between two mats. Roots cut on two sides facing the mats were counted.

RESULTS

Flora in the first trial was predominantly *Paspalum conjugatum* with *Brachiaria paspaloides*, *Eleusine indica*, *Imperata cylindrica*, *Ageratum conyzoides* and *Eupatorium odoratum* also occurring. There were differences in the original flora between the replicates in the second trial. In two of these, *Centrosema pubescens* and *Desmodium uncinatum* had been sown, but there was much *Eleusine indica*, *Cleome ciliata*, *Paspalum conjugatum* and nutgrasses in that order. In the other two unplanted replicates, *Paspalum conjugatum*, *Brachiaria paspaloides* and nutgrasses predominated in about equal proportions. Effect of six months' treatments on flora is shown in Table 1. For the purposes of estate management, *Imperata cylindrica* was controlled with separate applications of aromatic oils.

Between individual treatments, in the first trial, there was no significant difference in sucker numbers after six months, though, taken together, those with DSMA had fewer suckers than the others. Effects of treatments on abaca growth in the second trial are shown in Table 2. There were no significant differences in leaf area between treatments a fortnight after the start of the trial. At the end of the trial there were very highly significant differences between number, height and volume of stems, and significant differences in root numbers.

Table 1

Treatments in terms of active ingredients and their effect on weeds

Treatment, sprayed monthly except those marked ∅ once every two months	Trial	lb a.i. /ac /application	% control of weeds	Weeds: Commonest in order of dominance	Weeds: Also present
Paraquat	2	0.50	73	j,s,p,e	d,f,g,i,m,y
Paraquat	1 & 2	0.25	76 & 48	s,j,y,d,p	a.e.g.m.u
Paraquat & 2,4-D	2	0.50 & 1.80 a.e.	81	j,s,d,p	f*,g,i
Paraquat & 2,4-D	2	0.25 & 0.90 a.e.	61	j,d,s,p	g,i,y
Aminotriazole/Paraquat	2	0.75/0.50	60	p,j,d,h,y	f*,g,i,r
Aminotriazole/Paraquat	2	0.38/0.25	96	j,p,h,y	f*,g,r
Dalapon/Paraquat	2	2.22/0.50	84	p,e,s	f*,j*,y
Dalapon	2	4.44	50	u,s,f,v,t	a,l,m,n,x,y
Dalapon	2	2.22	23	s.f.t.u	j.l.m.v.x
DSMA ∅	1	4.80	57	j,u,d,a,b	c,e,k,l,m,o,w,x
DSMA ∅	1	3.20	28	not recorded	not recorded
DSMA ∅	1	1.60	22	d,a,s,u,b	c,e,i,j,k,l,m,n,o,q,w,x
MSMA	2	4.95	63	j,p,f,u,d	g,m,x
MSMA	2	2.48	48	j,d,u,g	f,i,m,p
Sodium arsenite ∅	1	8 to 12	41	d,s	b,e,i,j,u,w
Selective hand weeding	1 & 2	-	98	e+, u*, p, f*, j*, s*	a*, e*, k*

\+ left in selective weeding.   * Principally seedlings.

a. *Ageratum conyzoides*
b. *Alocasia* spp.
c. *Asystasia gangetica*
d. *Brachiaria paspaloides*
e. *Centrosema pubescens*
f. *Cleome ciliata*
g. *Cynodon dactylon*
h. *Digitaria* spp. including *D. sanguinalis*, *D. longiflora*
i. *Echinochloa colona*
j. *Eleusine indica*
k. *Erechthites valerianifolia*
l. *Eupatorium odoratum*
m. *Euphorbia hirta*
n. *Lantana aculeata*
o. *Melothria affinis*
p. Nutgrasses including *Cyperus cyperoides*, *C. rotundas*, *Kyllinga brevifolia*, *K. monocephala*
q. *Panicum auritum*
r. *Paspalum commersonii*
s. *Paspalum conjugatum*
t. *Passiflora foetida*
u. *Peperomia pellucida*
v. *Physalis angulata*
w. *Pitryogramma calomelanosa*
x. *Solanum* spp. including *S. nigrum*, *S. torvum*
y. *Sorghum halepense*

Table 2

Effect of treatmens on abaca

Treatment ∅	Rate	Mean single leaf area in in^2	No. suckers & stems /mat	No. stems /mat	Mean stem height in ft	Stem volume in ft^3/ treatment	Live root no. /sample	Dead root no. /sample
Paraquat	High	1827	10.2	5.0	8.1	59.8	28.5	12.8
Paraquat	Low	1888	10.6	6.3	8.9	91.8	22.8	15.5
Paraquat & 2,4-D	High	1839	10.6	4.7	9.0	67.9	20.5	12.5
Paraquat & 2,4-D	Low	1826	9.9	5.6	9.1	82.7	31.0	15.8
Aminotriazole/ Paraquat	High	1853	11.4	5.9	8.7	78.0	30.0	15.8
Aminotriazole/ Paraquat	Low	2120	11.4	7.4	9.5	126.6	40.5	27.0
Dalapon/Paraquat *		1983	10.4	6.1	9.0	89.1	30.3	19.8
Dalappn	High	1963	10.9	6.4	9.0	100.5	31.0	25.3
Dalapon	Low	1704	10.3	5.5	8.0	63.5	20.0	24.3
MSMA *	High	1873	11.4	7.0	8.6	87.0	24.3	29.0
MSMA *	Low	1749	10.7	6.2	8.5	79.6	28.8	29.8
Hand slashing *		1630	9.5	5.5	8.0	63.5	19.8	21.0
Hand weeding		1942	11.1	7.3	9.3	120.2	28.5	27.8
Mean		1861.3	10.63	6.06	8.72	85.39	27.37	21.27
Standard Error		76.2	0.50	0.45	0.12	10.99	4.43	4.76
Significant difference, 5%		219.9	1.45	1.31	0.34	31.74	13.08	13.73

∅ Details given in Table 1.

* Changed to this treatment from 2,4-D or sodium chlorate.

DISCUSSION

Weed Control

It was hoped to use the lower rate of herbicide in practice while the higher rate would give an indication of toxicity. Rates of application were more frequent than estate practice, again to check the safety of any recommended application and to give a more rapid indication of troublesome weeds.

Each herbicide produced characteristic changes in flora. In the second trial it was soon found that neither 2,4-D nor sodium chlorate at the lower rate gave adequate control; these were modified.

DSMA had little rapid effect at 3.2 lb a.i./ac. Paspalum conjugatum was gradually suppressed, Brachiaria paspaloides remained and dicotyledonous weeds increased. At 4.8 lb a.i./ac, Paspalum conjugatum was eliminated, Brachiaria paspaloides suppressed, leading to bare ground. This was colonized by Eleusine indica and Peperomia pellucida, so that these weeds and other dicots predominated.

With sodium arsenite, Brachiaria paspaloides, Paspalum conjugatum and Eleusine indica were resistant. While they were scorched by the application of the herbicide, regeneration was rapid. The first two weeds dominated the cover in sunlight; in shade only Eleusine indica grew well.

A good level of weed control was rapidly achieved with sequential applications of aminotriazole or dalapon with paraquat. Where paraquat was used alone or with 2,4-D, several sprayings of the higher rate were necessary to achieve adequate control. At the lower rate this was achieved only where the abaca grew well, providing an increasing level of shade. There were some resistant or colonizing weeds in all plots where weed control was good. This provided a clear indication of what would happen in estate practice, where the application of herbicides was less frequent than in the trial. Nutgrasses survived all these treatments. With aminotriazole, Eleusine indica, Digitaria sanguinalis, Sorghum halepense, Paspalum commersonii and Cynodon dactylon remained present. With dalapon Paspalum conjugatum remained. With paraquat alone, or with 2,4-D, Eleusine indica, Paspalum conjugatum, Cynodon dactylon and Sorghum halepense remained. The bare ground was constantly recolonized between sprayings with Eleusine indica and Cleome cilitia seelings. Where dalapon was used alone, suppressed Paspalum conjugatum was present with Peperomia pellucida, Cleome ciliata and Passiflora foetida. The higher rate encouraged Peperomia pellucida at the expense of the Paspalum conjugatum and Cleome ciliata, while the lower rate had the reverse effect.

MSMA, while elimating Paspalum conjugatum and Sorghum halepense, had markedly little effect on Eleusine indica. Brachiaria paspaloides and Cynodon dactylon were also present, though more markedly suppressed at the higher rate, where Clemme ciliatia and Peperomia pellucida took their place. Nutgrass was present in all treatments which reduced the other weeds and was apparently absent only where suppressed or shaded out by weed competition.

With hand weeding, colonizing weeds that were constantly being removed were Eleusine indica, Paspalum conjugatum and Cleome ciliata.

In some cases it was difficult to decide how much development of flora was due to effect of herbicides, how much tocompetition between weeds. For example with MSMA, it was clear that Eleusince indica was competitive with other plants, while with dalapon at the low rate of 2.22 lb a.i./ac the vigour of the Paspalum conjugatum and Cleome diliata discouraged Peperomia pellucida.

Growth of abaca

Sodium chlorate at 19.6 lb a.i./ac harmed abaca, producing a dark purple spotting of the petioles, followed by the death of the older leaves.

Weed competition reduced leaf area. Number of stems and suckers were similar in each treatment due to estate practice limiting the total number. However development of suckers to stems reflected weed competition and showed that the higher rate of paraquat checked their development. Potential production of the field was considered to be an estimation of volume of standing stems derived from stem number, girth and height. Only aminotriazole at 0.375 lb. a.i./ac with paraquat at 0.25 lb a.i./ac, and dalapon at 4.44 lb a.i./ac were not significantly less than hand weeding. Good stem growth at the low rate of aminotriazole and paraquat was reflected in root growth. In all other treatments with paraquat, there were fewer dead roots than with hand weeding.

The conclusion drawn from the trials was that all the weeds, with the exception of the nutgrasses,could be controlled by appropriate selection of chemicals, the most promising of these were aminotriazole at 0.375 lb. a.i./ac with paraquat at 0.25 lb a.i./ac, and dalapon at 4.44 lb a.i./ac. Sodium chlorate was likely to be harmful.

Application to other crops

The trials showed the need to choose the right herbicide to control the various weeks on the plantation. There was little point in eliminating one set of weeds only to be faced with another, more competitive and harder to control.

There were indications that crop growth with the use of herbicides could be as good with clean hand weeding. For instance in the trial, there was no significant difference between dalapon at 4.44 lb a.i./ac and hand weeding, even though the dalapon gave only a 50% control of weeds. In immature rubber, the growth under clean weeding appeared no better than where weeds were suppressed once a quarter with herbicides.

The trial gave an early indication of which weeds would be troublesome under the different spraying regimes used in estate practice, and early action could therefore be taken to control these by selective hand weeding before they had an opportunity to spread. In one area, where it had been decided not to use cover crop, a pure stand of Paspalum conjugatum was established by spraying dalapon to eliminate Eleusine indica before planting oil palms. Once the palms had been planted, weeded circles could be maintained with the use of pre-emergence herbicides and the encroachment of Paspalum conjugatum completely controlled by sublethal applications of aminotriazole, sufficient to suppress the grass but not to produce bare ground for colonization by weeks.

Acknowledgments

I am particularly indebted to Dr. H. M. Burkill for help with identification of the weeds and to Dr. W. Meijer and Mr. Y. K. Wong. I also wish to thank Mr. D. Lim Hong Kee and my staff for their support in carrying out these two trials and to the Commonwealth Development Corporation for permission to present this paper.

Proc. 9th Brit. Weed Control Conf. (1968)

CHEMICAL CONTROL OF WEEDS IN N.E. INDIAN TEA

S.K. Dutta
Chief Advisory Officer
Tocklai Experimental Station, Jorhat-8, Assam, India

INTRODUCTION

The tea in North East India is grown mainly in the Brahmaputra and Surma Valleys of Assam, in the Jalpaiguri district of North Bengal, in the hills of Darjeeling and in a small area in Tripura. These districts fall within latitudes 24°40' N to 27° N and longitudes 88.3° E to 95° E. The elevational ranges and the mean maximum and minimum temperatures in January (mid winter) and July (mid summer) of these districts are:

State	Region	Mean Elevational Range	Average temperatures			
			January (Mid winter)		July (Mid summer)	
			Max.	Min.	Max.	Min.
Assam	South Bank	200 to 450 ft.	72°F	49°F	90°F	76°F
Assam	North Bank	200 to 450 ft. (flat area) 450 to 650 ft. (foot hill area)	72°F	52°F	90°F	77°F
Assam	Cachar	100 to 250 ft. (flat area) 250 to 450 ft. (teela area)	79°F	52°F	90°F	77°F
West Bengal	Dooars	250 to 1000 ft.	75°F	51°F	86°F	75°F
West Bengal	Darjeeling	1000 to over 6000 ft.	60°F	46°F	75°F	67°F

Tea growing in N.E. India is the largest single enterprise of its kind in the world in terms of acreages, labour employed and financial investment and turnover. In North East India at present, there are over 650,000 acres of tea giving employment to nearly 650,000 labourers daily and the cost of labour is the most expensive item in the recurrent cost of production. The bushy nature of the tea plants aligned at close spacing, the presence of a large number of open drains and in many instances, the topography of the land make it impossible to use manually operated or tractor-drawn implements in mature tea.

In poorer soils with low water tables, the tea roots penetrate to depths of 20 feet or more. But, in areas where the water table is high, the roots do not go deeper than about three feet. In all cases, however, the majority of the feeder roots are in the top four inches of the soil. Hence, any form of soil stirring always brings about severe damage to these roots.

Experiments carried out as long ago as in 1930 by this Station proved that soil stirring was not necessary and the mere scraping of the soil with a cheel hoe to cut off the top growth of weeds, gave sustained good yields and maintained the physical condition of the soil better than deeper cultivation. A cheel hoe is a hand tool with a wide and flat blade at right angles to the shaft and purposely designed for scraping the soil rather than digging. It penetrates only about half an inch into the top soil. Although cheel hoeing and sickling control weeds much more cheaply than deeper cultivation, they are still slow processes and require a large amount of labour. On an average, in young sections where the ground cover offered by the tea bushes is not yet complete, anything upto 75 man days a year are required per acre and in mature tea sections where weed suppression by the older bushes is better, 30 man days may be required.

The weeds that are commonly found in tea areas of North East India are:

> Imperata cylindrica, Arundinella bengalensis, Saccharum spontaneum, Setaria palmifolia, Mikania micrantha, Borreria hispida, Ageratum conyzoides, Chrysopogon aciculatus, Colocasia antiquorum, Commelina benghalensis, Cynodon dactylon, Drysophylla aricularia, Eleusine indica, Eragrostis uniloides, Erechthites valerianaefolia, Eupatorium odoratum, Ficus hirta, Hedyotis lineata, Hydrocotyle asiatica, Hydrocotyle rotundifolia, Hypericum japonicum, Ipomea cymosa, Litsea citrate, Melastoma malabathricum, Oxalis acetosella, Oxalis corniculata, Panicum flavescens, Paspalum conjugatum, Paspalum scrobiculatum, Phragmites karka, Phyllanthus nirurii, Peperomia pellucida, Rubus moluccanus, Scoparia dulcis, Sida rhombifolia, Solanum nigram, Stephania elegans, Torenia bicolar and Urena lobata.

Amongst those weeds, the first six are the most pernicious. Mikania micrantha is a comparatively new weed in N.E. India and its seeds, being wind-dispersed, are carried over great distances. This extremely fast growing creeper has reached epidemic proportions and many tea estates are having to spend large sums of money on its control but unless it is controlled it can, in a matter of one to two years, completely smother the tea bushes and place the section out of production. Imperata cylindrica, Arundinella bengalensis and Saccharum spontaneum being stoloniferous and deep rooted weeds and Setaria palmifolia a rhizomatous weed, are very difficult to control by manual cultivation and multiply profusely both vegetatively and also by seeds which are carried long distances by wind. Borreria hispida mainly multiplies by seeds which are not normally carried by wind, but are dispersed over wide areas by rain water flowing over the soil surface or in drains.

CHEMICALS TRIED

A very wide range of chemicals has been tried to control these major dicotyledonous and monocotyledonous weeds. The chemicals used include the auxin types of growth regulators, aminotriazoles, substituted urea herbicides, triazine herbicides, quaternary ammonium compounds as well as various contact herbicides.

CHEMICAL CONTROL IN PRACTICE

Tea estate managers are realising with increasing assurance that, in the present era of rapidly increasing costs, both direct and indirect it is becoming more difficult and not economically attractive to control weeds by using vast amounts of hand labour. Furthermore, hand control never permanently eliminates competition from weeds because regrowth during the monsoon between rounds of hand cultivation is extremely rapid.

On the basis of a very large number of field experiments as well as commercial scale trials, definite but simple methods of chemical control have now been evolved. For this purpose, I have classified the weeds of tea estates into the following three types:

1. GRASSY AREAS : Where Imperata cylindrica, Arundinella bengalensis and Saccharum spontaneum are the predominant weeds.

2. MIKANIA OR BORRERIA AREAS : Where Mikania micrantha and/or Borreria hispida are the predominant weeds.

3. GENERAL WEEDS : Where neither the deep rooted stoloniferous grasses nor Mikania or Borreria are predominant.

Methods of control:

The effective chemical control of weeds for large scale commercial conditions using unskilled and illiterate labour demands methods which must of necessity be simple. It is also best that the methods should not involve too many different chemicals and complicated spraying equipment. A number of very efficient hand operated low pressure sprayers is now being manufactured in India and using these, it has been possible to spray anything upto 7 acres with two sprayers in an 8-hour working day using 3 men.

The system of chemical control of weeds, therefore, has at present been oriented around the use of dalapon, simazine, 2,4-D and Gramoxone (paraquat) only and the following methods are being recommended for commercial use.

(1) GRASSY AREAS: Where grasses such as Imperata cylindrica, Arundinella bengalensis and Saccharum spontaneum are predominant, spray dalapon at 3 lb per acre in spring when the grass is actively growing and it is not more than 6 to 10 inches tall. About 5 to 7 days after this, spray Gramoxone with a hand operated low pressure sprayer such as the "Holder Harriden Mini Knapsack Sprayer" fitted with a pressure regulator to discharge at not more than 10 lb per sq. inch pressure. A standard solution of half pint Gramoxone in 100 pints of water should be used and sprayed efficiently, taking the utmost care to ensure that no spray droplets fall on the leaves or any other green parts of the tea plants. Sprayers fitted with a flood jet of the fan type are best because a wider sweep of spray is obtained in a single operation resulting in larger areas being covered by each sprayer.

(2) MIKANIA OR BORRERIA AREAS: Where Mikania or Borreria species are severe and are the predominant weeds, in the first year of chemical control, the ground should be clean cheeled in February/March. Then as soon as the first rains fall, and before the weeds emerge, the area

should be sprayed with Simazine 50W at the rate of 2.5 to 3.5 lb per acre using an ordinary hand operated sprayer. When the weed including Mikania and/or Borreria begin to grow, these should be sprayed with Gramoxone in a similar manner to that described for grassy areas. Repeat sprayings with Gramoxone only, should be continued until all the weeds have been brought under control. From the second year onwards, Gramoxone only need to be sprayed.

Recent trials have also shown that if the first round of spray is given with 0.5 lb 2,4-D active ingredient per acre, taking care not to spray the foliage of the tea, excellent control of Mikania can be obtained at a very low cost of about Rs 5/- (5s 6d) per acre.

Mikania has reached epidemic proportions and there are tea sections which have been completely smothered by the weed and are consequently out of production. Very recent experimental work offers hope that these sections can be reclaimed by what may appear to be a drastic treatment. 2,4-D at the rate of half pound active ingredient per acre dissolved in the required volume of water and sprayed on to Mikania which completely envelopes the tea bushes, kills the Mikania and causes some deformity symptoms to the tea leaves. But the tea bushes later grow away satisfactory and drastic as the cure is it is undoubtedly better than having to abandon tea.

(3) GENERAL WEEDS: Where neither grasses nor Mikania or Borreria are severe, perfectly satisfactory control of weeds is normally obtained by spraying with only Gramoxone from the very beginning. The method of spraying Gramoxone is exactly the same as that described above.

COSTS

In the case of purely manual control of weeds, 30 to 75 man days a year are required and the cost varies between Rs 150/- (£8-6-8) and Rs 375/- (£20-16-8) per acre per year in mature and young tea respectively.

In the first year, for the chemical control of general weeds in mature tea, on the basis of present costs, the quantities of chemicals, man days required and the cost of chemical will be approximately as follows:-

Chemical,				
	1st round	-	1.42 pint Gramoxone per acre	= Rs 32.00
	2nd "	-	0.71 " " " "	= Rs 16.00
	3rd "	-	0.71 " " " "	= Rs 16.00
	4th "	-	0.36 " " " "	= Rs 8.00
Labour,				
	1st round	-	1.2 man days per acre	= Rs 6.00
	2nd "	-	0.8 " " " "	= Rs 4.00
	3rd "	-	0.8 " " " "	= Rs 4.00
	4th "	-	0.2 " " " "	= Rs 1.00
				Rs 87.00

Therefore, in the first year, the cost per acre = Rs 87/- (approx.) (£4-16-8)

The amounts of chemicals and man-days required will diminish with each successive year if the methods are persisted with. Normally, from the third or the fourth year, one or two sprays are adequate and the cost per acre will be considerably less than Rs 30.00 (£1-13-4).

In the case of very grassy or severely Mikania infested areas, where the first application will have to be with dalapon and simazine at the rate of 2.5 lb and 2.5 to 3.5 lb per acre respectively, the cost will be somewhat greater but normally, less Gramoxone will be used later.

It has been estimated that the continuous use of herbicides in the entire tea areas of North East India will result in an overall saving of nearly Rs 58,500,000 (£3¼ million) per year in cultivation costs alone apart from their convenience in use.

It is also only too well known what difficulties and onerous responsibilities are involved in the employment of labour. Usually these difficulties and responsibilities are far more in the developing countries than in the developed ones, because the trade union leaders have not yet in all cases fully understood the concepts of trade unionism. In tea estates, the labourers as well as their large number of dependants have to be housed, supplied with cereal rations at subsidised rates, adequate quantities of fuel for cooking and provided with elementary schools, medical and maternity benefits. Amongst many other things, the management has also to look after their general welfare and settle all their personal and family disputes.

Spraying machines do not have to be provided with all these benefits and amenities. They are much more convenient and cause much less worry to the management which is difficult to measure in cash terms.

In peak growing periods, many tea estates are often compelled to use extra labour by employing casual workers. Therefore, any industry which can be run with a reduced number of labourers, can be managed much more smoothly and efficiently because the managerial staff can devote more of their time to the more productive aspects of their work.

CUP CHARACTERS

Tea liquors made from areas where weeds have been controlled chemically, have been tasted by a number of tasters. According to their opinions the use of the recommended herbicides has had no untoward effects on the liquor characters of the manufactured tea.

Proc. 9th Brit. Weed Control Conf. (1968)

SELECTIVE ACTIVITY AGAINST WEEDS OF HERBICIDES USED IN VINEYARDS

B.T. Daris

Vine Institute, Lykovrissi, Kifissias, Greece

Summary The application, for several years, of the same herbicide in a vineyard can produce the selection of certain resistant weeds. The resistant weeds differ, depending on the herbicide used.

After 4 years of trials with 28 herbicides, the author observed that 14 of them used continuously on the same experimental plots produced a selection of different weeds for each herbicide. These were: Sorghum halepense, Cynodon dactylon, Cyperus sp., Convolvulus arvensis, Avena fatua, Erodium cicutarium, Daucus carota and othersless significant.

After 3-4 years the resistant weed covered the entire area of the experimental vineyard completely and showed the necessity of changing the herbicide used, after 2 years, to another one controlling the resistant weeds in order to have complete weed control in the vineyards.

INTRODUCTION

Since 1964 the Greek Vine Institute of the Ministry of Agriculture has studied the efficacy and the influence of different herbicides applied in vineyards. Twenty-eight pre-and post-emergence herbicides were tested in different experimental vineyards all over Greece.

After the second year of application several of the herbicides used left a selection of 1-3 weeds, that were resistant to the herbicide. These weeds remaining alone in the weed-free vineyard and without competition from the other weeds, multiplied rapidly and completely covered the entire area of the treated vineyard within a period of four years.

The main resistant weeds were: Convolvulus arvensis, Avena fatua, Cynodon dactylon, Sorghum halepense, Cyperus sp., Erodium cicutarium and Daucus carota. Several of the above mentioned weeds, like Avena fatua and Daucus carota were selected only by certain herbicides used, containing active ingredients belonging to the same group of chemical substances (urea family).

Other authors also have observed this weed selection in vineyards after the continuous use of the same herbicide for several years.

Julliard (1968) using monuron (8kg/ha), found a selection of Convolvulus arvensis and Fumaria officinalis, with atrazine, (5 kg/ha) Ranunculus repens and Convolvulus arvensis, with diuron (3,2 kg/ha) Convolvulus arvensis and Cirsium arvense and using dichlobenil (6 kg/ha), Cirsium arvense remained resistant. Zanardi (1959), using aminotriazole (2 kg/ha), found a selection of Cynodon dactylon and of

Agropyron repens.

Lange (1968) states that vineyardists of California using herbicide for weed control, such as simazine (1-4 lb/ac), or diuron (1.6-3.2 lb/ac) or a combination of simazine and aminotriazole (2 lb/ac), after several years, were facing a serious problem of controlling the resistant weeds Cynodon dactylon, Cyperus sp., Convolvulus arvensis, and Tribulus terrestris.

Lider et al. (1960) applied simazine and diuron in the vineyards of the Californian valleys and after several years had serious infestations of Convolvulus arvensis in the vineyards treated with diuron and of Convolvulus arvensis, Rumex acetosella and Mentha sp., in the vineyards treated with simazine.

Stalder and Barben (1967), experimenting with different herbicides in Switzerland (1964-1966), found Ranunculus repens resistant in plots treated with chlorthiamid and Artemisia ferlotorum in plots treated with paraquat.

METHODS AND RESULTS

In the region of Attica (Lykovrissi, Kifissias), near Athens, the Vine Institute has organised several experimental vineyards for the application of herbicides. The observations listed below were made by the author in three of those vineyards.

The field trials, in these vineyards, were started in January 1965.

a) Vineyard No. 1:

Cultivated variety: Different greek varieties of table grapes and of grapes for wine production.

The weeds found there are:

Anthemis chia
Avena fatua
Calendula arvensis
Chrysanthemum segetum
Convolvulus arvensis
Erodium cicutarium
Euphorbia sp.
Fumaria officinalis
Galium aparine
Hypericum crispum
Lamium amplexicaule
Malva sylvestris
Matricaria chamomilla
Portulaca oleracea
Sinapis arvensis
Sisymbrium irio
Sonchus oleraceus
Sorghum halepense

Total area for experimentation = 3.570 m^2
Area for experimental plot = 105 m^2

The herbicides used, the doses applied and the resulting resistant weeds are given in Table 1.

b) Vineyard No. 2:

Cultivated variety: Savvatiano
The weeds found there are:

Anthemis chia
Avena fatua
Sinapis arvensis
Euphorbia sp.

Calendula arvensis
Chenopodium sp.
Cynodon dactylon
Cyperus sp.
Daucus carota
Hypericum crispum
Lamium amplexicaule
Malva sylvestris
Plantago lanceolata
Reseda alba
Sisymbrium irio

Total area for experimentation = 3.000 m^2
Area per experimental plot = 100 m^2

The herbicides used, the doses applied as well as the resulting resistant weeds are given in Table 2.

c) Vineyard No. 3:

Cultivated variety: Muscat of Hamburg
The weeds found there are:

Anagallis arvensis
Anthemis chia
Avena fatua
Calendula arvensis
Capsella bursa-pastoris
Chenopodium sp.
Cyperus sp.
Fumaria officinalis
Lamium amplexicaule
Sisymbrium irio
Matricaria chamomilla

Total area for experimentation = 700 m^2
Area per experimental plot = 100 m^2

In this vineyard only pre-emergence granular herbicides were tested, their composition and doses applied as well as the weeds remaining after treatment are given in Table 3.

DISCUSSION

Comparing the results of the three tables we can see that the main resistant weeds in these vineyards are Convolvulus arvensis, Avena fatua, Sorghum halepense, Cyperus sp., and Cynodon dactylon.

Herbicides based on triazines (atrazine and simazine) applied in a dose of 10 kg/ha had selected out the perennial weeds Convolvulus arvensis, Cyperus sp., Cynodon dactylon and Sorghum halepense. Applied in a smaller dose (5-7, 5 kg/ha for the first year and 3 kg/ha in subsequent years) even more weeds were resistant including Avena fatua, Erodium cicutarium, Sonchus oleraceus, Matricaria chamomilla and the weed control was less satisfactory.

The above herbicides mixed with aminotriazole were effective, in post-emergence applications, against Cynodon dactylon.

Herbicides based on urea (monolinuron, linuron) had failed to eliminate the same weeds as triazine, and also Avena fatua and Daucus carota. In mixtures with aminotriazole, post-emergence application, they resulted in a good control of Cynodon dactylon and Avena fatua.

The granular herbicides used in the third vineyard succeeded in good control of all annual weeds. Of course their action varied (the mixtures of dichlobenil and triazines shower best results), and a very evident selection of Cyperus sp., resulted after

Table 1

Experimental vineyard No. 1

Herbicide		Dose kg/ha	Resistant weeds: Predominant	Resistant weeds: Secondary
Atrazine 18% + aminotriazole 36%	==	10	Convolvulus arvensis	Sorghum halepense
Linuron 6% + monolinuron 6% + aminotriazole 38%	==	10	Convolvulus arvensis	Sorghum halepense Hypericum crispum
Atrazine 50%	oo	10	Convolvulus arvensis	Sorghum halepense
		5-3	Convolvulus arvensis Erodium cicutarium	Sorghum halepense Sonchus oleraceus
Linuron 50%	oo	6	Avena fatua Convolvulus arvensis	Erodium cicutarium
Monolinuron 50%	oo	8-12	Avena fatua Convolvulus arvensis	Erodium cicutarium
Linuron 25% + monolinuron 25%	oo	10	Convolvulus arvensis Avena fatua	Erodium cicutarium
Simazine 50%	oo	10	Convolvulus arvensis Sorghum halepense	-----
		7,5-3	Convolvulus arvensis Sorghum halepense Avena fatua	Matricaria chamomilla Erodium cicutarium
Diuron 21,5% + aminotriazole 37%	==	13,5	Convolvulus arvensis	Sorghum halepense

oo : Pre-emergence
== : Post-emergence

Table 2

Experimental vineyard No. 2

Herbicide	Dose kg/ha	Resistant weeds Predominant	Secondary
Atrazine 18% == + aminotriazole 36%	10	*Cyperus* sp.	-----
Atrazine 50% oo	10	*Cyperus* sp. *Cynodon dactylon*	*Hypericum crispum*
	5	*Cyperus* sp. *Cynodon dactylon* *Avena fatua*	*Hypericum crispum*
Monolinuron 50%oo	8	*Cyperus* sp. *Cynodon dactylon*	*Avena fatua* *Daucus carota*
Linuron 25% + monolinuron 25%oo	12	*Cyperus* sp. *Cynodon dactylon*	*Avena fatua* *Daucus carota*

Table 3

Experimental vineyard No. 3

Herbicide	Dose kg/ha	Resistant weeds Predominant	Secondary
Dichlobenil 7,5%oo	120	*Cyperus* sp.	-----
Chlorthiamid 7,5%oo	120	*Cyperus* sp.	-----
Atrazine 2% + dichlobenil 3% oo	250	*Cyperus* sp.	-----
Atrazine 2% + dichlobenil 2% oo	250	*Cyperus* sp.	-----
Simazine 2% + dichlobenil 2% oo	250	*Cyperus* sp.	-----
Simazine 2% + dichlobenil 3% oo	250	*Cyperus* sp.	-----

oo: Pre-emergence
==: Post-emergence

the second year of application.

These experiments, in addition to others done before, prove that the ideal herbicide for the vineyards is not yet found so that a complete and lasting weed control, without side effects on the vines, cannot yet be obtained.

By using the same herbicide for a series of years we destroy the competition between weeds and the resistant weeds cover all the surface. Then a new problem arises in how to control that weed. This problem shows the necessity of using mixtures of herbicides or first a pre-emergence and then, depending on the surviving weeds, the appropriate post-emergence herbicide, in order to cover the deficiency that every herbicide has in its herbicidal action.

Acknowledgements

I would like to thank very much Mr. J. Kelperis, Director of the Vine Institute, for his very useful technical advice, as well as all the Chemical companies that offered me their herbicides for experimentation, without forgetting the members of their personnel with whom I discussed the different problems on weed resistance.

References

JULLIARD, B. (1958) Essais de desherbage chimique de la vigne à la station de recherches viticoles de Colmar (I.M.R.A.) Progrès Agric. et Vitic. 75, 272-279, 76, 153-158, 179-182.

LANGE, A.H. (1968) Weeds and control problems in Fruit Crops. Calif. Agriculture 22, 8-10.

LIDER, L.A. et al (1960) Field trials with herbicides in vineyards under costal valley conditions. Calif. Agriculture 14, 11-13.

STALDER, L. and BARBEN, E. (1967) Probleme bei Unkrautbekampfung in Weinbau.

ZANARDI, D. (1959) Probe di diserno dei vigneti con Aminotriazolo. Notiziario sulle malattie delle piante 42, 21.

Proc. 9th Brit. Weed Control Conf. (1968)

THE WEED SPECIES CONTROLLED BY TWENTY RESIDUAL HERBICIDES IN ARABLE LAND IN NORTHERN TANZANIA

John Foster and P. J. Terry

Tropical Pesticides Research Institute, Arusha, Tanzania

Summary Twenty residual herbicides were applied to freshly-cultivated soil at each of four sites. The layout was a split-plot design, with four doses (including zero) as sub-plots. The density and ground cover of each species were assessed as appropriate. The weed spectra controlled are considered,and the relevance of this to the potential uses of the herbicides in East African arable crops is discussed.

INTRODUCTION

The use of herbicides to control weeds in crops involves the use of phytotoxic chemicals, at doses which kill some species but not others. In agricultural situations, there is commonly a wide range of weeds, exhibiting varying degrees of phylogenic and ecological relationship with the crop. The characteristic spectra of species controlled by verious herbicides must be known for selection of appropriate treatments. In a programme during the 1968 "long rains" twenty residual herbicides were applied to a freshly-cultivated soil at four sites. No crops were sown: they were studied in complementary programmes. All the herbicides had previously shown promise at the Institute. In particular, ten had been in similar trials during the 1967-68 "short rains" (Foster and Terry,1968).

METHODS AND MATERIALS

The soil at Oljoro was a black clay-loam. That at M'ringa was a light grey volcanic ash of the type used in most of the Institute's earlier work. That at Lyamungu was a red lateritic clay loam, while at Burka it was a silty loam.

At each site, 240 sub-plots, each 3 x 2 yds. were marked out. The design was split-plot with three randomised blocks: the main plots were herbicides, and the sub-plots the four doses (including zero). The substituted ureas metobromuron, chlorbromuron, monolinuron, linuron (all 5)% W.Ps.), diuron, fluometuron and norea (all 80% W.Ps.) were applied at 0.75, 1.5 and 2.25 lb.a.i./ac. The triazines simazine, atrazine, propionitrile, ametryne, prometryne and terbutryne (all 50% W.Ps.) were applied at the same doses. UC-21693 (methyl-2,3,5,6-tetrachloro-N-methoxy-methylterephthalamate, as a 24% E.C.)and BV-207 (1-(3chloro-4-methylphenyl)-3-methyl-2-pyrrolidinone, as a 24% E.C.) were each applied at 2.4 and 6 lb a.i./ac. OCS-21799 (2-(4-chloro-o-tolyl)oxy) N-methoxyacetamide, as a 75% W.P.), CP-50144 (2-chloro-2'-6'-diethyl-N-(methoxymethyl) acetanilide, as a 48% E.C.) and C-6989 (2,4'-dinitro-4-trifluoromethyldiphenylether, as a 30% E.C.) were sprayed at 1, 2 and 3 lb a.i./ac. Propachlor was applied at 1.5, 3 and 4.5 lb a.i./ac.

All the sites had been conventionally cultivated, and were raked within a day of spraying, which was with an Oxford Precision Sprayer, operating at 30 p.s.i. and fitted with "O" fan-jet nozzles applying a volume rate of 40 gal/ac. Application was to a dry soil surface on 7/3/68 at Oljoro,to a moist surface on 13/3/68 at M'ringa, to a moist surface on 20/3/68 at Lyamungu, and to a dry surface on 8/5/68 at Burka. The "long rains" began in the second half of February. There was heavy rain through March and April. The spraying at Burka was followed by a week's dry spell after which there was further rain for two or three weeks.

Various parameters of the weed species were recorded at the following times after spraying: Oljoro-2 and 10½ weeks; M'ringa - 2½. 4 and 9 weeks; Lyamungu - 5 and 12 weeks; Burka - 7 and 13 weeks. Density was assessed subjectively on an arbitrary scale (Foster and Terry, 1968). Ground cover was assessed subjectively as a percentage.

RESULTS

The results for the more prominent species are in the Tables. They are expressed on the 0-9 scale:- No effect (0), Slight effect at high dose (1), medium and high (2), all doses (3). Moderate effect at high dose (4), medium and high (5), all doses (6), Severe effect at high dose (7), medium and high (8), all doses (9). For covers, a 15% reduction (control as 100%) was considered slight, 35% moderate, and 80% severe. For densities the classification was more subjective, as the original scale was arbitrary. The ureas had a poor (diuron, fluometuron, norea) or short-term effect against Argemone mexicana (Papaveraceae). Apart from propionitrile, and perhaps simazine, the triazines were effective - specially at Burka. The other chemicals were poor - particularly C-6989 and BV-207. Only propachlor was consistently tolerated by Portulaca oleracea (Portulaceceae). The effect of OCS-21799 was transient at Burka. Fluometuron and OCS-21799 gave the only signs of effect on Oxalis latifolia (Oxalidaceae).

Of the Compositae, Acanthospermum hispidum was resistant to metobromuron and monolinuron, but not to the other ureas. The triazines, except propionitrile and terbutryne were effective. It was resistant to OCS-21693 and C-6989. The behaviour of Galinsoga parviflora was variable. At M'ringa only OCS-21693 and BV-207 were ineffective. The early effects of chlorbromuron, prometryne, OCS-21799 and C-6989 were transient. All others were good. Everything except OCS-21693, metobromuron and chlorbromuron was effective at Burka. At Lyamungu it was not reduced by OCS-21693, diuron, fluometuron, atrazine, propionitrile, ametryne or prometryne. At this late stage at Lyamungu, only chlorbromuron was obviously affecting the cover of Gnaphalium peregrinum. Chlorbromuron, diuron and fluometuron were effective against Cynoglossum caeruleum (Boraginaceae). The other ureas - particularly metobromuron and monolinuron - were not. Propionitrile was the only poor triazine. C-6989 was very ineffective. The effects of OCS-21799, propachlor and CP-50144 were only transient. Ipomoea sp. (Convolvulaceae) was resistant to chlorbromuron, linuron, UC-22463, OCS-21693, CP-50144 and BV-207. The only ineffective triazine was ametryne: atrazine and simazine were especially good.

Of the Solanaceae, Datura stramonium was very resistant to all the ureas, except monolinuron and possibly diuron. The triazines, except propionitrile, were reasonably effective. UC-22463 and OCS-21693 had no effect: those of OCS-21799, CP-50144 and C-6989 were transient. Propachlor and BV-207 affected its cover. Nicandra physaloides was more sensitive than the previous species to ureas, although the relative efficiencies of individual ureas varied among sites. The triazines were good, as were C.6989, CP-50144 (except at Lyamungu) and (to some extent) UC-22463. The effect of OCS-21799 and propachlor were transient. BV-207 had little effect.

Justicia exigua (Acanthaceae) was resistant to fluometuron, norea, simazine, ametryne, prometryne, propachlor, CP-50144 and the OCS compounds. The labiate Leucas glabrata was resistant to chlorbromuron and norea. The other ureas and the triazines controlled it well; so did UC-22463, OCS-21693, CP-50144 and BV-207. OCS-21799 and propachlor had no effect. All the ureas except norea, controlled Chenopodium opulifolium (Chenopodiaceae); as did the triazines - especially atrazine. BV-207 was excellent: propachlor, CP-50144 and C-6989 were ineffective. At Lyamungu only atrazine was good against Oxygonum sinuation (Polygonaceae). The response of this species varied more at Oljoro. Fluometuron, and perhaps metobromuron and chlorbromuron were the only effective ureas. Ametryne and terbutryne were poor; the other triazines good. C-6989 was excellent, whilst propachlor, CP-50144 and BV-207 had no effect.

Table 1.

Comparative responses of various weed species to the twenty herbicides at M'ringa.

Effects on density (D) and cover (C) at three recording occasions (1, 2, 3), based on an arbitrary scale (0 = no effect; 9 = severe effect by all three doses used). See text for full details. All figures based on mean densities and cover for three replicates.

A.m = Argemone mexicana; Ch = Chenopodium oppulifolium; C.c = Cynoglossum caeruleum
D.s = Datura stramonium; Di = Digitaria velutina; G.p = Galinsoga parviflora;
N.p = Nicandra physaloides; TA = Total (All species).

Chemical	A.m		Ch	C.c				D.s				Di	G.p				N.p		T A		
	D1	D2	C3	D1	D2	C2	C3	D1	D2	C2	C3	C3	D1	D2	C2	C3	C2	C3	D2	C2	C3
Metobromuron	6	1	8	1	1	4	0	6	0	4	0	0	4	5	8	5	8	5	4	6	2
Chlorbromuron	4	2	7	6	4	7	4	5	0	0	0	0	7	1	4	4	7	6	4	4	3
Monolinuron	3	6	6	4	0	4	0	6	6	6	3	0	6	7	8	6	8	4	5	6	3
Linuron	6	3	8	6	6	7	4	5	0	5	0	2	6	5	7	7	7	1	6	6	1
Diuron	6	0	7	5	2	5	2	3	2	6	4	1	7	5	9	9	7	1	4	6	4
Fluometuron	6	4	5	6	5	8	5	3	0	4	1	6	4	4	9	6	7	0	6	6	1
Norea	4	0	2	5	2	5	2	1	1	1	0	2	4	4	8	6	6	5	3	5	3
Simazine	6	5	6	6	5	7	4	6	6	9	6	4	-	8	9	7	9	8	6	5	5
Atrazine	7	-	9	7	8	9	8	6	-	9	6	0	-	9	-	9	-	7	5	6	6
Propionitrile	6	4	6	4	4	5	0	6	1	6	0	4	6	6	9	7	8	5	6	6	4
Ametryne	4	4	6	6	6	9	6	5	5	8	5	3	6	7	8	6	8	4	6	7	5
Prometryne	6	3	5	6	6	7	5	3	4	7	4	6	6	6	9	3	-	6	5	6	4
Terbutryne	5	6	5	5	6	7	7	6	6	9	4	6	7	6	8	7	9	5	7	8	5
UC-22463	3	0	6	6	6	9	4	-	0	0	0	0	6	3	5	5	7	7	3	6	3
OCS-21693	3	1	6	7	4	9	7	0	0	0	0	6	2	0	0	0	0	0	1	4	3
OCS-21799	4	4	5	5	4	7	0	6	2	1	0	0	7	4	7	1	9	6	5	5	0
Propachlor	4	2	0	3	3	5	0	0	1	5	0	5	5	4	4	5	6	0	5	5	2
CP-50144	3	0	0	4	4	4	0	4	4	7	0	7	3	5	8	5	9	5	4	6	2
C-6989	5	1	0	0	0	0	0	5	0	5	0	4	6	6	9	4	9	8	4	6	3
BV-207	6	0	8	4	4	7	4	3	0	5	5	1	3	0	5	3	0	0	2	4	3

Chlorbromuron, monolinuron, linuron, norea, propachlor and the OCS-compounds were ineffective against *Commelina benghalensis* (Commelinaceae). Atrazine and terbutryne were very effective: the other triazines were poor.

Several grasses were recorded. Fluometuron was the only urea to control *Digitaria velutina* well. Among the triazines, atrazine was well tolerated. UC-22463, OCS-21799 and BV-207 were ineffective. At Burka only atrazine and OCS-21799 were very poor against *Setaria verticillata*: this was amply supported for atrazine at Oljoro. *Setaria homonyma* was resistant to monolinuron, linuron, norea, simazine, atrazine, propoinitrile, OCS-21799, propachlor, CP-50144 and BV-207. The other grasses only occurred at Oljoro. *Brachiaria deflexa* was resistant to metobromuron, norea, simazine, atrazine, UC-22463 and BV-207.

Table 2

Comparative responses of various weed species to the twenty herbicides at Burka.

Effects on density (D) and cover (C) at two recording occasions (1,2), based on an arbitrary scale (0 = no effect; 9 = severe effect by all three doses used). See text for full details. All figures based on mean densities and covers for three replicates.

A.m = Argemone mexicana; G.p = Galinsoga parviflora; N.p = Nicandra physaloides; P.o = Portulaca oleracea; S.v = Setaria verticillata; TA = Total (All species).

Chemical	A.m			G.p		N.p			P.o			S.v			T A		
	D1	C1	C2	C1	C2	D1	C1	C2	D1	C1	C2	D1	C1	C2	D1	C1	C2
Metobromuron	2	5	0	4	4	4	5	6	5	7	4	4	6	5	4	5	4
Chlorbromuron	4	7	0	5	2	2	5	1	4	7	6	7	6	6	5	6	3
Monolinuron	4	7	1	9	7	4	7	5	7	7	7	7	7	4	5	7	4
Linuron	7	8	1	8	6	4	7	4	8	8	7	8	8	7	7	8	4
Diuron	0	1	0	8	7	1	0	4	8	9	8	7	7	6	4	5	4
Fluometuron	0	0	0	7	6	4	4	5	7	7	7	6	6	6	2	5	2
Norea	0	1	0	6	5	4	1	0	6	6	6	4	4	6	2	2	0
Simazine	7	8	4	9	9	6	9	6	8	9	6	6	9	4	7	8	6
Atrazine	8	8	7	9	9	8	8	8	8	9	8	4	5	0	7	8	7
Propionitrile	4	5	0	7	7	6	7	7	8	7	6	7	6	7	5	6	4
Ametryne	8	8	7	8	7	8	8	7	8	8	6	8	8	5	8	8	7
Prometryne	7	8	7	8	8	7	7	7	8	7	7	8	8	9	7	8	7
Terbutryne	8	8	8	8	8	8	8	8	8	9	7	8	7	5	8	8	8
UC-22463	5	7	0	7	6	2	7	5	5	7	6	8	8	6	5	7	5
OCS-21693	1	4	0	0	4	5	5	5	6	6	6	7	5	5	1	4	1
OCS-21799	1	0	0	-	7	4	5	6	5	7	1	4	3	0	1	3	2
Propachlor	4	7	0	8	9	6	9	7	4	7	0	9	9	6	5	7	2
CP-50144	4	4	0	6	9	9	9	9	7	8	6	9	6	6	6	7	4
C-6989	0	0	0	7	9	8	8	7	8	8	8	8	5	5	3	4	0
BV-207	0	0	0	7	9	0	3	0	7	8	5	8	7	7	0	4	2

Brachiaria eruciformis was more easily controlled, being obviously resistant only to simazine and BV-207. Dactyloctenium aegyptium was resistant to linuron, diuron, ametryne and OCS-21799. Eragrostis cilianensis, and probably Eragrostis tenuifolia seemed rather sensitive to everything.

Three families were very localised. An unidentified cucurbit at Oljoro seemed sensistive to the ureas and most of the triazines. It had some resistance to OCS-21693, propachlor and CP-50144. Boerhaavia diffusa (Nyctaginaceae) seemed resistant to OCS-21799, propachlor, C-6989 and BV-207 at Ojoro. There were two members of the Amaranthaceae. Norea, propionitrile and BV-207 seemed weak against Amaranthus hybridus at M'ringa and Oljoro. At Oljoro Alternanthera pungens responded with increased cover to the lessened competition, with all herbicides except simazine, atrazine and BV-207.

Table 3.

Comparative responses of various weed species to the twenty herbicides at Oljoro and Lyamungu

Effects on density (D) and cover (C) at two recording times (1, 2), based on an arbitrary scale (0 = no effect; 9 = severe effect by all three doses used). See text for full details. Figures based on mean densities and covers for three replicates.

A.h = Acanthospermum hispidum; B.d = Brachiaria deflexa; B.e = Brachiaria eruciformis
C.b = Commelina beghalensis; D.a = Dactyloctenium aegyptium;
I.s = Ipomoea species; L.g = Leucas glabrata; N.p = Nicandra physaloides
O.s = Oxygonum sinuatum; P.o = Portulaca oleracea; AG = all grasses. AO = all others.
G.p-Galinsoga parviflora; Je-Justicia exigua; O.l-Oxalis latifolia
S.h-Setaria homonyma; TA - Total (All species).

Chemical	OLJORO Ah C	Bd C	Be C	Cb C	Da C	Is C	Lg C	Np C	Os C	Po C	AG C	AO C	LYAMUNGU Gp C2	Je C2	Np D1	Np C2	Ol C2	Sh C2		TA
Metobromuron	0	0	6	4	6	4	7	4	4	8	6	2	5	8	6	0	0	6	5	0
Chlorbromuron	6	7	8	0	7	0	0	5	4	9	6	4	8	9	6	2	0	7	6	0
Monolinuron	0	7	7	0	5	7	5	8	0	6	3	5	7	8	7	4	0	0	6	4
Linuron	7	-	9	0	0	0	9	6	1	9	7	3	6	-	7	6	0	0	6	3
Diuron	7	6	-	7	0	4	8	8	0	9	6	5	0	5	7	7	0	8	7	5
Fluometuron	7	7	8	7	9	7	8	8	7	9	6	7	0	0	6	4	7	4	4	4
Norea	5	0	9	0	4	5	0	4	0	6	4	2	7	0	5	0	2	0	5	0
Simazine	7	0	0	0	6	8	9	8	7	9	6	9	7	0	8	6	0	0	6	5
Atrazine	9	0	6	8	4	9	9	9	7	9	4	9	0	7	9	7	0	0	6	6
Propionitrile	0	7	7	0	5	6	7	9	8	6	7	6	0	7	7	5	1	1	6	2
Ametryne	8	6	9	0	1	0	7	9	0	7	6	5	0	0	8	5	0	5	7	4
Prometryne	-	6	-	0	7	4	7	9	7	7	6	4	0	0	7	5	4	3	6	4
Terbutryne	0	7	7	8	6	4	7	8	1	9	5	6	4	6	8	6	0	5	7	6
UC-22463	7	0	-	4	7	0	7	8	5	6	7	4	8	8	7	3	0	6	5	2
OCS-21693	0	9	-	0	8	0	7	5	4	8	6	3	0	0	4	1	2	6	4	0
OCS-21799	4	7	7	1	0	7	0	8	4	6	3	4	6	0	6	0	6	0	6	0
Propachlor	7	9	7	0	7	4	0	0	0	0	7	2	7	0	5	0	0	0	5	0
CP-50144	7	8	-	8	3	0	7	9	0	8	7	2	6	0	6	2	3	0	6	2
C-6989	0	8	7	6	4	7	3	9	9	8	7	6	4	7	7	5	0	4	6	2
BV-207	9	0	0	3	6	0	8	1	0	9	0	1	6	6	4	0	0	0	5	0

DISCUSSION

Ecological differences complicate the interpretation of such work. Some species (e.g. A.mexicana, A.hispidum germinate later in the "rains" than others (e.g.N.physaloides). Some species (e.g.A.mexicana, D.stramonium) emerge from deeper in the soil than others (e.g. N.physaloides, G.parviflora). Therefore, differences between the responses of different species to herbicides will be affected by the relative persistences and mobilities of the chemicals in the soil, as well as by inherent physiological selectivities.

There was variation between the spectra of weeds controlled by the ureas, but they were potentially weak against solanaceous species.

Among the triazines, atrazine and simazine were outstanding aginst broad-leaved species, but (especially atrazine) poor against some annual grasses. This would sometimes restrict their use alone in crops like maize and sugar cane. The other triazines had varying weaknesses, but were in general better against annual grasses. Terbutryne gave excellent control of A.mexicana, which is a problem in beans in some areas.

CP-50144 and C-6989 were the most interesting of the other products. As noted before (Foster & Terry, 1968), they were potentially outstanding agsint Solanaceae and Gramineae. This spectrum and the broad range of crops, suggests wide potential uses. Both have weak points and would often be more useful in mixtures than alone. UC-22463 is interesting, but the high doses raise economic doubts. OCS-21693 and BV-207 have too many weaknesses. Propachlor has too many to be used alone, but might be considered in mixtures for maize and sorghum. OCS-21799 had a short residual duration, and was poor against grasses.

The relative responses of a given species to herbicides differed with the application: rainfall was probably important here. C-6989 gave better control of N.physaloides than did the more soluble CP-50144, early in the "rains" at M'ringa and Lyamungu. Later at Burka, the reverse was true. The relative responses of this species to chlorbromuron and the more soluble metobromuron were similar. Similarly, G.parviflora developed on the plots of our triazines (including the three most soluble,and the fifth) at Lyamungu. However, too facile comparisons with solubility should be aboided, as absorption also affects mobility. A more detailed study of such factors is being prepared by the authors, based on these and other results.

Acknowledgments

The authors are grateful to the C.R.S. Lyamungu, Burka Cofee Estates, and Messrs. Mahon and Aitkenhead for land. Ciba,du Pont, Fisons, Geigy, Hercules, Hoechst, Monsanto, Murphy, Rohm & Haas, Shell, Twiga, Union Carbide and Velsicol gave chemicals and information. Mr. C. J. Mosha and others helped enormously.

References

Foster, J. and Terry, P.J. (1968). Field screening trials against various weed species in six arable crops during the short rains of 1967-68. I. The effects on the weed species. T.P.R.I.Misc. Report 643.

Proc. 9th Brit. Weed Control Conf. 1968)

LONG-TERM EFFECTS OF VARIOUS SYSTEMS OF WEED CONTROL ON THE WEED FLORA UNDER MATURE ARABICA COFFEE IN NORTHERN TANZANIA-AN INTERIM REPORT

John Foster, P.J. Terry and C.J. Mosha,
Tropical Pesticides Research Institute, Arusha, Tanzania.

Summary

Two examples of each of three systems of herbicide usage and a cultivation system was compared in a long-term trial beginning with the 1967 "long rains." Diuron and atraton were applied to freshly-cultivated soil; paraquat and aminotriazole, and mixtures of diuron + paraquat and atraton + aminotriazole to growing weeds. Each chemical or mixture was at two doses. All systems were repeated at two frequencies, determined by the growth of the weeds. The composition of the weed flora was recorded before each treatment, and progress is reported for the first fifteen months. Several important species are considered, and ecological and agricultural implications are discussed. A system based on paraquat, but with flexibility to deal with problem species is most appropriate.

INTRODUCTION

Early work in East Africa demonstrated the potentialities of three basic systems of general herbicide usage in plantations of mature coffee. These involve applications of: (i) primarily soil-acting herbicides (residuals) to freshly-cultivated soil or to young seedlings (Green and Kalogeris, 1964). (ii) primarily foliar-absorbed herbicides (contacts) to seedlings or older weeds (Mitchell, 1967). (iii) mixtures of the above two groups (Green and Kalogeris, 1964).

In trials comparing several contacts (Foster and Green, 1967), paraquat was the best against annual weeds: the stage of growth at spraying was very important. Foster et al. (1968) compared the three systems, and various herbicides within each class; confirming the outstanding efficiency of diuron + paraquat and, to some extent, atraton + amitrole. However these results were after single applications. It was obviously important to investigate continued use of the particular systems, especially as each herbicide had weak spots in the species spectrum controlled.

Accordingly, a long-term trial, comparing two examples of each system with each other and with hoeing, was begun at the Coffee Research Station, Lyamungu.

MATERIALS AND METHODS

The coffee on a 10 x 6 ft. hedge spacing and adjacent to that used previously by Green, Foster and their co-workers (loc. cit.), grew in a red lateritic clay loam. Previous cultivation had been by rotovation. Each of the hundred and forty plots was 10 yd. long and two complete inter-rows wide. The area was divided into five randomised blocks.

The whole trial was rotovated on the 25/3/67. Treatments were subsequently applied when necessary. Control plots were hand-hoed with jembes. Two examples of each system were used. The residuals diuron (80% W.P.) and atraton (50% W.P.) were applied to freshly-jembed soil; the contacts paraquat (20% A.C.) and aminotriazole (50% S.P.) were applied to growing weeds, as were the mixtures diuron + paraquat and atraton + aminotriazole. The two average doses (see Tables) were each applied at two frequencies (see below). An Oxford Precision Sprayer was used for the applications at a volume rate of 30 gal/ac. Slightly more was sprayed onto

Table 1.

Mean number (total of five plots) of treatments per quarter for each treatment. Also the mean percentage ground cover of Galinsoga parviflora for the treatments (five replicates on herbicide plots, ten on controls) within each quarter.

Treatment	Dose	Frequency	Number of treatments: Quarter 1	2	3	4	5	Cover of Galinsoga parviflora: Quarter 1	2	3	4	5
Diuron + paraquat	1+0.25	Frequent	10	6	7	7	5	2	+	+	0	0
		Infrequent	8	6	8	6	3	2	1	0	0	0
	2+0.5	Frequent	7	7	6	7	3	1	2	0	0	0
		Infrequent	6	5	5	6	2	5	10	8	0	0
Diuron	1	Frequent	8	10	10	9	4	2	2	0	0	0
		Infrequent	8	7	10	9	4	1	1	0	0	0
	2	Frequent	8	8	7	10	2	1	1	0	0	0
		Infrequent	8	6	5	6	2	2	1	0	0	0
Paraquat	0.25	Frequent	11	12	10	10	10	2	2	2	1	1
		Infrequent	10	8	11	10	7	5	4	6	2	0
	0.5	Frequent	10	8	9	9	9	1	5	4	2	1
		Infrequent	8	7	7	7	7	6	12	5	1	2
Atraton + amino-triazole	1+1	Frequent	12	10	4	8	9	+	0	0	0	0
		Infrequent	10	5	6	5	5	3	1	0	0	1
	2+2	Frequent	10	7	5	3	4	+	0	0	0	0
		Infrequent	5	7	5	4	4	3	+	0	0	0
Atraton	1	Frequent	10	13	9	8	10	+	+	0	0	0
		Infrequent	10	10	7	9	10	2	1	0	0	0
	2	Frequent	9	9	8	6	10	1	3	0	0	0
		Infrequent	10	7	5	5	7	2	0	0	0	0
Aminotriazole	1	Frequent	15	21	9	10		1	2	0	1	
		Infrequent	15	13	13	9		3	2	2	1	
	2	Frequent	15	15	9	9		1	+	+	0	
		Infrequent	10	8	7	6		3	+	+	0	
Jembed control		Frequent	15	20	18	13	16	20	10	14	6	14
		Infrequent	15	16	12	8	12	8	15	18	0	10

the inter-rows than the tree-rows, fitting in with problems of residual toxicity and the fact of easier weed control under shade.

The weeds were inspected approximately fortnightly. It was planned to treat weeds when 1 in. (frequent) or 3-4 (infrequent) high; but on the first occasion, it was decided that decisions based mainly on cover (frequent, 30%; infrequent 65%) were more feasible. Before each treatment, various parameters were recorded for each weed species: the only one relevant here is percentage ground cover. Separate recordings were made for the inter-rows and tree-row, but they have been averaged for this paper, which considers only a few representative species. Aminotriazole was so slow and ineffective overall that the schedule was ignored in the second quarter, and the plots abandoned after the fourth.

Table 2.

Mean percentage ground covers of Oxygonum sinuatum and of Commelina benghalensis for the treatments (five replicates on herbicide plots, ten on controls) within each quarter.

Treatment	Dose	Frequency	Cover of O.sinuatum Quarter 1	2	3	4	5	Cover of C.benghalensis Quarter 1	2	3	4	5
Diuron + paraquat	1+0.25	Frequent	+	0	0	+	0	1	2	5	12	14
		Infrequent	+	+	0	0	0	+	2	2	12	9
	2+0.5	Frequent	+	3	0	0	0	+	3	5	7	7
		Infrequent	+	+	+	0	0	+	3	4	20	12
Diuron	1	Frequent	6	1	+	+	0	1	14	27	25	23
		Infrequent	7	2	+	+	0	3	12	39	28	42
	2	Frequent	1	6	1	0	0	+	1	35	40	39
		Infrequent	1	6	1	0	0	+	1	35	40	39
Paraquat	0.25	Frequent	0	0	0	0	0	+	+	1	0	2
		Infrequent	+	0	0	0	0	+	1	+	2	3
	0.5	Frequent	1	0	0	0	0	+	+	1	4	3
		Infrequent	+	0	0	0	0	1	+	1	4	9
Atraton + amino-triazole	1+1	Frequent	8	32	5	2	0	3	4	15	21	12
		Infrequent	3	8	+	0	0	1	5	25	32	24
	2+2	Frequent	4	15	2	3	2	+	3	7	12	14
		Infrequent	2	7	0	0	0	+	6	22	17	19
Atraton	1	Frequent	2	3	1	0	0	1	12	16	19	14
		Infrequent	1	3	+	0	2	2	23	35	21	11
	2	Frequent	5	1	+	3	2	+	12	15	15	10
		Infrequent	3	8	0	0	2	+	10	21	18	21
Aminotriazole	1	Frequent	10	24	+	0		8	2	2	6	
		Infrequent	7	20	5	0		1	+	2	7	
	2	Frequent	9	20	2	3		1	1	+	8	
		Infrequent	5	29	1	1		+	0	1	4	
Jembed control		Frequent	1	+	+	0	+	4	12	18	17	24
		Infrequent	1	+	+	+	0	3	15	35	34	31

RESULTS

In the tables, the results are averaged for each of the five quarters, beginning 25/3/67, 25/6/67, 25/9/67, 25/12/67 and 25/3/68 respectively. The 1967 "long rains" fell during the first quarter, the 1967 "short rains" during the middle of the third, and the 1968 "long rains" began during the fourth and continued through most of the fifth.

The mixtures caused most progressive reduction in the number of applications per quarter (Table 1). Diuron alone was good, but atraton much less so. There was no progressive change with paraquat. As explained above, the figures for aminotriazole were not comparable: suffice to say that it was inefficient.

Table 3.

Mean percentage ground covers of Oxalis species and of Cyperus rotundus for the treatments (five replicates on herbicide plots, ten on controls) within each quarter.

Treatment	Dose	Frequency	Cover of Oxalis species Quarter 1	2	3	4	5	Cover of C.rotundus Quarter 1	2	3	4	5
Diuron + paraquat	1+0.25	Frequent	0	1	0	0	0	13	18	34	25	21
		Infrequent	+	+	0	0	0	5	20	39	23	30
	2+0.5	Frequent	0	+	0	0	0	11	12	19	25	14
		Infrequent	0	1	0	0	0	8	10	21	18	20
Diuron	1	Frequent	1	+	0	0	0	14	4	9	16	18
		Infrequent	+	+	+	0	0	10	4	6	8	6
	2	Frequent	+	+	0	0	0	12	10	12	17	15
		Infrequent	0	0	0	0	0	10	4	13	14	15
Paraquat	0.25	Frequent	1	5	+	0	0	10	8	13	22	10
		Infrequent	1	3	+	0	0	7	6	7	19	10
	0.5	Frequent	2	1	1	0	+	3	3	5	19	18
		Infrequent	1	2	3	0	+	4	6	4	16	11
Atraton + amino-	1+1	Frequent	3	2	14	0	2	n8	4	17	15	14
		Infrequent	1	10	18	0	4	12	7	13	16	11
	2+2	Frequent	+	9	10	4	0	10	5	13	13	15
		Infrequent	+	7	10	2	0	10	11	16	12	9
Atraton	1	Frequent	+	14	12	0	2	11	7	7	16	16
		Infrequent	1	13	5	0	5	3	8	10	9	15
	2	Frequent	6	15	13	0	6	17	7	12	14	10
		Infrequent	8	31	37	0	4	14	2	8	12	14
Aminotriazole	1	Frequent	6	5	2	4		11	9	10	11	
		Infrequent	2	9	5	6		12	3	9	12	
	2	Frequent	2	4	+	0		5	2	8	10	
		Infrequent	+	2	3	0		3	4	9	17	
Jembed control		Frequent	+	1	+	0	+	5	2	2	4	2
		Infrequent	1	1	1	0	+	2	1	2	3	4

Galinsoga parviflora was rare in the presence of aminotriazole or the residuals (Table 1). The initially appreciable cover on the paraquat plots progressively decreased. On the controls, the cover was lowest during the hot dry season and the beginning of the "long rains".

Oxygonum sinuatum was very sensitive to paraquat (Table 2), and more susceptible to diuron than to atraton. Although, initially very resistant to aminotriazole, its cover declined abruptly after the second quarter.

With jembeing, the cover of Commelina benghalensis progressively increased (Table 2), with residuals (especially diuron) or without: more frequent applications of atraton lessened this trend. It also occurred on the atraton + aminotriazole plots, particularly after fewer applications, but hardly on those

Table 4.

Mean percentage ground covers of "couch grass", of Digitaria velutina and of Setaria homonyma for the treatments (five replicates on herbicide plots, ten on controls) within each quarter.

Treatment	Dose	Frequency	Cover of "couch" Quarters 3	4	5	Cover of D.velutina Quarters 3	4	5	Cover of S.homonyma Quarters 3	4	5
Diuron + paraquat	1+0.25	Frequent	4	9	15	4	10	1	0	0	0
		Infrequent	12	12	14	4	2	0	0	0	0
	2+0.5	Frequent	4	10	7	2	3	0	0	0	0
		Infrequent	2	17	25	16	6	0	0	0	0
Diuron	1	Frequent	4	9	5	8	10	2	0	0	0
		Infrequent	6	15	17	10	5	0	0	0	0
	2	Frequent	2	9	3	8	5	12	0	0	0
		Infrequent	4	4	12	14	5	5	0	0	0
Paraquat	0.25	Frequent	4	17	9	14	12	3	0	0	3
		Infrequent	3	18	23	34	17	8	0	0	0
	0.5	Frequent	2	4	4	11	12	1	+	0	1
		Infrequent	4	20	12	28	11	3	0	0	2
Atraton + amino-triazole	1+1	Frequent	0	7	6	+	4	4	0	1	5
		Infrequent	1	2	3	3	9	4	0	0	1
	2+2	Frequent	1	7	3	6	3	0	1	0	0
		Infrequent	+	7	4	4	11	5	1	5	2
Atraton	1	Frequent	1	8	10	4	9	4	0	2	0
		Infrequent	7	26	33	11	4	2	0	0	7
	2	Frequent	9	22	16	3	4	2	0	0	1
		Infrequent	+	23	22	10	6	0	0	5	8
Aminotriazole	1	Frequent	+	10		7	18		0	4	
		Infrequent	+	12		13	18		0	4	
	2	Frequent	3	8		4	11		6	16	
		Infrequent	1	11		5	13		0	11	
Jembed control		Frequent	1	6	7	11	14	6	2	+	1
		Infrequent	2	10	8	14	15	4	1	2	3

with aminotriazole alone. There was no increase with paraquat, and only an intermediate one with diuron + paraquat, unless applications were very infrequent.

Oxalis species were very prominent during the cool dry season and "short rains" and notably sparse during the ensuing hot dry season and the beginning of the "long rains" (Table 3). It was very sensitive to diuron, but less so to aminotriazole alone. With atraton, the Oxalis was almost all O.corniculata, and mostly O.latifolia.

All herbicides resulted in a greater cover of Cyperus rotundus than on the jembed controls (Table 3). This was greatest and earliest with diuron + paraquat.

The "couch" variously consisted of <u>Digitaria scalarum</u> and/or <u>Cynodon dactylon</u>. On the controls, there was less during the "short rains" than subsequently (Table 4). Aminotriazole, alone or with atraton, was at least as effective as jembeing: so were frequent applications of diuron or paraquat and the frequent high dose of diuron + paraquat, but not the other treatments with these chemicals. "Couch" was much more tolerant of atraton than of diuron.

There was more <u>Digitaria velutina</u> during the "short rains" and hot dry season than in the "long rains" (Table 4). Neither contact was very effective against it, infrequent applications of paraquat being particularly weak. The residuals and mixtures had some effect.

<u>Setaria homonyma</u> was very sensitive to paraquat and especially diuron. It was very resistant to aminotriazole and moderately so to atraton.

DISCUSSION

Two ecological principles complicate the interpretation of herbicide experiments. Firstly, the response of any individual species to a treatment depends partly on the associated species. <u>S.homonyma</u> and <u>Oxalis</u> were more prominent at high doses of aminotriazole and atraton respectively than at low ones. Observations that <u>O.sinuatum</u> is normally only important as a weed when herbicides are used was confirmed. Secondly, the seasonality of such species as <u>G.parviflora</u> and <u>D.velutina</u> complicates characterization of the species resistant to residual herbicides after single applications. Also, it is uncertain whether the decline of <u>O.sinuatum</u> after repeated aminotriazole was herbicidal or seasonal.

The resistances of <u>O.sinuatum</u> to aminotriazole and <u>Oxalis</u> to atraton (Foster et al., 1968) were confirmed, but there was less coincidence between their spectra than had been feared. Repeated applications of paraquat kept <u>C.benghalensis</u> in check. <u>C. rotundus</u> increased rapidly on all herbicide plots, as did "couch" on most. These were left dominant with the removal of associated species: moreover, they were probably selected for by taking cover as the criterion for retreatment. These perennials are observed to be especially competitive against coffee. Jembeing was not as effective against <u>C.benghalensis</u> as the earlier rotavation had been.

A system based on paraquat is the best way of dealing with annual weeds, for establishment of seedlings soon declines without cultivation. The resistance of perennial grasses and sedges necessitates a flexible system. The use of dalapon to kill "couch" is well established (Austin, 1967), but a more rapid technique for controlling <u>C.rotundus</u> is required. More frequent spot-spraying with paraquat would help here (Mitchell, 1967). The importance of the stage of growth for <u>D.velutina</u> (Foster and Green, 1967) and "couch" was confirmed. The better performance of both contacts rather than the respective mixtures against <u>C.benghalensis</u> was probably a frequency effect. The great effectiveness of the mixtures supports the case for flexibility. Residuals can be included at the start of the "rains" at low doses (which are relatively more efficient than higher ones), but the serious consequences to a perennial crop of accidental overdoses should be borne in mind.

<u>Acknowledgements</u>

The authors wish to thank Messrs. L. Fernie and M. Blandy of the C.R.S. for their help and interest. Several employees of T.P.R.I. worked hard, especially Messrs. S.L. Mollel and N. Ndelanga. Twiga Chemical Industries Ltd. and Fisons (E.A.) Ltd. provided the herbicides and much information.

References

AUSTIN, J.S.F. (1967) The control of "couch" and other grass weeds in coffee. Tanganyika Coffee News, 2, 47-50.

FOSTER, J. and GREEN, D.H. (1967) Variable-dosage-plot trials with various foliage-applied herbicides on annual weeds under Arabica coffee in 1965-1966. T.P.R.I. Misc. Report 595.

FOSTER, J., TERRY, P.J., GREEN, D.H., MOSHA, C.J. and MITCHELL, H.W. (1968) Variable-dosage-plot trials involving residual herbicides, alone and in mixtures, on weeds under mature Arabica coffee in 1965-66. T.P.R.I. Misc. Report 607.

GREEN, D.H. and KALOGERIS, B. (1964) Soil-acting herbicides in coffee. Proc. 3rd E.A. Herb. Conf., 171-182.

GREEN, D.H. and KALOGERIA, B. (1964) Further evaluation of mixtures of soil-acting and contact herbicides for the control of weeds in coffee in Tanzania. Proc. 3rd E.A. Herb. Conf. 343-351.

MITCHELL, H.W. (1967) The possibility of weed control with minimum cultivation. Kenya Coffee, 32, 232-235.

Proc. 9th Brit. Weed Control Conf. (1968)

THE HERBICIDAL AND STIMULATORY VALUE OF A COMBINATION OF 2,4-D AND UREA IN WHEAT CULTIVATION[1]

Agatsya Mishra and V.S. Mani

Division of Agronomy, Indian Agricultural Research Institute, New Delhi

Summary Field experiments were conducted for studying the individual and combined spray application of 2,4-D and urea on weed control and grain production in wheat (variety: N.P. 718) grown under different levels of soil-applied nitrogen. The combination treatment of a low dosage level of 2,4-D (0.42 kg a.e./ha) and 3.0 percent urea sprayed 4 weeks after crop sowing, affected the growth of annual weeds as evidenced by reduction in population, dry matter accumulation and nutrient depletion. The combination treatment was beneficial to the crop as it stimulated dry matter production, nutrient removal and final grain and straw yield. This treatment increased the grain and straw yield by 6.34 and 7.46 q/ha* respectively as compared to hand-weeding. Neither the efficiency in weed control nor the stimulatory effect on crop growth was improved by combining urea with a higher dosage level of 2,4-D (0.84 kg a.e./ha).

INTRODUCTION

One of the serious problems facing wheat growers is the presence of weeds on account of which the crop yield is reduced. Mani et al. (1968) reported that weed growth in wheat fields may reduce the crop yield by more than 20 percent.

If weeds are removed earlier, greater would be the benefit to the crop from elimination of competition by weeds at an early stage. Young weed seedlings can be killed by low doses of 2,4-D or MCPA. Earlier from this laboratory, Mukhopadhyay (1961) obtained selective weed control in wheat from 2,4-D at 0.42 kg a.e./ha applied 4 weeks after sowing. This low dosage level was extremely lethal to fathen. Weeds other than fathen, did not succumb readily to low doses of 2,4-D. Experiments were therefore undertaken for studying the effect of combining urea with 2,4-D on weeds in a wheat crop grown under different levels of nitrogen application to soil, the objectives being: (i) to compare the herbicidal efficiency of 2,4-D alone and its combination with urea, (ii) to study the selectivity of the 2,4-D urea combination on wheat growth, development, yield and chemical composition of the grain, (iii) to explore the possibility of fertiliser and herbicide application simultaneously on wheat crop.

METHOD AND MATERIALS

The experiment was carried out in a split-plot design with four replications comprising weed control methods as main-plot and nitrogen levels as sub-plot treatments.

---

[1] Based on the Ph.D. work of the senior author.
q = quintal; 1 quintal = 100 kg.

(a) Main-plot treatments (12) — Time of application

		Time of application
T1	: Urea alone 1.5%	4 weeks after sowing
T2	: Urea alone 1.5%	6 weeks after sowing
T3	: Urea alone 3.0%	4 weeks after sowing
T4	: Urea alone 3.0%	6 weeks after sowing
T5	: 2,4-D 0.42 kg a.e./ha	4 weeks after sowing
T6	: 2,4-D 0.84 kg a.e./ha	6 weeks after sowing
T7	: 2,4-D 0.42 kg a.e./ha plus urea 1.5%	4 weeks after sowing
T8	: 2,4-D 0.84 kg a.e./ha plus urea 1.5%	6 weeks after sowing
T9	: 2,4-D 0.42 kg a.e./ha plus urea 3.0%	4 weeks after sowing
T10	: 2,4-D 0.84 kg a.e./ha plus urea 3.0%	6 weeks after sowing
T11	: Hand-weeding	6 weeks after sowing
T12	: Control (no weeding, no spraying)	

(b) Sub-plot treatments (3)

Different levels of nitrogen applied to the soil as ammonium sulphate

N0 - no nitrogen
N1 - 20 kg N per hectare
N2 - 40 kg N per hectare

The experimental plot was laid out in a split plot design with 12 main plot treatments and three nitrogen levels as sub-plot treatments. The treatments were replicated four times. The wheat variety used in this investigation was N.P. 718.

Observations on crop related to population, maximum shoot number, dry matter production, final grain yield and its components and straw yield. The chemical composition (percentage of N, P, K, Ca and Mg) was determined of plant samples and grain at maturity. Observations on weeds included periodic population counts, dry matter accumulation and chemical composition.

RESULTS

The data concerning the main-plot treatments are presented in Tables 1 and 2.

Table 1 (Expt. 1963-64)

Plant and weed observations

Treatments Main plot	GY	SY	DMC	NRC	PW	DWW	NDW
D4	36.95	91.45	55.57	84.02	0.724	0.53	1.47
D6	36.47	90.44	55.08	85.20	0.758	0.65	1.58
DU4	41.41	94.66	56.45	88.03	0.788	0.43	1.22
DU6	34.45	91.21	55.26	80.87	0.758	0.58	1.41
HW	34.69	87.47	53.75	82.55	1.027	0.47	1.31
O	29.27	77.59	45.86	65.52	2.048	9.50	23.55
'F' test	Sig.**	Sig.**	Sig.**	-	Sig.**	Sig.**	-
S.Em.±	1.05	1.67	0.80	-	0.060	0.69	-
C.D. 5%	2.92	4.63	2.49	-	0.167	1.89	-
C.D. 1%	3.84	6.08	3.51	-	0.220	2.67	-

For abbreviations, see below Table 2

Table 2 (Expt. 1964-65)

	GY	SY	DMC	NRC	PW	DWW	NDW
D4	36.47	87.76	56.66	88.36	0.894	0.72	1.77
D6	35.70	89.49	56.33	87.85	0.940	0.65	1.50
DU4	41.65	95.20	59.90	93.42	0.935	0.43	1.08
DU6	35.22	92.23	56.81	88.60	0.919	0.67	1.66
HW	35.70	87.47	57.43	89.56	1.085	0.67	1.55
O	27.55	75.57	49.11	73.09	1.989	7.17	17.45
'F' test	Sig.**	Sig.**	Sig.**	-	Sig.**	Sig.**	-
S.Em.±	0.82	1.67	1.04	-	0.049	0.61	-
C.D. 5%	2.27	4.63	3.25	-	0.135	1.90	-
C.D. 1%	2.99	6.08	4.59	-	0.178	2.68	-

D4 : 2,4-D 0.42 kg a.e./ha 4 weeks;
D6 : 2,4-D 0.84 kg a.e./ha 6 weeks;
HW : hand-weeding 6 weeks;
GY : grain yield q/ha;
SY : straw yield q/ha;
DMC : dry matter of crop in grams (30 cm linear strip);
NRC : nitrogen removal by crop (Kg N/ha);
DU4 : 2,4-D(D4) and urea 3% 4 weeks
DU6 : 2,4-D(D6) and urea 3% 6 weeks
O : untreated control
PW : annual weed population (logarithmic value) in 1.12 M^2 recorded 85 days after crop sowing
DWW : dry weight of weeds (in grams) in 0.09M^2 recorded 95 days after crop sowing
NDW : nitrogen depletion by weeds estimated 95 days after crop sowing

The grain and straw yield were significantly more under hand weeding as compared to untreated control. Hand-weeding increased the grain and straw yield over the untreated control by 6.78 and 10.89 q/ha respectively (average for the two seasons). The combination treatment involving the low dosage level of 2,4-D and urea 3.0% applied 4 weeks after sowing (DU4) increased the grain and straw yield by 6.34 and 7.46 q/ha respectively as compared to hand-weeding (HW).

The annual weed population as well as the dry matter accumulation in weeds were significantly reduced under hand-weeding as compared to untreated control (O). The reduction in weed population was significantly less under DU4 as compared to HW. The dry matter accumulation in weeds under this combination treatment was as low as that under hand-weeding.

The dry matter production of the crop was significantly improved under hand-weeding as compared to control. The combination treatment (DU4) effected a substantial enhancement in the dry matter produce of the crop as compared to hand-weeding.

The uptake of N by the crop was 90.73, 86.06 and 69.31 kg/ha under DU4, HW and O respectively. The depletion of nitrogen by weed growth under these treatments was 1.15, 1.43 and 20.50 kg/ha respectively.

The data relating to the sub-plot treatments are presented in Table 3.

Table 3 (1963-64 I ; 1964-65 II)

	I				II			
	NO	N1	N2	C.D.5%	NO	N1	N2	C.D.5%
GY	28.32	35.52	39.93	0.89	29.45	35.58	36.83	0.56
SY	74.08	89.96	95.20	1.55	71.16	90.92	95.50	1.85
DMC	42.68	52.35	61.54	1.26	41.11	58.63	66.99	2.83
NRC	59.96	79.15	98.17	-	57.75	90.74	110.85	-
PW	1.335	1.325	1.290	N.S.	1.379	1.411	1.346	N.S.
DWW	3.18	4.19	4.87	0.71	2.37	3.60	4.05	0.62
NDW	5.75	11.09	16.50	-	3.87	9.56	12.15	-

Nitrogen application to the soil stimulated crop growth leading to significantly greater production of dry matter (DMC) and higher amount of nitrogen removal (NRC) in both the seasons. In respect of grain yield (GY) and straw yield (SY) also the highest produce was obtained under N2 which was significant over N1 and NO. N1 was superior to NO.

The annual weed population (PW) did not differ significantly among, NO, N1 and N2 in both the seasons. With regard to dry matter accumulation in weeds (DWW), it was significantly more under N1 and N2 as compared to NO. The dry weight of weeds under N2 and N1 did not differ statistically. In regard to nitrogen depletion by weeds, the highest amount was under N2 and the lowest under NO.

DISCUSSION

In the present investigation, the selectivity of the combination of 2,4-D and urea on the crop was studied in terms of yield, dry matter production and nutrient uptake; and its activity on weeds was assessed in terms of the effect of the treatment on population, dry matter accumulation and nutrient removal by weeds.

In the employment of herbicides in crop fields, the likelihood of any injury to crops from herbicide use has to be kept in mind. The low dosage level of 2,4-D produced as much quantity of grain as that resulting from hand-weeding thereby proving that the crop did not receive any setback in grain production from the use of low dosage level of 2,4-D which was sprayed 4 weeks after sowing (=4 leaf stage of the crop). The use of 2,4-D in the young crop removed the competition from weeds at an early stage and that was why the grain yield under this treatment was at par with that of hand-weeding or a high dose of 2,4-D applied 6 weeks after sowing (=6 leaf stage of the crop). Blackman and Roberts (1950) also observed that yield increases were likely to be greatest if weeds were removed in the early seedling stages.

The grain yield from the lower dosage level of 2,4-D combined with urea 3.0% applied 4 weeks after sowing was superior even to hand-weeding (DU4 $<$ HW). As the grain yield from higher dosage level of 2,4-D combined with urea applied 6 weeks after sowing did not differ from hand-weeding (DU6 = HW) which was also given 6 weeks after sowing, it appeared that yield increases from the combination treatment of lower dosage level of 2,4-D and urea resulted partly from the stimulatory effect besides elimination of weeds at an early stage. The beneficial effects of combining 2,4-D with nutrients (N, P, K or Fe) were reported by Salontai (1960), Altergot (1962) and Wort (1962).

In 1963-64, there was no significant difference in straw production between the low dosage level of 2,4-D alone and its combination with urea applied 4 weeks after sowing (D4 = DU4), whereas in 1964-65 the latter was superior to the former. In both the seasons, the straw production under high dosage level of 2,4-D alone and its combination with urea applied 6 weeks after sowing did not differ (D6 = DU6). The combination of a low dosage level of 2,4-D and urea influenced favourably both straw and grain production. This combination treatment was, therefore, highly selective on the crop. As both straw and grain yield were favourably influenced by the combination treatment, it appeared that there was complete compatibility of mixing 2,4-D with urea. The compatibility of 2,4-D and urea has also been pointed out by Woodford and Evans (1965).

The annual weed population was significantly reduced in both the seasons under the chemical treatments as compared to hand-weeding (D4, D6, DU4 and DU6 HW). In respect of dry matter accumulation, the chemical treatments were at par with hand-weeding. The depletion of nitrogen by weed growth in the herbicide-treated and hand-weeded plots was more or less equal. However, the lowest dry matter accumulation and nitrogen depletion occurred in the plots that received the low dosage level of 2,4-D and urea (DU4). These observations were suggestive of the improvement in the herbicidal effect of low 2,4-D dosage level in presence of urea.

The population of annual weeds did not differ among the nitrogen levels (N0, N1 and N2) in both the seasons. In regard to dry weight, both N2 and N1 which did not differ between themselves, registered a significantly higher weight. The highest amount of nitrogen was removed by N2, followed by N1. These observations indicated that nitrogen application to soil stimulated weed growth just as it stimulated crop growth. To make efficient utilisation of nitrogen applied to soil, it is therefore important to control weed growth at the earliest opportunity. In the present investigation the combination treatment of low 2,4-D dosage level (0.42 kg a.e./ha) and urea appeared to perform the dual role of reducing weed growth and stimulating grain production in wheat.

References

ALTERGOT, V. F. (1962) The physiological principles underlying the effective use of herbicides and fertilisers on cereal crops in West Siberia. Izv. Sibrsk. Otdel. Akad. Nauk S.S.S.R. (9), 88-100 (c.f. Weed Abstr. 12, (5), 220; 1963.)

BLACKMAN, G. D. and ROBERTS, H. A. (1950) Studies in selective weed control. II. The control of annual weeds in spring cereals. J. agric. Sci. 40, 70-81.

MANI, V. S., GAUTAM, K. C. and CHAKRABORTY, T. K. (1968) Losses in crop yield in India due to weed growth. PANS 14, (2), 142-58.

MUKHOPADHYAY, S. K. (1961): Comparitive efficiency of 2,4-D, MCPB and cultural methods of controlling weeds in wheat. Ph.D. thesis. Post-graduate School, Indian Agricultural Research Institute, New Delhi.

SALONTAI, A. (1960) The influence of herbicide 2,4-D upon the germination of wheat seeds when applied simultaneously with foliar nutrients. Lucrgr Stiint. 16, 105-10. (c.f. Weed Abstr. 12, (6), 274; 1963).

WOODFORD, E. K. and EVANS, S. A. (1965) "Weed control handbook". 4th ed. Blackwell Scientific Publications, Oxford, London.

WORT, D. J. (1962) The application of sublethal concentrations of 2,4-D in combination with mineral nutrients. World Rev. Pest Control 1 : 6-19.

Proc. 9th Brit. Weed Control Conf. (1968)

CONTROL OF CYPERUS ROTUNDUS L. AND CYNODON DACTYLON PERS. BY A COMBINATION OF MECHANICAL, CHEMICAL AND CROPPING METHODS[1]

Ram Gopal and V. S. Mani

Division of Agronomy, Indian Agricultural Research Institute, New Delhi

Summary Experiments involving a combination of mechanical, chemical and cropping methods were undertaken with a view to control nutsedge and Bermudagrass. The technique consisted of giving 2 or 4 ploughings in May and June followed immediately by spraying the ploughed land with a mixture of 2,4-D and dalapon (2.0 kg a.e./ha each) and growing hybrid corn (variety : Ganga 101) in summer and wheat (variety : N.P. 718) in winter. This cycle was repeated for two years. 2 times chemical application in conjunction with 2 ploughings led to a significant reduction in the number and weight of the rhizomes of these two and an appreciable decrease in the starch reserve of nutsedge tubers. This treatment was beneficial to corn as it improved substantially the seed yield, dry matter production and nutrient uptake. Wheat raised after corn harvest was unaffected by the herbicide application made to the latter.

INTRODUCTION

In North India, corn-wheat rotation is an important cropping sequence. As nutsedge and Bermudagrass are troublesome in corn during its early stage of growth, it is felt that a reasonable degree of control of these two could be achieved in the beginning so that corn can establish itself quickly and later on by its own growth does not allow these weeds to be of much consequence. Field investigations involving a combination of mechanical, chemical and cropping methods were carried out during 1964-65 and 1965-66, the main objectives being: (i) to study the herbicidal efficiency of a mixture of dalapon and 2,4-D with and without ploughings on nutsedge and Bermudagrass; (ii) to study the effect of the herbicide application made prior to planting corn (variety Ganga 101) on its growth, development and seed production and (iii) to assess the residual toxicity, if any, of the chemicals applied to hybrid corn in the summer on wheat (variety N.P. 718) grown in the winter.

METHOD AND MATERIALS

The experiment was run in a randomised block design with 9 treatments replicated five fold. The treatments commenced in 1964 and repeated in the same plot in 1965 were applied in May and June. Hybrid corn and wheat were grown in the summer and winter seasons respectively in both the years. The details of the treatments are as under:

	Time of application	
	1964	1965
(1) No ploughing and no chemical (POCO)	-	-
(2) Two ploughings and no chemical (P2CO)	P: May 14, June 3	May 20, June 4
(3) Four ploughings and no chemical (P4CO)	P: May 14 & 24 June 3 & 13	May 20 & 28 June 4 & 12
(4) No ploughing and chemical twice (POC2)	C: May 14, June 3	May 20, June 4
(5) No ploughing and chemical four times (POC4)	C: May 14 & 24 June 3 & 13	May 20 & 28 June 4 & 12

[1]Based on the Ph.D. work of the senior author.

(6) Two ploughings and chemical twice (P2C2)	P & C as at 2 & 4	As at 2 & 4
(7) Two ploughings and chemical four times (P2C4)	P as at 2	As at 2
	C as at 5	As at 5
(8) Four ploughings and chemical twice (P3C2)	P as at (3)	As at 3
	C as at (4)	As at 4
(9) Four ploughings and chemical four times (P4C4)	P as at 3	As at 3
	C as at 5	As at 5

The chemical treatment which was made immediately after ploughing consisted of a combination of 2,4-D and dalapon each at the rate of 2.0 kg a.e./ha applied as a spray in 1350 litres of water.

The initial infestation of nutsedge and Bermudagrass before start of the experiment was assessed by dividing the entire field into 20 plots and recording the number and dry weight of rhizomes in 0-15 and 15-30 cm. depths by placing a quadrat at one spot in each plot. Observations on number and weight of rhizomes were recorded at 12 days after completion of the treatments, at corn harvest (125 days after completion of the treatments) in the first year and at 12 days after repetition of the treatments and at harvest of corn in the second year. Starch content according to the method described by Nielsen and Gleason (1945) was estimated in samples of nutsedge collected immediately after treatment application and after one year. Observations on corn included seed and straw yield, dry matter production and nutrient uptake. Observations on wheat related to growth, development and seed production.

RESULTS

The dry weight of nutsedge tubers worked out to 408.1 kg and the number 2,341,900/ha in the 0-15 cm. depth. In the 15-30 cm. depth the tuber weight and number worked out to 250.3 kg and 1,464,900/ha respectively. The corresponding values for number and weight of Bermudagrass rhizomes in the 0-15 and 15-30 cm. depths were 224.0 kg and 716,900; and 2.8 kg and 10,480/ha respectively.

The data on number (N) and weight of nutsedge tubers (D) recorded at 12 days after repetition of the treatments (I) and at harvest of corn (II) in the second year are presented in Table 1 and that on Bermudagrass in Table 2.

Table 1

Mean Number (N) and dry weight (D) in grams of nutsedge tubers

Depth	0-15 cms				15-30 cms			
	N		D		N		D	
Treatment	I	II	I	II	I	II	I	II
P0C0	41.0	26.0	7.56	5.60	16.2	17.4	3.12	2.96
P2C0	14.8	2.2	3.06	0.50	8.8	2.2	1.36	0.34
P4C0	14.4	1.6	2.96	0.20	2.8	1.2	0.50	0.10
P0C2	13.6	0.6	2.98	0.08	2.0	0.2	0.30	0.02
P0C4	10.4	0.6	2.66	0.08	1.6	1.0	0.30	0.08
P2C2	9.4	1.8	2.24	0.40	0.4	1.0	0.08	0.16
P2C4	7.6	1.6	2.92	0.18	0.2	1.0	0.04	0.10
P4C2	8.8	0.4	2.18	0.12	0.4	1.0	0.08	0.08
P4C4	9.8	-	2.12	-	-	1.4	-	0.14
'F' test	Sig.**	Sig.**	Sig.**	Sig.**	Sig.**	Sig.**	Sig.**	Sig.**
S. Em.±	1.91	2.13	0.27	0.51	1.42	0.82	0.13	0.07
C.D. 5%	5.50	6.11	0.77	1.45	4.06	2.36	0.36	0.20
C.D. 1%	7.43	8.28	1.05	1.98	5.52	3.19	0.50	0.27

Table 2

Mean number (N) and dry weight (D) in grams of Bermudagrass rhizomes

(Depth 0 - 15 cms.)

	1964				1965			
	N		D		N		D	
	I	II	I	II	I	II	I	II
Treatment								
POCO	9.2	11.0	3.12	3.10	9.2	6.8	2.58	3.58
P2CO	4.2	8.2	0.66	0.68	6.6	5.8	0.44	2.22
P4CO	3.0	9.8	0.66	0.98	3.6	6.2	0.26	3.48
POC2	4.2	7.8	1.08	1.18	3.0	4.6	0.16	3.92
POC4	2.8	7.6	0.46	0.82	1.4	3.2	0.09	1.44
P2C2	2.2	6.8	0.82	0.66	3.0	4.8	0.22	2.22
P2C4	1.8	3.8	0.48	0.36	1.6	2.6	0.05	1.18
P4C2	1.6	4.0	0.26	0.58	1.2	3.8	0.07	2.10
P4C4	1.8	1.6	0.21	0.52	1.4	1.2	0.24	1.38
'F' test	Sig.**	Sig.**	Sig.**	Sig.**	Sig.**	Sig.**	Sig.**	Sig.**
S.Em$\pm$	1.11	2.01	0.22	0.16	1.26	1.34	0.14	0.16
C.D. 5%	3.22	5.83	0.64	0.46	3.65	3.89	0.41	0.46
C.D. 1%	4.32	7.82	0.86	0.62	4.90	5.21	0.54	0.62

Chemical application alone, cultivation alone and a combination of these brought down the tuber number and dry weight significantly as compared to control (POCO) in both 0-15 and 15-30 cm. depth.

The number and dry weight of Bermudagrass rhizomes suffered a significant reduction in both the seasons under cultivation or chemical treatments alone or their combination.

The starch content in the samples of nutsedge tubers collected 12 (I) and 125 (II) days after completion of treatments in 1964 and 12 days (III) after repetition of treatments in 1965 is presented in Table 3.

Table 3

Content of starch (in mgs.) in 60.9 cm^2 area

Depth	0 - 15 cms.			15 - 30 cms.		
	I	II	III	I	II	III
Treatments						
POCO	1400	1340	1390	1120	530	410
P2CO	320	340	450	640	50	190
P4CO	530	320	440	900	160	120
POC2	160	340	220	910	140	30
POC4	130	190	320	240	50	10
P2C2	460	230	510	280	110	10
P2C4	190	150	340	340	10	10
P4C2	170	200	270	290	110	10
P4C4	140	220	320	440	-	10

Starch content was markedly reduced by ploughings or cultivation or by a combination of these. In the 15-30 cm depth all combinations of chemical and ploughing treatment brought down the starch content to 10 mg. per 60.9 cm^2 area as compared to 410 mg under control (POCO).

The data on yield, dry weight and nitrogen removal by corn at the end of the second year are presented in Table 4. Observations on wheat are presented in Table 5.

Table 4

Treatment	Grain yield q*/ha	Dry wt/plant gms (42 days) (6th week stage)	Nitrogen removal Kg N/ha (100 days old crop)
P0C0	21.84	12.16	89.13
P2C0	30.48	13.12	104.71
P4C0	26.42	13.86	99.15
P0C2	34.41	13.94	110.06
P0C4	30.61	12.90	103.24
P2C2	38.27	14.08	119.72
P2C4	32.41	13.16	107.41
P4C2	36.79	13.94	114.47
P4C4	35.76	13.82	110.14
'F' test	Sig.**	Sig.**	-
S.Em.±	2.95	0.09	-
C.D. 5%	8.49	0.27	-
C.D. 1%	11.47	0.35	-

*q = quintal = 100 kg.

Table 5

Observations on wheat in the second season

Treatment	Grain yield q/ha	Plant number (100 cm long strip)	Shoot dry weight (gm.) in 100 cm. strip. 8th week stage	Nitrogen uptake (8th week stage) Kg N/ha
P0C0	28.61	50.4	58.09	35.4
P2C0	28.96	48.6	62.20	37.1
P4C0	29.01	52.2	65.52	36.0
P0C2	28.83	42.2	60.67	37.1
P0C4	30.01	55.6	70.42	37.1
P2C2	29.62	43.8	59.65	37.7
P2C4	29.86	49.2	69.41	36.8
P4C2	29.72	43.0	67.39	36.5
P4C4	30.17	55.2	64.44	37.9
'F' test	N.S.	N.S.	N.S.	-
S.Em.±	1.53	7.92	5.91	-

The highest corn yield recorded (38.27 q/ha) was in P2C2. P4C4 and P0C2 did not differ statistically from P2C2. The lowest yield (21.84 q/ha) was in P0C0. The dry weight as well as the uptake of nitrogen were the highest under P2C2, and lowest in P0C0. The stand, dry matter production, nitrogen uptake and final grain production in wheat were not influenced by any of the treatments.

DISCUSSION

Dry matter accumulation in nutsedge tubers: In the 15-30 cm depth (table 1) the dry weight under the combination of two ploughings and two times chemical application was significantly less as compared to four or two times ploughing treatment (P2C2 < P4C0 and P2C0). Chemical treatment alone two or four times also brought down the dry weight as compared to ploughing treatment alone applied twice (P0C2 and P0C4 < P2C0). In Bermudagrass too, the number as well as dry matter accumulation suffered the most both at the beginning and at the end of maize growth in the second year. These observations suggested translocation of the chemicals to lower depths on account of which accumulation of dry matter in the underground parts received a set back. The usefulness of combining mechanical and chemical methods has been also pointed out by Verhoeven and Cowdry (1961) and Bhardwaj (1965) in the case of nutsedge and Santlemann and Meade (1956) in the case of Bermudagrass.

Starch content in nutsedge tubers: 2 or 4 times chemical application alone (POC2 and POC4) brought down the starch content appreciably in the tubers located at 0.15 cm depth as compared to 2 or 4 times ploughing alone (P2CO and P4CO) (Table 3 I). This suggested that starch accumulation was more severely affected by the chemical application as compared to ploughing. In the tubers located at lower depth (15-30 cm.) the differences between ploughings and chemicals were not as much as in the case of tubers located in the 0-15 cm depth. This meant that chemicals scored over ploughings in their initial toxic effect on the tubers located in the upper depth.

In the second observation recorded at maize harvest, the content of starch (total of all 9 treatments - Table 3) did not, on the whole, appreciably differ from the first observation in the 0-15 cm. depth. The dilution effect of the treatments with time might have been caused by a variety of factors the most plausible ones being (i) leaching of the chemical from plot to plot (ii) losing of the toxicity of the chemical with time (iii) hybrid corn growth (iv) the spread of the underground tubers from plot to plot and (v) the different locations of sampling at the two times. It was, however, observed that starch accumulation in the tubers located in the deeper layers was prevented to a greater extent by chemicals or their combination with ploughings in contrast to ploughings alone. The effect of cultivations on carbohydrate reserves in perennial weeds has been pointed out by Arny (1932) and Timmons (1941). In the present study, combination of ploughings and chemicals appeared to prevent starch accumulation in nutsedge tubers.

Corn growth as affected by treatments: The yield of corn was highest under P2C2. This treatment proved beneficial in respect of dry matter production and nitrogen uptake and was most effective in reducing the number and dry matter accumulation in nutsedge tubers.

Four times chemical application (POC4) did not prove harmful to corn as the yield under this treatment did not differ statistically from P2C2 and P4CO. This treatment (POC4) was most effective against Bermudagrass both in respect of number and dry weight.

References

ARNY, A. C. (1932) Variation in the organic reserves in underground parts of five perennial weeds from late April to November. Minn. Agr. Expt. Stn. Tech. Bull., 84, 1-28.

BHARDWAJ, R. B. L. (1965) Control of nutgrass (Cyperus rotundus L.) by cultural and chemical methods. Ph.D. thesis. Post-Graduate School, Indian Agricultural Research Institute, New Delhi.

NIELSON and GLEASON, P. C. (1945) Rapid determination of starch. Factors for starch and comparison with acid and enzyme hydrolysis. Indus & Engng. Chem. Analytical Ed. 17, 131-34.

SANTLEMANN, P. W. and MEADE, J. A. (1956) Bermudagrass control. Mimeo. Publ. Univ. Md. Agron. Dep. 20.

TIMMONS, F. L. (1941): Results of birdweed control experiments at the Fort Hays Branch Station, Hays, Kansas, 1935-40. Kans. Agr. Expt. Stn. Bull. 296, 1-50.

VERHOEVEN, G. and COWDRY, W. A. R. (1961) New attack on nutgrass in the Burdekin. Qd. agric. J. 87, (4), 239-42.

Proc. 9th Brit. Weed Control Conf. (1968)

STUDIES ON THE CONTROL OF CYPERUS ROTUNDUS L.(NUTSEDGE) DURING SUMMER FALLOWS IN RED LOAMS

M. Balasubramanian and D. Daniel Sundararaj,
Agricultural College & Research Institute, Coimbatore, India.

Summary Control of nutsedge during summer fallows was investigated in plots planted with tubers of uniform size and number. Post-emergence treatments were given 40 days later employing dicamba, aminotriazole and dalapon, in five weekly doses at 1 kg a.i./ac/week. Final counts on green shoots made 12 weeks after, recorded 6% (dicamba), 40% (aminotriazole) and 105% (dalapon) as against 69% in hand weeding and 100% in control. Pre-emergence herbicides simazine, diuron and EPTC each at 3 kg a.i./ac, applied once, recorded 2%, 10% and 97% green shoots respectively, as against 100% in control, showing simazine and diuron as most effective. EPTC inhibited sprouting of tubers initially for 15 days. Dalapon in lower concentrations proved more hormonal than herbicidal. Bioassay studies with bean and cotton grown in situ showed symptoms of wilting even after 3-4 months, in plots treated with simazine and diuron. There was depression in bacterial population in all the herbicide treatments.

INTRODUCTION

Cyperus rotundus L. (nutsedge) is the most common weed in the garden lands of Madras State, especially in red loams. The persistence of the weed is aided by its rapid spread and quick regeneration after mechanical removal, defying all cultural techniques to control the weed. The object of this paper is to discuss investigations made for the chemical control of the weed employing pre-emergence and post-emergence herbicides during summer fallows, before the following cropping season.

Several workers have been concentrating on the biology and control aspects of this cosmopolitan weed. Cobley (1967), Berger (1966), Horowitz (1964), Sasser and Locascio (1966) and Leydon (1967) are a few who have worked on it in recent years.

Literature suggests the use of over a hundred herbicides which have been tried. Of these, aminotriazole, atrazine, 2,4-D, dalapon, diuron, EPTC and simazine may be mentioned as the few that have been shown to be of some promise in keeping this weed under check. In the investigations presented here, two sets of trials were conducted simultaneously employing split doses of aminotriazole, dalapon and dicamba as post-emergence treatments and diuron, EPTC and simazine as pre-emergence applications.

METHODS AND MATERIALS

The experiments were conducted at the Agricultural College and Research Institute, Coimbatore during the year 1968, in red loamy soil under irrigated conditions, in summer fallows (April-July). The studies were made in plots measuring 5 ft x 4 ft, each planted with 150 fresh tubers of the weed and replicated four times.

Post-emergence studies: The herbicides aminotriazole, dalapon and dicamba were sprayed on 15 April, 1968, in split doses at 1 kg a.i./ac/week, for five consecutive weeks on a 40-day old established stand of the weed raised from single tubers planted on 5 March, 1968.

Pre-emergence studies: The herbicides included diuron, EPTC and simazine and were sprayed on 18 April, 1968 i.e., three days after the planting of tubers. The spraying was done only once.

Treatments

Post-emergence	Pre-emergence
Control	Control
Handweeding	Diuron at 2 kg a.i./ac
Amitrol at 5 kg a.i./ac	EPTC at 2 kg a.i./ac (incorporated)
Dalapon at 5 kg a.i./ac	Simazine at 2 kg a.i./ac
Dicamba at 5 kg a.i./ac	

The spray volume was maintained at 50 gal/ac and surfactant was used only for post-emergence applications. The green shoot counts were recorded from the entire plot at weekly intervals for 12 weeks. The bacterial population counts and fresh weight of green shoots were made at the end of the 12 week period. Bioassay studies using bean (*Dolichos lablab*) and cotton (*Gossypium hirsutum*) were made for eight weeks to assess the residual effects of the herbicides in the soil after the twelfth week, by sowing the seeds *in situ*. The counts of the tubers developed under each treatment were made by digging the soil at 0-6 in., 7-12 in. and 13-18 in. depths, after the bioassay studies.

RESULTS

Post-emergence studies: The population counts made were calculated with reference to the initial counts of the respective plots, reckoned as 100%, on the date of treatment. The weed population showed an initial increase during the first week and subsequently the effect of herbicides was noted as follows (Table 1):

Aminotriazole: Suppression of weeds was gradual only up to the first ten weeks, compared to control and handweeded plots.

Dicamba: Reduction in green shoots was more striking than that in aminotriazole treated plots and by the sixth week, the shoots recorded only 5% of the initial stand and the same was further reduced to 3% in the tenth week.

Dalapon and control: Both these treatments showed an identical trend recording uninterrupted increases in green shoots every week.

Handweeding: Regrowth of the weed increased quickly every week from 29% to 98%, by the fifth week and 165%, by the twelfth week.

Table 1

Weekly green shoot counts

(Mean of four replicates - expressed as % of initial counts)

Treatment	IC*	Weeks 1	2	3	4	5	6	7	8	9	10	11	12
Control	100	131	136	156	167	193	198	200	208	225	225	218	239
Handweeded	100	29	53	74	86	98	112	116	146	149	157	161	165
Amitrol	100	114	100	95	87	90	72	72	75	65	66	90	95
Dalapon	100	133	142	169	179	207	208	209	219	227	233	246	252
Dicamba	100	112	53	44	29	15	5	5	4	3	3	11	15

IC* - Initial counts recorded on the date of treatment (15 April, 1968)

Green shoot weight and number: The weight and total number of green shoots were the minimum in dicamba, followed by aminotriazole. The weight of single plants (i.e., shoot weight/shoot number) also showed that in dicamba and aminotriazole plots, the shoots were less vigorous than that in the control. The vigour of shoots in the handweeded plots was greater than that in the control, though the number was less. The effect of the herbicide dalapon had exceeded that in the control in all these aspects (Table 2).

Tuber production: Total tuber production was least in dicamba, and less than the control in all the other treatments. The herbicides had favoured maximum distribution of tubers in the 0.6 in. depth. The total production potential of tubers ranged between 107% and 748%, of the initially planted number (Table 2).

Bacterial population: The population showed a depression in all the treatments, compared to control and the minimum was seen in aminotriazole (Table 2).

Table 2

Data on green shoots, tubers and bacterial population

(Mean of four replicates - as % on control)

Treat- ments.	Green shoots		Tuber distribution & production % Distribution.			Total	PP*	Bacterial population	
	wt.	no.	0-6 in.	7-12 in.	13-18 in.	No. produced.**		No/g soil 1x10⁴	%
Control	100.0	100.0	43.1	37.7	19.2	100.0	748.3	72.5	100.0
Handweeded	82.4	68.8	51.4	36.1	12.5	63.8	477.7	52.0	71.7
Aminotriazole	37.9	44.4	71.4	25.6	3.0	36.9	275.0	33.5	46.2
Dalapon	114.5	109.4	69.2	25.2	5.6	91.1	682.0	61.0	83.7
Dicamba	4.4	7.0	75.2	19.6	5.2	14.3	107.3	60.5	83.5

PP* - Production potential of tubers (as percentage of the originally planted tubers, reckoned as 100%); ** = This refers to the actual number of tubers worked out as % of control, control reckoned as 100%.

Pre-emergence studies: Population counts on the green shoots seemed to vary with different treatments as can be seen from table 3. Population counts are expressed as percentages with reference to the weed stand in the control plots reckoned as 100% every week, as this facilitated precise assessment of the efficacy of the herbicides, in the absence of any weed growth at the start.

Table 3.

Weekly green shoot counts (mean of four replicates)

Treatments	IC*	Weeks 1	2	3	4	5	6	7	8	9	10	11	12
Control*	Nil	100	100	100	100	100	100	100	100	100	100	100	100
Diuron	Nil	35	74	43	5	4	4	4	4	4	6	7	10
EPTC	Nil	16	20	34	55	58	61	62	67	72	85	85	97
Simazine	Nil	53	58	40	5	1	1	2	3	1	2	2	2
Control**	Nil	100	116	130	156	190	195	230	242	248	254	256	257

IC* - Initial counts recorded on 18 April, 1968, the date of treatment.
Control** - These figures indicate the actual increase in weed stand in control plots, but which has been reckoned as 100% (at control*), for facilitating the assessment of relative efficacy of the herbicides, during each week of observation.

Diuron: Nearly 75% of the tubers sprouted within a fortnight after the spraying. But the green shoot count dropped to 43% by the third week and to just 5% in the next week. The weed was effectively checked up to the tenth week.

EPTC: Suppression of sprouting of tubers was significant up to the third week only. The gradual establishment of the weed reached the 97% mark by the twelfth week.

Simazine: As in diuron, during the first two weeks, the weed showed an increase in green shoot counts; but the plants started to wilt from the third week and survival was only 5%, a week later. The weed growth was negligible subsequently.

Control: The weed growth showed a steady increase and recorded 257% of the stand of the first week, reckoned as 100% (cf. control** in table 3).

Green shoot weight and number: All herbicides had reduced the total weight of green shoots, total number and also the weight of single shoots (i.e., shoot weight/shoot number). The outstanding reduction of these three aspects was noted in simazine, followed by diuron (Table 4).

Tuber production: The total tuber production was reduced in all the herbicide treatments. Nearly 75% of the tubers were found in the first zone (0-6 in.) in EPTC and diuron, the rest in the second zone (7-12 in.) and negligible in the third (13-18 in.). Simazine recorded 53%, 37% and 10% in these three zones respectively, whereas control plots had 91% of the tubers in the first zone itself. The production potential of tubers showed increases of 350% as a maximum in the control, followed by EPTC with 274% and the least in diuron and simazine plots with 43% and 24% respectively (Table 4).

Bacterial population showed a depression in all the three herbicide treatments, particularly in diuron and simazine plots (Table 4).

Table 4.

Data on green shoots, tubers and bacterial population
(Mean of four replicates, expressed as % of control)

Treatments.	Green shoots wt.	Green shoots no.	Tuber distribution & production: % Distribution 0-6 in.	7-12 in.	13-18 in.	Total No. produced**.	PP*	Bacterial population No/g soil $1x10^4$	%
Control	100.0	100.0	90.7	8.6	0.7	100.0	350.0	133.0	100.0
Diuron	6.8	9.4	74.2	25.8	---	12.2	42.7	65.0	48.9
EPTC	61.4	89.6	74.4	24.9	0.7	78.2	273.7	81.0	60.9
Simazine	0.3	2.1	53.4	37.0	9.6	6.9	24.3	63.5	47.7

PP* - Production potential of tubers (as percentage of the originally planted tubers, reckoned as 100%).

** - This refers to the actual number of tubers worked out as % of control, control reckoned as 100%.

Bioassay studies: In the post-emergence treatments, the bean seedlings a week after their emergence, showed malformations under dicamba. The leaves were deformed, plants stunted and new shoots resembled 'little leaf' disease. The plants remained like that for eight weeks. Simazine treated plots under pre-emergence treatments did not support bean and cotton beyond a week after germination. Diuron was toxic to bean.

DISCUSSION

Post-emergence studies: Among the herbicides, dicamba recorded the lowest regrowth (3%) of the weed for ten weeks, despite slight increases later. Sasser and Locascio (1966) had also observed that dicamba at 4 lb/ac., had checked nutsedge completely but as a pre-emergence spray. Aminotriazole was less effective, imparting only a 35% check at the end of ten weeks, but the subsequent regrowth was so quick as to nullify even this temporary control. Dalapon at low, split doses had proved more hormonal than herbicidal, inducing more vegetative growth which exceeded even that in the control. However, Sasser and Locascio (1966) and Nair and Chami (1964) have recorded that single applications of 3-20 kg/ha give moderate to good control. Dalapon had also delayed flowering, thereby promoting tuber formation. Handweeding had only aided the re-establishment of the weed in five weeks and in the subsequent increases in the weed stand.

The tuber studies reveal that a single tuber of nutsedge could give rise to 7-8 over a period of 16-18 weeks and this observation is similar to the findings of Tumbleson and Kommerdahl (1960) on *Cyperus esculentus*. The patterns of tuber distribution and production potential in all the herbicide treatments show the inhibitory effect of the herbicides. The reduction in tuber formation upto 36.2% in the handweeded plots, has been noted here; Horowitz (1965) observed that even 60% reduction of tubers is possible, by clipping the aerial shoots of nutsedge every 2-4 weeks.

Pre-emergence studies: The two herbicides that imparted an effective check on the weed were diuron and simazine; both consistently recorded very low green shoot counts (less than 5%), from the fifth week onwards, till the end of the experiment. Observations with *Cyperus rotundus*, in sugarcane indicate that diuron at 1-1.5 lb/ac suppressed the weed for eight weeks (Whitehead, 1965). Sivaji and Rao (1965) reported similar findings with simazine at 6-8 lb/ac for checking nutsedge in the maize crop. Simazine also appears to be more potent than diuron as is evident from the total number and weight of green shoots, reduction in the tuber production and weekly green shoot counts. However, the residual effects of these two herbicides appear to remain in the soil for prolonged periods, as seen from the bioassay studies. There was reduction in the bacterial population also. EPTC gave an initial suppression of sprouting of the propagules, with a resultant check to 66% in the first three weeks, but subsequently the green shoot counts reached almost as high as the control at the end of the experiments. In citrus gardens, a similar observation has been made by Leydon (1967).

Tuber distribution under pre-emergence studies indicate that in the control, development of tubers has been up to 91% in the first 0-6 inch zone, while under herbicide treatment it was 53-75% in the first six inch zone. This suggests an inhibitory effect of the herbicides in preventing the localization of tubers in the first six inches, which is the zone where most multiplication of the weed takes place (Horowitz, 1965 and Tumbleson and Kommedahl, 1961). The total number of tubers was less in all the treatments and the least was recorded under simazine.

References

BERGER, G.B. (1966) Dormancy, Growth Inhibition and Tuberization of Nutsedge (*Cyperus rotundus* L.) as affected by Photoperiods. Ph.D., Thesis, Univ. Calif., Riverside, 1966, pp. 128 (Weed Abst., 1968, 17: 805)

COBLEY, R.S. (1967) Pre-emergence and Post-emergence control of Yellow Nutsedge with Herbicide Combinations and Oils. Proc. 21st Ann. Mtg. NE Weed Control Conf., pp. 307-314.

HOROWITZ, M. (1965) Data on the Biology and Chemical Control of the Nutsedge (*Cyperus rotundus* L.) in Israel. (PANS (C), 11: 389-416. (Weed Abst., 1967, 16: 187).

LEYDON, R.F. (1967) Control of Nutsedge in Texas Citrus Orchards. Proc. 20th Ann. Mtg. Southern Weed Conf., 130-133.

NAIR, R.G. and CHAMI, P. (1964) Studies on the Control of Nutgrass *Cyperus rotundus* L. in Coconut Gardens by Chemical Weedicides Indian J. agric Sci., 34: 66-70.

SASSER, J.M. and LOCASCIO, S.J. (1966): Effects of several Herbicides of Nutsedge control. Proc. 19th sth. Weed Conf., pp. 254-260.

SIVAJI, R.S. and RAO, R.S. (1965) Studies on the effect of Simazine and Atrazine on Weed Control in Hybrid Maize. Andhra agric. J., 12: 153-166.

TUMBLESON, M.E. and KOMMEDAHL, T. (1961) Reproductive Potential of *Cyperus esculentus* by Tubers. Weeds, 9: 646-653. (Weed Abst., 1962, 11, 184).

WHITEHEAD, C. (1965) Sugarcane in South Africa - its Production and Management. Bull. S.Afr. Sug. Ass. Exp. Stn, 1. pp. 24 (Weed Abst., 1967, 16: 134).

Proc. 9th Brit. Weed Control Conf. (1968)

CHEMICAL CONTROL OF NUTGRASS (CYPERUS ROTUNDUS L.)

Mukhtar Singh, R. K. Pandey and R. P. Singh

Indian Grassland & Fodder Research Institute, Jhansi (U.P.) India.

Summary A field experiment on the control of nutgrass was conducted at the Central Farm of the Indian Grassland and Fodder Research Institute, Jhansi (India) during 1966-67 and 1967-68. The treatments included applications of amine salts of MCPA and 2,4,5-T at two levels (2 & 4 kg a.e./ha) in two and four sprays in the monsoon season in each of the two years, in addition to hand weeding and unweeded control. Treatment effects were studied on the weed population, the number and the weight of tubers, and the yields of the following crop of wheat grown in the winter seasons. The effect of the post-emergence application of 2,4-D @ 1 kg a.e./ha as compared with one weeding was also studied on the yield of wheat. MCPA at 4 kg a.e./ha applied in two sprays at weekly intervals in each of the two years virtually eliminated the weed by the end of the second year and increased wheat yield in both the years. The post-emergence applications of 2,4-D increased the wheat yield and proved superior to hand weeding. The principles of control of nutgrass in relation to crop production under irrigated and non-irrigated conditions in India are discussed.

INTRODUCTION

Frequent cutting of the aerial parts of nutgrass deplete and weaken the underground storage organs and help in reducing its population (Thakur & Singh, 1955), but the cost of this operation is likely to be prohibitive. In some parts of Southern India 'crowbarring' is practised on nutgrass-infested fine-textured black soils. Such a practice is, however, expensive and occasional showers may thwart the entire effort. Moreover, this method cannot be adopted on coarse-textured and loamy soils. As a measure of economy, instead of crow-barring, hot weather cultivations or deep ploughing could be adopted, but this is likely to be less effective (Rao & Moses, 1949; Bhardwaj, 1965).

A promising approach would be the use of suitable hormone-type weed-killers. 2,4-D and MCPA in doses as high as 16 to 18 lb /acre applied in four to nine splits have been tried for nutgrass control in India and abroad with encouraging results (Narayanan & Meenakshisunderan, 1957; Hauser, 1963; Sinha & Thakur, 1966). The rates usually recommended are quite high which not only increase the cost but may preclude a following crop because of the risk of high residual toxicity. 2,4-D and 2,4,5-T at lower doses (1.5 to 2 lb./acre) have been tried by some workers with encouraging results (Appalanaidu and Singh 1962; Adlakha at al 1963). Herbicides have also been tried both in India and abroad in combination with cultivations on the control of this weed with varying degree of success (Bara Temes & Ceballos Jimenez, 1961; Verhoeven & Cowdry, 1961; Bhardwaj, 1965).

In view of the seriousness of the problem of nutgrass in India, an experiment was conducted during 1966-67 and 1967-68 at Indian Grassland & Fodder Research Institute, Jhansi to study the effectiveness and economics of the use of MCPA and 2,4,5-T in controlling this weed.

METHODS AND MATERIALS

A piece of fallow field with sandy loam soil and infested with nutgrass was selected for the experiment. The treatments, applied in the monsoon seasons of 1966-67 and 1967-68, were as follows:

a) Pre-sowing treatments

T0	No treatment
T1	Hand weeding
T2	MCPA amine @ 2 kg a.e./ha in two sprays
T3	MCPA amine @ 2 kg.a.e./ha in four sprays
T4	MCPA amine @ 4 kg.a.e./ha in two sprays
T5	MCPA amine @ 4 kg.a.e./ha in four sprays
T6	2,4,5-T amine @ 2 kg.a.e./ha in two sprays
T7	2,4,5-T amine @ 2 kg a.e./ha in four sprays
T8	2,4,5-T amine @ 4 kg.a.e./ha in two sprays
T9	2,4,5-T amine @ 4 kg.A.E./ha in four sprays

b) Post-emergence treatments to wheat

W	Hand weeding
D	2,4-D sodium @ 1 kg.a.e./ha at 5-leaf stage

Treatments were tried in six blocks of ten plots each confounding 1 degree of freedom with block differences. The gross and net plot sizes were 4 m x 4 m and 3 m x 3 m respectively.

Fertilizer was applied @ 40 kg N/ha to the wheat crop, var.C-591, in 1966-67 and @ 80 kg N/ha and 30 kg P_2O_5/ha to wheat, var.lerma rojo, in 1967-68.

The schedule of cultural operations is given below:

Monsoon season operations	1966-67	1967-68
Spraying herbicides	27/8, 3/9, 10/9, 20/9	12/7, 20/7, 18/8, 23/8
Hand weeding	5/9, 20/9	22/7, 18/8
Winter Season operations		
Sowing of wheat	6/11	20/11
Hand weeding	26/12	29/12
2,4-D application	26/12	29/12
Fertilizer	29/1	5/12
Irrigations	5/11, 20/12, 29/1, 17/2	4/12 1/2, 21/2, 6/3
Harvesting	4/4	26/3

The data on nutgrass were recorded in randomly selected quadrats each 25 cm x 25 cm. The soil from each quadrat was dug to a depth of 30 cm and the number of intact tubers and their dry weight was recorded. Observations on nutgrass were recorded initially before treatments and periodically after the application of treatments.

EXPERIMENTAL FINDINGS

General observations: Yellowing and necrosis of leaves of nutgrass started within a week after the application of MCPA and 2,4,5-T. The effect of MCPA was more marked than that of 2,4,5-T and the higher rates of application were more effective than the lower.

Treatment effects on the weed population (Table 1). Application of MCPA and 2,4,5-T resulted in a significant reduction in the number of nutgrass plants. MCPA at 4 kg./ha in two sprays each year was found to be the most effective in killing the aerial parts of the weed and virtually eliminated it by the end of the second year. 2,4,5-T applied at 4 kg./ha in two or four sprays each year was also highly effective. Two hand weedings did not suppress the population of nutgrass.

Treatment effects on underground growth (Tables 2 and 3). The effects of the herbicides on the number of tubers and their dry weight were similar to those on the aerial shoot. Two applications of MCPA at 4 kg./ha reduced the number of tubers by 79% (Table 2). It was also observed that the surviving tubers from the treated plots were atrophied (Table 3). 2,4,5-T at 4 kg./ha was less effective in reducing the number of tubers than MCPA.

Residual effects on the following wheat crop (Table 4). All the pre-sowing weed control treatments improved the yield of wheat significantly. MCPA at 4 kg./ha proved superior to 2,4,5-T in increasing the yield of wheat grain as well as straw. Post-emergence spraying with 2,4-D at 1 kg./ha gave higher yield of grain as well as straw, as compared with one hand weeding.

Economics of treatments (Table 5). MCPA at 4 kg./ha applied in two sprays was the most remunerative treatment. Application of 2,4-D at 1 kg./ha as post-emergence treatment also gave an additional income of Rs.287 per hactare as compared with hand weeding.

Table 1. Effect of treatments on plant population of Cyperus rotundus.

Treatments	Initial Count/ quadrat	Plant population/quadrat after treatment			
		Average (5 periodic counts).	Final count 1966	Final count 1967	Average of final counts
T0	54.5	37.5	21.8	24.0	22.9
T1	60.5	46.0	38.0	31.3	34.6
T2	34.5	21.0	11.3	9.0	10.1
T3	51.7	30.0	12.3	11.5	11.9
T4	48.2	3.5	1.2	0.0	0.6
T5	52.7	20.5	7.2	7.8	7.5
T6	62.7	30.5	15.3	7.7	11.5
T7	38.8	27.5	19.2	16.7	17.9
T8	64.2	15.0	7.0	5.5	6.2
T9	44.5	17.0	4.7	2.5	3.6

$S.E_m \pm$ 3.5 C.D. (1% level) 12.4

Table 2. Effect of treatments on the number of Cyperus rotundus tubers

Treatments	Initial count/ quadrat	No. of tubers/quadrat after treatment. Average (5 periodic counts.)	Final count 1966	Final count 1967	Mean of final counts
T0	119.3	105.2	116.5	94.3	105.4
T1	130.0	107.6	118.5	91.8	105.1
T2	76.3	68.2	61.5	68.0	64.7
T3	110.0	83.1	93.5	73.5	83.5
T4	108.0	52.6	54.2	22.6	38.4
T5	115.0	64.8	70.2	45.5	57.8
T6	122.0	64.8	68.5	55.3	61.9
T7	95.3	73.1	80.5	63.6	71.9
T8	125.0	60.7	65.0	34.8	49.9
T9	110.5	54.4	55.3	35.3	45.3

$S.E_m \pm$ 7.6   C.D. (1% level) 20.9

Table 3. Effect of treatments on the dry weight of Cyperus rotundus tubers

Treatments	Initial dry wt. quadrat (gm)	Dry weight of tubers/quadrat (gm) after treatment Average 5 periodic observations	Final observation 1966	Final observation 1967	Mean of final observations.	Weight 100 tubers finalcount (mgm.)
T0	26.0	25.9	30.7	18.0	24.3	192
T1	29.0	23.5	25.3	16.1	20.7	175
T2	28.5	13.1	14.7	11.3	13.0	167
T3	58.5	15.8	20.0	13.0	16.5	179
T4	39.5	8.7	10.7	3.0	6.8	133
T5	20.0	12.7	16.2	7.8	12.0	172
T6	24.0	12.6	15.7	10.1	12.9	185
T7	30.0	14.5	18.2	10.5	14.3	167
T8	26.0	11.9	14.3	6.0	10.1	172
T9	22.5	10.9	10.8	7.3	9.0	208

Table 4. Effect of treatments on the yield of wheat

Treatments	Grain yield (q/ha)			Straw yield (q/ha)		
	1966-67	1967-68	Mean	1966-67	1967-68	Mean
For nutgrass control.						
T0	11.10	22.41	16.75	22.20	41.28	31.74
T1	13.90	21.30	17.60	28.90	39.71	34.30
T2	16.00	22.52	19.26	31.40	37.05	34.22
T3	14.90	24.92	19.91	30.90	45.11	38.00
T4	17.50	25.99	21.74	32.00	47.28	39.64
T5	17.20	24.39	20.79	34.30	46.24	40.27
T6	14.40	22.11	18.25	24.40	40.73	32.56
T7	13.40	21.70	17.55	26.10	35.63	30.86
T8	13.20	23.21	18.20	33.10	39.50	36.30
T9	12.90	23.43	18.16	22.90	41.77	32.33
$S.E_m$ ±	1.58	± 0.37	C.D. (5% level)	N.S.	0.72	
For Wheat						
W	12.40	22.50	17.45	26.60	41.52	34.06
D	16.40	23.90	20.15	30.70	42.97	36.83
$S.E_m$ ±	0.71	± 0.39	C.D. (1% level)	2.57	1.08	

Table 5 Economics of the treatments (Rupees)

Treatments	Cost weed control.	Crop value	Crop value minus treatment cost	Profit (+) or Loss (-) over untreated control
Pre-sowing				
T0	0.00	1657.00	1657.00	-
T1	100.00	1751.00	1651.00	- 6.00
T2	65.00	1883.80	1818.80	+ 161.80
T3	75.00	1972.80	1897.80	+ 240.80
T4	120.00	2135.60	2015.20	+ 358.60
T5	130.00	2063.20	1933.20	+ 276.20
T6	128.00	1785.00	1657.00	0.00
T7	138.00	1712.00	1574.00	- 83.00
T8	246.00	1819.00	1573.00	- 84.00
T9	256.00	1776.10	1520.10	- 136.90
Post-sowing				
W	50.00	1736.60	1686.60	-
D	6.69	1980.30	1973.61	+ 287.01

Basis of calculations:

Labourers /ha per weeding	20
Labour wages	Rs. 2.50 / day
Cost MCPA amine (400 gm/1)	Rs. 11/1
Cost 2,4,5-T amine (200 gm/1)	Rs. 11.80/1
Cost 2,4-D sodium sale (80%)	Rs. 5.35/Kg
Price of wheat grain	Rs. 80/ q.
Price of wheat straw	Rs. 10/ q.

DISCUSSION

It is normally to be expected that a herbicide will be most effective at the time when a perennial weed with underground storage organs is actively growing. There is evidence to show that the herbicide kills the growing tubers at the time of application but does not affect the dormant ones (Stamper & Melville, 1956). A higher concentration of herbicide which destroys the foliage quickly may not prove to be an effective method of control as the underground parts may remain unharmed (Craft & Robbins, 1962). Repeated applications of the herbicide may therefore be necessary to control the weed effectively. On the other hand, successful control of the weed with high doses of herbicides is reported (Sinha & Thakur, 1966). Economy in the rate of application is possible if a modest dose which tends to weaken the above ground part without destroying it completely is used in the first place so that translocation of herbicide to underground parts is not impeded. In the experiment reported here, the effectiveness of the amine salt of MCPA applied at the rate of 4 kg /ha in two sprays at an interval of one week during the month of July - the most active growth period of nutgrass, killed the aerial parts as well as some of the tubers. The application had however, to be repeated in the second year before almost all the tubers could be killed. This is to be expected because MCPA does not persist for more than 1 to 4 weeks in warm, moist loamy soil (Klingman 1961). This is in fact an advantage in that residues are reduced to a level where a winter crop of wheat can be taken successfully. In this experiment applications at 1 kg /ha at weekly intervals were slightly less effective than two applications at 2 kg /ha. It seems that if repeated applications at low level are resorted to, weekly intervals may be rather too long. Perhaps the best approach may be to start with a small dose and give progressively increasing doses at shorter intervals.

It is generally conceded that successful control of this perennial weed will necessitate fallowing for part of the year. In fact in most of the previous studies on nutgrass no crop was grown for a year or so. From the economic point of view, it is important that weed control should be effected, if possible, without sacrificing a crop. In the present study a wheat crop was taken each year in the season followin the application of herbicide in the rainy season. Under farming conditions where a winter crop is taken on the moisture conserved during the rainy season, the herbicides can be easily applied in the pre-sowing rainy season, but in non-irrigated areas having sandy soils and those receiving low rainfall it is particularly important t at a crop is not sacrificed during the rainy season which is the only season when cropping is possible. Here, it will be neces ary to adopt weed control treatment in autumn immediately after the crop is harvested or whenever the weed growth is encouraged after occasional rain in the following season.

The present trend in India for double cropping with irrigation necessitates the evolution of methods whereby the weed is controlled and yet two crops are taken in a year. This does not appear to be difficult of achievement as nutgrass could be tackled in the hot months of May and June by encouraging the weed to grow with one or two irrigations before spraying with MCPA or 2,4-D. Moreover, during the hot season hot weather cultivation could be given to further reduce the nutgrass infestation. This will requir the field to remain fallow for a couple of months only. During the nutgrass control programme, it will be desirable to grow a crop tolerant to MCPA or 2,4-D.

The experiment also showed conclusively the relative performance of the two herbicides MCPA and 2,4,5-T. It was noted that 2,4,5-T was not as effective as MCPA, even though 2,4,5-T is known to be slightly more persistent. (Klingman, 1961).

References

1. Adlakha, P.A., Thakur, N.M. and Singh, H. (1963). Preliminary studies on the control of nutgrass by chemical method in the Punjab. India J. Sugarcane Res. 7, 136.

2. Appalanaidu, B. and Singh, D.J.C. (1962). Studies on the control and eradication of nutgrass, Cyperus rotundus L. by chemicals. Andhra Agric. 9, 108-23

3. Bara Temes, S. and Ceballos Jimenez, A. (1961). Cyperus rotundus and its control with herbicides. Conmun.Inst.For.Invest. Exp.,Madrid. 9, 35

4. Bhardwaj, R. B. L. (1965). Control of nutgrass (Cyperus rotundus L.) by cultural and chemical methods. Ph.D.thesis.I.A.R.I. New Delhi (India).

5. Craft, A.S. and Robbins, W.E. (1962). Weed Control (3rd Ed.). McGraw-Hill Book Co. Inc. New York. pp 581.

6. Hauser, E.W. (1963). Response of purple nutsedgeto amitrol, 2,4-D, and EPTC.Weeds. 11, 251-52.

7. Klingman, G.C. (1961). Weed Control: As a Science. (2nd Ed.). John Wiley Sons Inc. New York. pp.140

8. Narayanan,T.R. and Meenakshisunderan, D. (1957). Studies on weed control by herbicides. Madras Agric. J.44, 81-83

9. Rao, P.K. and Moses, L. (1949). Effect of summer ploughing on the germination of Karai weed (Cyperus rotundus). Madras Agric. J.36, 247-249.

10. Sinha, T.D. and Thakur,C. (1966). Eradication of nutgrass by killing its tubers with 2,4-D. Proc. Second Weed Control Seminar, Hissar (India). 31-32.

11. Stamper E.R. and Melville, G. (1956) Studies in the control of nutgrass (Cyperus rotundus). Proc. 9th Sth Weed Control Conf. 32.

12. Thakur, C. and Singh, H.N. (1955) Tillage comtrol of nutgrass in relation to its organic reserves. Proc.Bihar. Acad.Agric. Sci. 6, 67-74.

13. Verhoeven, G. and Cowdry, W. A. R. (1961). New attack on nutgrass in the Burdekin. Qd. Agric. J. 87, 239-42.

Proc. 9th Brit. Weed Control Conf. (1968)

THE EFFECT OF PICLORAM ON ACACIA HOCKII DE WILD, WHEN APPLIED IN DIFFERENT MONTHS, DIFFERENT TIMES OF DAY AND IN DIFFERENT FORMULATIONS

G. N. Harrington

Ministry of Animal Industry, Game & Fisheries, Uganda

Summary A. hockii de Wild, is the most widespread small Acacia sp. in E. Africa and the most difficult to eradicate. 30,000 sq. miles of potentially high quality rangeland are affected by this species. Foliar spraying of Tordon 22K (picloram potassium 26.9%) proved to be a superior method of killing this species to foliar sprays of Tordon 101 (tri--isopropanol-amine salts of 2,4-D 39.6% + picloram 10.2%) and 2,4,5-T or Tordon granule (picloram) application. In February, August, September and October, in western Uganda, A. hockii was much more susceptible to the Tordon spray than in other months.

INTRODUCTION

Acacia hockii de Wild. is a troublesome weed of rangeland throught East Africa and particularly in Uganda. It is probably the most widespread of all the small Acacia species and is certainly one of the most difficult to eradicate (Ivens 1960). It is found both as trees and bushes and, when senile, the former revert to the latter, under the influence of fire, and become rejuvenated.

The tree form does not produce good shade and completes with the herb layer for moisture (unpublished results). The bush form maintains thorny branches within the herb layer and prohibits grazing. Harker (1959) has recorded 1,500 plants per acre and 500 plants per acre is a quite normal population in Ankole District, which indicates the deleterious effect of this species upon grazing land.

In western Uganda and north-west Tanzania approximately 30,000 square miles of potentially highly productive rangeland are populated by A. hockii. A low standard of range and cattle management has been shown to give a net profit of £200 per square mile (Proc. Beef Cattle Breeding and Ranching Development Conference, Uganda, 1968), and good management should improve on this at least five times. Part of that good management involves the eradication of A. hockii.

Harker (1957) came to the conclusion, after a series of trials, that only an expensive combination of burning, stumping and spraying 2,4,5-T gave any measure of control, and even this was unreliable. Thornton (unpublished) tested 2,4-D and 2,4,5-T both as product and in a range dilutions, on leaves, stems, stumps and foliar regeneration and found that whilst temporary control of vegetative growth was obtained, most bushes eventually recovered. Ring-barking and the immediate application of 2,4-D product gave best results with a 60% kill, but such a procedure is expensive.

A trial using Tordon granules and foliar sprays of Tordon and Tordon + 2,4-D, compared to 2,4,5-T as a foliar spray in April 1965 (unpublished), suggested that A. hockii was more susceptible to picloram than 2,4,5-T.

It was noted that the phenology of A. hockii varied considerably from bush to bush. At a time when most bushes were in the reproductive stage, large minorities might be vegetative or even defoliated and some flowering bushes could be found at all seasons of the year. It was surmised that this characteristic might be responsbile for the lack of repeatability noted in previous workers results. It was also noted that no previous work had tested the time of year at which A. hockii was most susceptible to arboricides.

This preliminary observation trial was designed to test:-

(a) whether the picloram formulations used were superior to 2,4,5-T;
(b) the best time of year for arboricide application;
(c) the best time of day for arboricide application;
(d) the most effective strength of arboricide solution to use;
(e) whether the physiological condition of the bush i.e. dormant, producing leaves, extending shoots, flowering, producing seeds, influenced the effectiveness of the arboricide.

METHODS

A. 2,4,5-T in diesel at 0.36, 0.48, 0.60, 0.72, 0.84, 0.96, 1.08 and 1.20% active ingredient (a.i.).
B. 2,4,5-T in water as above.
C. Tordon 22K in water at 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8 and 2.0% a.i.
D. Tordon 101 in water as above. (20% of the a.i. is Tordon and 80% is 2,4-D).
E. Tordon 10K granules (10% a.i. by weight) at 25, 35, 45, 55, 65, and 75 gm. per bush.
F. Untreated controls.

A, B, C and D were foliar sprays which were applied to point of run-off (300-500 cc.). Each concentration was applied to a single bush. The granules in treatment E were scattered on the ground shaded by branches. The whole programme was repeated at 07.30, 10.00, 14.00 and 17.00 hr. (dawn and dusk are at 07.00 and 19.00 hr. approximately) in each month of the year. The experimental period was from April, 1966 to March, 1967.

At the time of treatment the following points were noted for each bush:-

Leaves	:	present or absent; young, mature or old; colour.
Shoots	:	extending or not.
Flowers	:	present or absent.
Seed pods	:	nil, young or old.
Bark	:	note of condition.
Size	:	3 - 6 ft or 6 - 10 ft in height.
General remarks	:	dew, special peculiarities etc.

The effect of rain on the sprayed bushes was ignored provided it fell not less than four hours after treatment. On one occasion it was necessary to retreat because of rain, and a different set of bushes was then used.

RESULTS

The figures in table 1 demonstrate that Tordon 22K (treatment C) was superior to all other treatments in every month of the year. There was no apparent advantage in spraying at any particular time of day but in certain months of the year the plants were apparently more susceptible than in others. The term "apparently dead" in this table indicates a completely dry, rotten trunk and no visible living shoots on roots.

Table 2 demonstrates that concentrations of 0.8% to 2.0% picloram gave superior results compared to lower concentrations in eight months of the year. February, August, September and October treatments are all clearly better than treatments in other months of the year.

Table 3 summarises the rainfall and the phenology of the A. hockii during the experimental period. There were many exceptions, amongst the treated bushes, to the general phenology, but no relationship between arboricidal kill and any particular physiological bush condition could be found.

The long dry season extended from early June to the third week of August. It is noteworthy that young leaves were continually produced through this period. Flower buds were also initiated during this period, causing a cessation in shoot extension,growth, but most of them did not open until November. Seed pods first appeared, in appreciable numbers, in January and were mainly shed in March.

DISCUSSION

It is clear that A. hockii can be controlled by foliar sprays of picloram and that time of year of treatment is important. The fact that the highest kills were achieved in the August - October period and in February is difficult to explain in terms of the physiological condition of the majority of the plants at those times, because they were quite different. In the August - October period the plants were producing young leaves and shoot extension growth was giving way to bud development (buds are developed at the end of new shoots), whereas in February the plants were actively producing seeds and were not producing new leaves or shoots. A further indication of the unimportance of these parameters studied, was the fact that individual bushes deviating from the general phenology were not noticeably susceptible or resistant to the arboricide.

It is worth noting that both periods of maximum kill immediately followed a time of drought and both occurred during what could be a time of physiological stress. It is difficult to account for the relatively poor January result, for young seeds were then appearing and were, presumably, just as great a drain on the plant's resources as bud initiation or seed development. The high kills did not occur during the actual term of the drought and it cannot be postulated that the plants were dormant because leaves were being produced at that time.

Ivens (personal communication), working with A. drepanolobium, obtained different kill patterns with picloram; his maximum kills were associated with drought. Parker & Parker (1966) working with 2,4-D on Euclea sp. showed increased kill at times when root starch reserves were lowest and the plant was relatively dormant. In both these sets of results and those now presented, maximum kill was obtained at a time of full leaf but when shoot extension growth was not active. The time of maximum growth would seem to be the time to avoid spraying all three species.

It is important to point out that these results, collected in November 1967 only 8 months after the last month of treatment cannot be considered final. Twiga Chemical Industries Ltd. (1967) have demonstrated that Acacia drepanolobium Harms ex Sjostedt stumps treated with picloram, showed recovery over the period 6 to 14 months after treatment but subsequently this recovery growth died back and most of the plants succumbed. In the current trial the author considers it extremely unlikely that plants recorded as apparently dead are capable of recover. It is possible that more picloram treated plants may eventually died as many of those recorded as alive exhibited only trunk or roots that were not dead and the plants had been strongly affected by the treatment.

The individual spraying of bushes over large areas of rangeland is not a practicable proposition. The present results reveal the time of year to experiment with aerial spraying techniques and the formulations required.

Table 1

Number of apparently dead bushes in November 1967 after treatment (A-F) in the indicated month

(Treatments A-F listed above. Number in brackets indicate number of bushes treated. a = 07.30 b = 10.00 c = 14.00 d = 17.00 hr.)

Month	April 1966				May 1966				June 1966				July 1966			
Time	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
A (8)	-	-	-	-	2	1	1	-	-	-	-	-	1	1	-	-
B (8)	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
C (10)	1	2	-	3	4	6	4	5	7	3	6	6	5	5	4	2
D (10)	-	-	-	1	2	1	-	1	1	2	1	1	2	2	-	2
E (6)	1	-	-	3	-	-	-	1	-	-	-	1	2	-	-	2
F (5)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Month	Aug. 1966				Sept. 1966				Oct. 1966				Nov. 1966			
Time	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
A (8)	1	-	-	1	2	-	2	1	4	-	1	-	3	1	-	-
B (8)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
C (10)	10	4	6	8	6	5	4	6	5	6	5	6	1	1	2	4
D (10)	3	2	1	2	3	1	5	6	3	-	3	2	-	-	-	2
E (6)	2	1	2	5	3	3	4	3	2	-	4	1	-	-	-	1
F (5)	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-

Month	Dec. 1966				Jan. 1967				Feb. 1967				March 1967			
Time	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
A (8)	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-
B (8)	-	-	-	-	1	-	-	-	-	2	-	-	-	2	-	-
C (10)	-	1	1	6	4	5	3	2	5	7	5	2	6	5	1	4
D (10)	-	-	-	2	2	2	1	-	2	1	-	1	1	1	-	1
E (6)	-	-	1	2	1	-	-	1	-	-	1	-	3	1	-	-
F (5)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2

Percentage of bushes apparently killed by November 1967 by foliar applications of 22K at the full range of concentrations and at concentrations of 0.8% - 2.0% a.i.

Month	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
All concs.	15	48	55	40	65	53	55	20	20	35	48	40
0.8% + a.i.	30	45	55	25	80	70	80	35	30	45	70	30

Table 3

Rainfall and phenology of the majority of bushes during the experimental period

(Nil = -; Young = Y; Mature = M; Old = O; Decreasing = D; Increasing = I; *Affected by mass insect damage)

Month	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Leaves	O.Y	Y	Y.M.	Y.M.	Y.M.	Y.M.	Y.M.	D*	Y	M	M	O
Shoot growth	-	I	I	D	D	D	D	-	-	-	-	I
Flowers	-	-	-	I	I	I	I	Y	M	D	D	-
Seed pods	O	-	-	-	-	-	-	-	-	I	M	M
Rain (ins.)	4.2	3.2	1.4	0.3	2.1	6.3	2.0	3.4	1.2	2.4	0.6	2.6

Acknowledgements

The author is grateful to the Permanent Secretary, Ministry of Animal Industry, Game and Fisheries for providing the facilities for this work and granting permission to publish the results. He would also gratefully acknowledge the assistance of Mr. D.D. Thornton in planning and discussion of the experiment at all stages and Mr. B. Egonyu, who supervised the field work.

References

HARKER, K.W. (1957) The economics of weed control on grazing land. E. Afr. Agric. J. 23, 6-21.
(The First East African Herbicide Conference. Summary of papers and discussions. Duthie, D.W.)

HARKER, K.W. (1959) An *Acacia* weed of Uganda grasslands. Trop. Agric. Trin. 36, 45-51.

IVENS, G.W. (1960) Species of Acacias as weeds. Symp. Brit. Ecol. Soc. 1, 167-75.

PARKER, J.W.P.L. and PARKER, A.M. (1966) E. Afr. Agric. For. J. 22, (2), 117-125.

TWIGA CHEMICAL INDUSTRIES LTD. (1957) Whistling thorn control with Tordon. Technical service note for farmers.

Proc. 9th Brit. Weed Control Conf. (1968)

INSECTS AND MITES AS POTENTIAL CONTROLLING AGENTS OF WATER HYACINTH (EICHHORNIA CRASSIPES (MART.) SOLMS.)

F.D. Bennett
Commonwealth Institute of Biological Control
Gordon Street, Curepe, Trinidad

Summary Surveys have been undertaken in northern South America, the West Indies, British Honduras and Florida to determine whether insects and mites capable of restricting the growth rate of water hyacinth occur.

In South America and Trinidad, two Pyralids Acigona ignitalis Hmps. and Epipagis albiquttalis Hmps. cause appreciable damage and appear adequately host specific to warrant further investigations. Similarily the leaf mining Oribatid mite, Leptogalumna sp., the stem boring weevil, Neochetina bruchi Hust., the grasshopper, Cornops longicorne (Bruner) and the Dolichipodid fly, Thrypticus sp. merit further studies. In Jamaica, only Leptogalumna sp. is considered of interest. This species which also occurs in Florida may be conspecific with the South American material. The only species of interest encountered in British Honduras was a grasshopper, Cornops sp. In Florida, the Noctuid Arzama densa (Walker) which prior to the establishment of E. crassipes bred on Pontederia cordata successfully attacks water hyacinth and if adequately host specific may be useful elsewhere.

Host specificity tests with Acigona and Epipagis are currently underway in Trinidad.

INTRODUCTION

Water hyacinth, Eichhornia crassipes (Pontederiaceae) is considered to be the most serious aquatic weed in many of the areas where it occurs in the tropics and sub-tropics. Several million pounds are spent annually on controlling or confining this weed by chemical or mechanical means; as the costs are recurrent other methods of control are desired (Bennett, 1967).

The West Indian Station of the Commonwealth Institute of Biological Control has initiated preliminary investigations in the Neotropics, the area where E. crassipes originated, to determine whether there are insects and mites with the potential to restrict the rate of growth and spread of this plant yet adequately host specific, to permit their introduction into Africa and Asia.

METHOD AND MATERIALS

Surveys of varying intensity have been undertaken in Guyana, Surinam and the Amazon region of Brazil in South America, in Trinidad and Jamaica in the West Indies, and in British Honduras and Florida on the North American mainland. In South America and Trinidad, quantitative and qualitative data on damage were obtained by examining and splitting various parts of the plant, recording the incidence of various types of injury and rearing for identification the insects and mites associated with the damage. Elsewhere only qualitative information was obtained.

Other plants, particularly allied species, were also examined for comparable injury and the causal organisms.

Certain of the more promising insects occurring in Trinidad are currently being subjected to host specificity tests. In these experiments insects are confined to test plants to determine whether they cause significant damage and whether or not they can breed on plants apart from water hyacinth and other members of the Pontederiaceae.

RESULTS

Preliminary data on the fauna associated with E. crassipes in South America and Trinidad have been presented elsewhere (Bennett and Zwölfer, 1968). On the basis of field observations in South America and Trinidad it was recommended that six species be investigated further: Acigona ignitalis Hmps. and Epipagis albiguttalis Hmps. (both Pyralidae: Lepidoptera), Cornops longicorne (Bruner) (Acrididae: Orthoptera), Neochetina bruchi Hust. (Curculionidae: Coleoptera), Thrypticus sp. (Diptera: Dolichopodidae) and Leptogalumna sp. (Galumnidae: Acaridae). Arzama densa (Walker) (Noctuidae: Lepidoptera) found in Florida and also recorded from Louisiana is considered to be adequately host specific and to be adequately destructive to warrant further investigation. In British Honduras, Cornops was collected on E. crassipes. Host specificity tests with A. ignitalis, E. albiguttalis and C. longicorne are in progress in Trinidad.

a) Acigona ignitalis - A stem boring caterpillar occurring in Trinidad and on the mainland from Guatemala south to Uruguay, has been recorded only from species of Eichhornia and Pontederia (Silveira-Guido, 1965; Bennett and Zwölfer, 1968). In the field heavy attacks cause an unthrifty appearance to affected groups of plants recognizable at some distance. Individual plants are weakened severely or may be killed outright. Host specificity tests to date indicate that whereas larvae will feed on several plants e.g. members of the genera Commelina, Rhoeo, Murdamia and Tradescantia (Commelinaceae), Xanthosoma and Colocasis (Araceae), Oryza and Saccharum (Graminaceae) they are unable to complete their development on these plants either under laboratory or field conditions and prolonged feeding occurs only if the larvae are closely confined and without the option of moving elsewhere in search of another source of food.

b) Epipagis albiguttalis - This species is known only from Trinidad and South America and recorded only from E. crassipes (Bennett and Zwölfer, 1968). The larvae bore in the stems tend to be more gregarious and to prefer younger plants than those of the preceding species. It appears to be more heavily attacked by parasites than is A. ignitalis. Results of the feeding tests undertaken so far are similar to those with A. ignitalis and indicate that larvae under starvation conditions will feed on other plants but are unable to complete their development or to reproduce on plants outside the Pontederiaceae.

c) Cornops longicorne Bruner - A complex of species including C. longicorne and C. aquaticum apparently restricted to E. crassipes and other members of the genus occurs in South America, Central America and Trinidad. Eggs are laid in an ootheca within the stem. Both nymphs and adults feed on the leaves and petioles and cause severe defoliation. In Trinidad, C. longicorne has been collected only in localities where E. crassipes occurs, suggesting that it normally breeds only on this species. However, in the laboratory nymphs and adults feed readily on members of the Commelinaceae and to a lesser extent on several other plants including Oryza, Newly-hatched nymphs have been reared to adults on two species of Commelina but attempts to rear them on Oryza and Saccharum have been unsuccessful.

d) Neochetina bruchi - This weevil has been recorded from Guyana, Brazil, Uruguay and Argentina from Eichhornia spp., and Reussia sp. (Pontederiaceae). Adults feed on the leaves and oviposit in the leaf petioles. The larvae tunnel in the stems and basal portions of the plant and pupate within a cocoon amongst the root hairs. Field observations and limited tests in Trinidad indicate that this species is restricted to the Pontederiaceae. Detailed studies on its biology and host specificity are underway in Argentina (Dr. D. Perkins, pers. comm.).

e) Thrypticus sp. - One species or possibly a complex of species belonging to this genus occurs on E. crassipes in northern South America and Trinidad. The larvae of these small flies create and live in small tunnels in the petioles below water level. The effect of heavy attack on the rate of plant growth has not been assessed but this species may render plants more prone to attack by secondary organisms.

f) Leptogalumna sp. - Mites of this Oribatid genus have been encountered in South America, Florida and Jamaica on E. crassipes. Silveira-Guido (1965) also encountered similar or the same species on Eichhornia azurea (Schwatz) Kunth and Pontederia cordata L., but not on other unrelated plants. The mites make narrow elongate mines on the leaves; frequently there are fifty or more tunnels per leaf with an accompanying destruction of a high percentage of leaf tissue.

g) Arzama densa - This large stem borer occurs in the south-eastern United States. Apparently its normal host prior to the establishment of E. crassipes in the USA was pickerel weed, Pontederia cordata. Details of its biology and potential have been studied in Louisiana by Vogel and Oliver (1968 and in press). As this species is larger than A. ignitalis or E. albiguttalis the extent of feeding and tunnelling is much greater, and hence if adequately host specific may be useful elsewhere.

DISCUSSION

Surveys on the fauna associated with Eichhornia crassipes and related Pontederiaceae have revealed a complex of species with adequate destructive potential and apparent host specificity to warrant detailed studies.

Frequently when working on the biological control of weeds the initial phase i.e. the discovery of promising phytophagous species, is relatively simple. Later phases, including the identification of specimens, the development of techniques to adequately assess the potential and absolute host specificity may be much more difficult and time consuming. During the present investigation several species on which further studies appeared to warranted were found in less than three months actual exploratory work. Although testing procedures utilized for another aquatic weed project (Bennett, 1966) at first glance appeared to be applicable they have not proven entirely satisfactory. In tests undertaken with larvae of Acigona ignitalis and Epipadis albiguttalis both speices, when closely confined with sections of several plants, tunnelled readily and fed to some extent, but small larvae under these conditions did not survive to the pupal stage. However, the survival rate of larvae confined to E. crassipes, although better than on any of test plants, has been too low to permit a critical assessment. The results of tests involving living plants in cages when the larvae were less closely confined are perhaps of greater significance. Larvae fed less and tended to leave the test plants within 24 hours and even when replaced on or within the plants they usually did not remain. Huffaker (1964), has stated "It is unreasonable to insist that an insect be unable to engage in any feeding on some economic plant under forced or unnatural stress. The capacity to breed upon a given plant is the main criteron". To date there are no indications that A. ignitalis nor E. albiguttalis can breed on any plant of economic value, but additional tests with refined techniques are deemed necessary before these species can be recommended for introduction elsewhere

The assessment of the results of tests with Cornops longicorne and the decision as to whether or not the introduction of this species to new areas is perhaps even more difficult. Tests have shown that nymphs can devlop to the adult stage at least on one species not belonging to the family Pontederiaceae but this plant is not suitable for oviposition. It is of course, at least theoretically possible that Cornops in the absence of Eichhornia would oviposit in the stems of other plants which might not be suitable for nymphal development; the nymphs upon hatching would move to nearby Commelina or other acceptable food plants. Additional behavioural studies with C. longicorne are required.

Arzama densa, an insect attacking Pontederia cordata in the southeastern United States prior to the establishment of the alien E. crassipes now breeds readily in the latter. It does not exert an outright controlling effect on E. crassipes under Florida and Louisiana conditions where it is subject to attack by a large complex of natural enemies. Its effect on the rate of growth and spread of water hyacinth if introduced into new areas in the absence of these natural enemies should be more significant. Similarily in South America natural enemies of A. ignitalis, E. albiguttalis and C. longicorne occur; these may also play an important role in limiting the effect of their hosts. Consequently their potential for exerting a measure of control of E. crassipes in new areas in the absence of these enemies may be considerably greater than in their country of origin.

In conclusion, it may be started that whereas investigations have not reached the stage where recommendations for the introduction of biological control agents into Africa and Asia can be recommended the prospects that this will be possible within the next year or so are good.

References

BENNETT, F.D. (1966) Investigations on the insects attacking the aquatic ferns, Salvina spp. in Trinidad and northern South America. Proc. Southern Weed Conf. 19: 497-504.

BENNETT, F.D. (1957) Notes on the possibility of biological control of the water-hyacinth Eichhornia crassipes. PANS (C) 13: 4: 304-309.

BENNETT, F.D. and ZWÖLFER, H. (1968) Exploration for natural enemies of water hyacinth in northern South America and Trinidad. Water Hyacinth Control Jour. 7: (in press).

HUFFAKER, C.B. (1964) Fundamentals of biological weed control. Biological Control of Insect Pests and Weeds, Ed. P. DeBach, Chapman and Hall, London, 844 pp.

SILVEIRA-GUIDO, A. (1965) Natural enemies of weed plants. Final report (unpubl. cyclostyled report). Dept. Sanidad Vegetal, Univ. de la Repurblic, Montevideo, Uruguay.

VOGEL, E. and OLIVER, A.D. (in press) Life history and some factors affecting the population of Arzama densa Walker (Lep., Noctuidae) in Louisiana. Ann. Entomol. Soc. Amer.

VOGEL, E. and OLIVER, A.D. (1968) Evaluation of Arzama densa Walker as an aid to control of water hyacinth in Louisiana. J. Econ. Entomol. 61: (in press).

Proc. 9th Brit. Weed Control Conf. (1968)

PRELIMINARY SURVEY OF POTENTIAL BIOLOGICAL CONTROL AGENTS OF EUPATORIUM ODORATUM IN TRINIDAD

R. E. Cruttwell
Commonwealth Institute of Biological Control, Curepe, Trinidad

Summary *Eupatorium odoratum* L., native to South and Central America, is a serious weed in the Old World Tropics. Existing methods do not control it satisfactorily, and work has been started towards possible biological control in Nigeria. A survey of the plant and the associated insects, especially host specific forms, has been undertaken in Trinidad where *E. odoratum* is a wide-spread and abundant perennial weed.

The plant supports a large insect fauna. The Arctiid *Ammalo arravaca* Jordan has been studied and host specificity tests have been undertaken. Larval development was completed on three species of *Eupatorium* but not on any crop species tested. Other host specific insects suitable for investigation occur and the complex may restrict the abundance of *E. odoratum* in Trinidad. Accordingly the prospects for biological control in Nigeria are promising.

INTRODUCTION

Eupatorium odoratum L. a composite native to the Neotropics has been introduced into the Old World where it is now a serious pest in amy countries, e.g. India, Siam, Nigeria, etc. (Bennett & Rao, 1968). Mechanical control is ineffectual because of rapid regrowth from the roots and from seed, and herbicidal control is too expensive for the relatively low value land affected. It has been suggested, therefore, that the possibilities of biological control be investigated (op cit).

Preliminary studies in Trinidad were initiated in 1966; the aims were to investigate the following:-

1) The factors restricting *E. odoratum* in Trinidad, and responsible for preventing it reaching in the New World the pest status it has attained in the Old.

2) The insects living on *E. odoratum* in Trinidad, their life histories, and host ranges.

3) Any species of insect showing sufficient host specificity to *E. odoratum* to permit introduction into Africa and Asia, and yet capable of affecting the rate of growth of the plant.

METHODS USED

1. *E. odoratum* was examined in a number of localities to discover the different habitats occupied, and the modifications of form associated with these. Other species of *Eupatorium* were also studied. Three sites, chosen to represent the extremes of habitat in which *E. odoratum* is found, were used for regular

collections of all animals found on the plant: Simla, a damp area in a river valley of the Northern Range, where E. odoratum grows in shade in and at the edge of a citrus plantation; Curepe, an abandoned pasture field on good land which is overgrown by Cordia curassavica (Jacq.) R & S, Mimosa pudica L. and E. odoratum; St. Joseph, a piece of open rocky land on the cleared slopes of the Northern Range, exposed and with a poor soil. A unit of 1000 leaves was examined; also the length of stem was measured and the number of growing tips counted. The number of insects found were recorded and specimens were taken for rearing and identification.

2. During the flowering season, December-February, flowers were collected and dissected to obtain counts of the various insects present, some of which were reared to the adult stage for identification. Collections were also made from the flowers of other species of Eupatorium and from related and common Compositae, during and outside the flowering period of E. odoratum.

3. Experiments have been started to examine the factors limiting E. odoratum by planting established plants in unsuitable habitats, and following their fate. Individual plants have also been labelled and measured in an attempt to determine the average life span, the cause and time of death, and the method of replacement. An experiment has also been started to determine the effect of periodic defoliation. None of these experiments has yet been continued long enough to give results, but they may when completed confirm or contradict some theories about the factors limiting the distribution and abundance of E. odoratum in Trinidad.

4. An Arctiid moth, Ammalo arravaca Jordan selected as a promising insect for control, was bred in the laboratory, and the larvae tested for host specificity on a variety of economic plants. An attempt was made to record seasonal fluctuations in the population of this species both by light trapping adults and also recording larval abundance.

RESULTS

1. Ecology of E. odoratum:- E. odoratum is a common weed throughout Trinidad. It grows in all of the soil types found here, but will not grow in water-logged areas such as natural savannahs, where at times there is standing water. It grows in exposed sites if there is sufficient moisture. In shade, the plant becomes etiolated and will not grow in shade more dense than that of a fairly sparse citrus plantation. It is thus scarce in the forest which covers the hills of Trinidad, being present only along tracks and in clearings. Otherwise, throughout Trinidad, E. odoratum grows in abandoned and neglected fields and pasture, along roads, on building sites, and any similar open ground.

On good land, it forms dense bushes of a tangled mass of branched stems up to 6-10 feet in length. Flowering starts in late December and as it is photo-period controlled, all plants come into bloom together. In February and March after flowering, the leaves wither and the old stems may die; the extent to which they do so depends on the severity of the dry season, which usually lasts from January till May. New growth from the axils of the old leaves starts immediately after flowering if the rainfall is adequate, or, if the dry season is severe, with the start of the rain. The plants are perennial and regenerate rapidly from the roots if cutlassed or burnt. Reproduction is only by the seeds, which are wind borne, and produced in great numbers. The seeds are found everywhere and germinate chiefly after the rains start in June.

Table 1.

Oligophagous insects associated with E. odoratum

Attacking the leaves

Gelechiidae (Lep.) Trictotaphe eupatoriella Chamb. Leaf roller, also on E. ivaefolium

Tortricidae (Lep.) Sparganothis restitutana Wkr. Leaf roller, also on E. ivaefolium E. iresinoides H.B.K., Bidens pilosa L. and Wedelia caracasana D.C.

Arctiidae (Lep.) Ammalo arravaca Jordan. General feeder.

Agromyzidae (Dipt.) Gen. & sp. indet. Leaf miner.

Cecidomyidae (Dipt.) Gen & sp. indet. Forms galls, also on E. ivaefolium

Hispidae (Col.) Pentispa explanata Chap. Leaf mining larvae.

Attacking the growing tips and buds

Pyralidae (Lep.) ?Acrobasis sp. Galls stem tips, also on E. ivaefolium

Cecidomuidae (Dipt.) Gen. & Sp. indet. Galls bud leaves.

Attacking the stems

Cecidomyidae (Dipt.) Gen. & sp. indet. Galls stems, also on E. ivaefolium

Agromyzidae (Dipt.) Gen. & sp. indet. Bores in terminal shoots, also on E. ivaefolium.

Lamiidae (Col.) Aerenica hirticornis Klug. Stem borer, adults general feeders.

In the flowers

Pterophoridae (Lep.) Adaina bipunctata Moschl. On the achenes, also in E. iresinoides.

Tinecidea (Lep.) Recurvaria sp. On the achenes, also in E. iresinoides.

Agromyzidae (Dipt.) Melanagromyza minima Mall. On the achenes.

Cecidomyiidae (Dipt.) Sp. A. Gen & sp. indet. On corolla.
Sp. B. Gen & sp. indet. Inside achenes.
Sp. C. Gen & sp. indet. Galls achenes.

Trypetidae (Dipt.) Procecidochares flummensis Lima. On achenes.
Aciura insecta Loew. On achenes. (rare).

Oscinellidae (Dipt.) Olcella pleuralis Becker. On achenes and corolla, also of E. ivaefolium and E. iresinoides.

Curculionidae (Col.) Apion sp. Larvae on achenes, adults general feeders.

Lep. = Lepidoptera   Dipt. = Diptera   Col. = Coleoptera

2. Insects associated with E. odoratum:- Insects believed to be oligophagous are listed in Table 1. Alternate host plants are listed. Many other species, especially Heteroptera, Orthoptera and a few curculionids, staphylinids and chrysomelids may cause considerable damage, but are not listed because they are polyphagous. Most of the insects are present at all sites, but many are markedly more common at the shadier sites, i.e. at Simla and to a lesser extent at Curepe.

3. Host specificity tests with Ammalo arravaca:- The arctiid Ammalo arravaca breeds easily in laboratory cages, each female laying 50-180 eggs in the 3-4 days following emergence. The life cycle takes 40-60 days and breeding is continuous throughout the year, and all stages are present in the field at all times. Adults are attracted to a mercury vapour light trap, from 1-80 being caught in a single night. The larvae are solitary and nocturnal, returning to ground level at dawn, and consequently are hard to find. The eggs are laid on the underside of E. odoratum leaves, but are also seldom found. Possibly the adults caught in traps, which are mostly males, are attracted from a wide area.

In the laboratory, the larvae of A. arravaca defoliate plants and will also eat the buds, causing a considerable set back to the growth of the plant. Under natural conditions, on only one occasion did numbers build up to very high levels in a restricted area, till some plants were more or less completely defoliated. This outbreak lasted for four months and then subsided, probably because of parasite attack and a virus disease. Five species of tachinids were reared from the larvae, and a Scelionid Telenomus sp. from the eggs.

Although the caged females will oviposit on any surface if E. odoratum is not avialable, a series of laboratory tests shows the larvae to be highly host specific. (Table 2).

Table 2.

Plants utilised in host specificity tests with Ammalo arravaca

Negligible feeding, all larvae died	Larvae fed but did not pupate	Normal development occurred
Mikania micrantha H.B.K.	Eupatorium pyncocephalum Less.	Eupatorium odoratum
Vernonia cineria Less.	E. laevigatum Lam.	E. microstemon Cass.
Bidens pilosa L.	Calendula officinalis L. (Marygold)	E. ivaefolium L.
Parthenium hysterophorus L.	Tridax procumbens L.	
Eupatorium iresinoides H.B.K.	Emilia sonchifolia D.C.	
E. inulaefolium H.B.K.	Dahlia; Zinnia	
E. macrophyllum L.	Lettuce; Coreopsis	
Wedelia caracasana D.C.		

Normal development is thus only possible on three species of Eupatorium, and of these, E. ivaefolium and E. odoratum are closely allied and frequently hybridize whenever they grow in close proximity.

There are no references in the literature to any other host plants for A. arravaca; presumably it has never been reported to feed on any crop or garden plant.

DISCUSSION

E. odoratum is a common plant of open ground in Trinidad, but does not have the aggressiveness it shows in the Old World. For example, in India, it is reported to grow up to 20 feet high as a semi-creeper under teak (Moni & George, 1959); in Trinidad it never exceeds 10 feet in height, nor will it grow in the shade of tall teak. Also, although it regenerates rapidly from the roots after cutlassing in Trinidad, E. odoratum does not choke out other plants, and may itself be replaced, particularly in exposed positions where sensitive plant, Mimosa pudica and razor grass Paspalum virgatum L. grow. Insect attack may be an important factor in this, and in checking the growth of E. odoratum under partial shade. All insects, both polyphagous and oligophagous species, are markedly more common in shady sites, and in particular three insects, the Hispid Pentispa explanata, the stem boring Agromyzid and the gall forming Tineoid, present in large numbers in shaded positions, are scarce in exposed positions. Plants growing in shade are thus much more likely to have the growing tips destroyed, and their growth checked. It is suggested therefore that in the absence of insect attack, E. odoratum is capable of growing in shade denser than its limit in Trinidad, but under heavy shade the reduced light and the consequent etiolation have already weakened the plants, and they succumb to insect attack.

Experiments involving the placing in deep shade of healthy plants growing in tins are in progress. By comparing these with control plants, it is hoped to determine if there is any significant difference in insect damage, which might be responsible for the eventual death of the plants.

Regrowth after cutlassing is also often heavily attacked; up to 40% of the growing tips may be destroyed and the young leaves seem to be particularly subject to attack by the leaf eating Lepidoptera. The outbreak of Ammalo arravaca took place on 1-2 feet high regrowth two months after cutlassing. Such attack slows growth and allows other plants to compete more effectively for the available space.

The only physical factors which limit the growth of E. odoratum seem to be on the one hand lack of sufficient moisture in very rocky exposed soils; and on the other, the presence of standing water in poorly drained soils. In the latter the plants are actually killed by fungus attack preceded by yellowing of the leaves.

Of the insects associated with E. odoratum, the Arctiid Ammalo arravaca has been tested first, because it was the easiest to breed in large numbers, but other species are worth testing for host specificity. The Hispid Pentispa explanata and the Lamiid Aerenica hirticornis have one generation a year, with mating and egg laying occurring at the end of the dry season. The adults as well as the larvae feed on the plant, and can cause considerable damage. Both species are considered to be host specific and should be studied further. All other insects, except those in the flowers, are like Ammalo arravaca in that they breed continuously and asynchronously. This has the advantage that firstly, there would be no difficulty in synchronising their development with the seasons in Nigeria or elsewhere, and secondly, the populations go through eight or more generations in a year and can increase in numbers very rapidly, and follow local fluctuations in the plant more accurately.

The three species attacking the buds, the Cecidomyiid, the Agromyzid and the Tineoid, all cause considerable damage under field conditions, stunting and retarding the growth of the plant.

The stem galls caused by Cecidomyiid, which is heavily parasitised, seem to do little damage to E. odoratum in Trinidad, but E. adenophorum in

Hawaii has been largely controlled by Procecidochares utilis Stone (Bess and Haramoto, 1956). This Trypetid forms galls very similar to the Cecidomyiid galls on E. odoratum and when present in large numbers, severely stunts the plant. It is possible therefore that if adequately host specific the Cecidomyiid freed of its parasites could assist in the control of E. odoratum in Nigeria.

The other leaf eating lepidoptera, Trichotaphe eupatoriella and Sparganothis restitutana are common insects but do little significant damage. In laboratory cages they can defoliate plants but breed slowly. The larvae are not very mobile, so the oviposition habits of the female as well as the host range of the larvae would be an important criteria.

The flowers are attacked by several species, some of which, notably the weevil, Apion, the Trypetid Procecidochares flummensis and the Agromyzid Melanagromyza minima can among them destroy the achenes in nearly 100% of the capitula by late February and March. However, insects attacking the flowers are unlikely to be successful in controlling E. odoratum because the first, and main, flowing is only lightly affected, less than 12% of the capitula being attacked. All plants flower together, and the populations of phytophagous insects apparently take some time to reach their maximum numbers. Freed of their parasites, the phytophagous species might increase to the point where the initial population of survivors from the previous year were numerous enough to destroy a significant number of the first crop of seeds, but it seems unlikely.

In conclusion, preliminary surveys of E. odoratum in its native country seem to indicate that biological control of this plant should be perfectly feasible. There are several promising insects attacking different parts of the plant, and some at least should prove sufficiently host-specific to be safe to introduce into Nigeria and other countries. The next step is to start breeding programmes and host specificity tests on other insects, and to extend the range of the food tests with the Arctiid Ammalo arravaca.

Acknowledgements

Identifications of insects provided by the Commonwealth Institute of Entomology are gratefully acknowledged.

References

BENNETT, F.D. and RAO, V.P. (1968) Distribution of an introduced weed Eupatorium odoratum L. in Asia and Africa and possibilities of its biological control. Proc. 9th Common. Forestry Conf. 7 pp.

BESS, H.A. and HARAMOTO, F.H. (1965) Biological Control of Pamakani in Hawaii. Proc. X Int. Congr. Ent. 4: 543-548

MONI, N.S. and GEORGE, M.P. (1959) Eupatorium odoratum, a common weed found in the teak plantations of Kerala State. Indian Forester 85, 728-730

Proc. 9th Brit. Weed Control Conf. 1968

MINIMUM CULTIVATIONS FOR CEREALS ON THE EXPERIMENTAL HUSBANDRY FARMS

L. W. Wellings
National Agricultural Advisory Service
Gleadthorpe Experimental Husbandry Farm, Welbeck Colliery Village, Mansfield, Notts

Summary Phased trials were laid down on five Experimental Husbandry Farms in 1964 to study the long term effect of direct drilling, shallow rotovation and ploughing on the yield, weed flora and soil conditions under cereals. Two wheat crops followed by barley have been grown after a ley killed with paraquat on soils ranging from sandy loam to heavy clay.

Six crop failures have occurred in twenty seven crops due to unsuitable drills and serious damage by slugs on one farm. On the successful crops yields following ploughing have been 8% above those following direct drilling and 10% higher than rotovation. Response to nitrogen has been similar following all cultivation treatments.

Grass weeds have increased under conditions of direct drilling or rotovation without chemicals and now constitute the major problem. With available chemicals some cultivation appears to be necessary for successful cereal production.

INTRODUCTION

Until the advent of herbicides, cultivation was necessary to control weeds but work at Rothamsted led to the conclusion, "That farmers had over-estimated the virtues of cultivation in so far as they affected soil tilth and that the principal criterion of good tillage was in its efficiency for weed control". Russell (1966)

The introduction of herbicides raised the question of the need for cultivation but the early chemicals available were either ineffective against some plant species or had undesirable residual activity.

The discovery of the bipyridyl herbicides, particularly paraquat, has made chemicals available which overcome most of these disadvantages and have enabled annual crops to be grown without cultivation. Work on the production of cereals without ploughing has been reported by a number of workers notably, Arnott and Clement (1966), Hood (1965) and Jeater (1966).

The first attempt to eliminate the plough on the Experimental Husbandry Farms was made at Boxworth in 1963 when spring wheat was sown without cultivation after a ley had been killed by paraquat, Whybrew (1968). Although the seed had only been sown with a normal disc drill, the grain yield was 70% of that of a crop grown on an adjacent ploughed area. Work was expanded onto five Husbandry Farms in 1963/4 with the object of finding suitable machinery for direct drilling, Whybrew (1965). Yields from the limited cultivation treatments were similar to those from crops grown on ploughed land although machine performance was generally poor.

The chief problem at this time apart from the mechanical one of sowing the seed appeared to be that of the long term effects of no or limited soil disturbance. It was decided to lay down long term trials on five Experimental Husbandry Farms to study the effects of varying amounts of soil disturbance on cereal yields, weed flora, and soil conditions. Details of the farms taking part are as follows:-

Farm	Annual rainfall (in.)	Soil texture	Soil series	Parent material
Gleadthorpe (Nottinghamshire)	24	Stony sandy loam	Newport	Bunter pebble beds
High Mowthorpe (Yorkshire)	30	Silty loam	Andover	Loess material overlying chalk
Bridget's (Hampshire)	30	Silty loam	Andover	Loess material and clay with flints overlying chalk
Rosemaund (Herefordshire)	26	Stoneless silty loam	Bromyard	Old red sandstone
Boxworth (Cambridgeshire)	22	Chalky boulder clay	Hanslope	Boulder clay

METHOD AND MATERIALS

Three cultivation treatments are compared on each farm:-

1. Ploughing followed by the necessary cultivation to produce a normal seedbed
2. One pass of a rotovator annually to give a shallow loose tilth for the germinating crop
3. Direct drilling into undisturbed soil

An additional direct drilled plot was added to each replicate to allow remedial measures to be taken if this should become necessary on a direct drilling system. Each cultivation treatment has four nitrogen levels applied to split plots.

The trials are phased with two intake years at Rosemaund and four intake years at all other centres. Each phase has two replicates which are cropped with two wheat crops followed by two crops of barley in the first four years of the trial. The first crop of wheat in each intake year follows a ley killed with paraquat. Subsequent herbicide treatment is determined by the weed flora present.

Drills designed to place seed into a loose tilth are unsuitable for hard soil conditions. None of the machines tested in 1963 were satisfactory but a disc and knife coulter modification of the Massey 735 drill developed by Plant Protection Limited, gave rather better results. Two of these drills were loaned for work on the Experimental Husbandry farms and were used to drill all the plots before spring 1967. Subsequently triple disc drills (Jeater 1966) again loaned by Plant Protection Limited, have been used. These are a considerable improvement on the original drills but need careful adjustment to work satisfactorily in all soil conditions.

RESULTS

Effect of paraquat on leys

It was recognised at the outset that starting a direct drilling system from grass was likely to present difficulties in killing the large amount of vegetation and the necessity to spray twice to kill the ley on some occasions reflects the need for experience to obtain optimum results. Table 1 shows the amount of paraquat used to kill the leys before coming into the first wheat crop.

Table 1

Use of paraquat before first wheat crop lb a.i. per acre

Farm	Year			
	1964	1965	1966	1967
Boxworth	2 + 1	2 + 1	1 + 1	1
Bridget's	2 + 2	1½	2	2
Gleadthorpe	2	1½	1½	1½
High Mowthorpe	2	1½	1 + 1	1½
Rosemaund	2 + 1	1½ + ½		

Crop establishment

Great difficulty has been experienced in establishing crops on many occasions during the period of these trials. In the dry conditions of the autumn of 1964 penetration of the hard soil proved a major problem and no crop was established at either Bridget's or Boxworth. A poor crop emerged at Gleadthorpe and must also be counted as a failure. Successful crops were grown at High Mowthorpe and Rosemaund.

In 1965 penetration was no problem in wet soil conditions but Bridget's had a severe attack of slugs which were not fully controlled by metaldehyde.

1966 was more successful and good crops were established on all farms. Bridget's have had so much trouble controlling weeds and slugs that it was decided to abandon the trial on this site after four crop failures in four years.

Yields

Yield comparisons are given for those crops where there has been good crop establishment on all cultivation treatments. Eleven comparisons of the effect cultivation on the yield of the first wheat crop have been made out of a possible fifteen. Six yield comparisons of second wheat crops have been made out of a possible nine of which one had no ploughed comparison and one had to be planted to barley instead of wheat due to excessive grass growth in the autumn.

Four successful barley crops have been harvested. The effect of cultivation treatment on yield of the successful crops is shown in Tables 2 to 4.

Table 2

Yield of wheat following leys killed with paraquat, cwt/acre at 15% m.c.

Farm (No. of crops grown)	Cultivation treatment: Ploughed	Shallow rotovation	Direct drilled
Boxworth (2)	34.0	32.0	38.2
Bridget's (2)	32.9	27.9	27.0
Gleadthorpe (2)	40.0	37.2	37.2
High Mowthorpe (3)	33.5	36.1	33.6
Rosemaund (2)	43.8	42.2	36.8
Mean (11)	36.8	35.1	34.5

3

Table 3

Yield of second wheat crop after ley
cwt/acre at 15% m.c.

Farm (No. of crops grown)	Cultivation treatment: Ploughed	Shallow rotovation	Direct drilled
Bridget's (1)	34.6	24.1	32.8
Gleadthorpe (2)	30.0	26.0	33.9
High Mowthorpe (2)	33.5	33.6	30.8
Rosemaund (1)	38.5	28.4	24.2
Mean (6)	34.2	28.0	30.6

Table 4

Yield of barley following wheat
cwt/acre at 15% m.c.

Farm (No. of crops grown)	Cultivation treatment: Ploughed	Shallow rotovation	Direct drilled
Gleadthorpe (1)	39.6	22.9	35.3
High Mowthorpe (1)	37.9	38.5	33.4
Rosemaund (2)	29.4	22.2	23.8
Mean (4)	34.1	26.5	29.1

When crops have been established on all cultivation treatments the yields of wheat after a ley have been as good following direct drilling as ploughing and normal seedbed preparation at Boxworth and High Mowthorpe. At Bridget's and Rosemaund yields have been distinctly worse following direct drilling which has given slightly lower yields at Gleadthorpe.

Shallow rotovation has given consistently good yields at High Mowthorpe but at other centres has tended to give yields which are intermediate between those from ploughing or direct drilling for the first wheat crop. In subsequent crops shallow cultivation has continued to give good yields at High Mowthorpe but has severely affected yields at Bridget's and Gleadthorpe.

Effect of period under cultivation treatment

Three farms have grown three successive crops under the cultivation treatments and the comparative yields from the extreme treatments of ploughing and direct drilling are shown in Table 5.

Table 5

Yield from direct drilling as percentage of ploughed yield in successive crops

Farm	1st crop	2nd crop	3rd crop
Gleadthorpe	93	112	90
High Mowthorpe	102	94	90
Rosemaund	87	65	80

In general there appears to be little evidence that continued direct drilling leads to a progressive reduction in yield compared with the ploughed treatment, although the yields at High Mowthorpe show a trend in this direction.

Effect of nitrogen

There have been limited responses to nitrogen at Boxworth and Rosemaund and good responses at the other centres. Table 6 shows the response to nitrogen on 12 crops of wheat at Bridget's, Gleadthorpe and High Mowthorpe.

Table 6

Effect of cultivation treatment and nitrogen level on the yield of winter wheat, cwt/acre at 15% m.c.

Nitrogen units/acre	Cultivation treatment Ploughed	Shallow rotovation	Direct drilled
0	26.2	23.3	25.8
30	33.3	31.7	31.5
60	37.4	34.3	36.4
90	38.8	37.2	36.8
Mean	33.9	31.8	32.6

At the nitrogen levels used general responses are similar under all cultivation treatments although there is a suggestion that marginal responses are continuing on the ploughed areas whereas the direct drilled areas have reached peak yield.

DISCUSSION

Yields have been quoted in some detail and if all problems of the direct drilling technique are resolved the effect on yield must be one of the main factors in determining its adoption. The early crop failures were due largely to mechanical problems. The triple disc drill has given good results although it has not been tested in hard soil conditions on the Husbandry Farms. Some operation is necessary to close the slits after drilling to prevent seed losses to birds and rodents and both chain harrowing and rolling have proved effective.

Yields from ploughed plots have generally been similar to or better than the normal for the farm field yields with the exception of Boxworth where first year wheat field yields are 40 to 45 cwt per acre. Plot yields of 34 cwts are therefore some 10 cwt below expectation and the cultivation comparisons at Boxworth should be viewed with this in mind.

The slits left by the drill have provided a good environment for slugs and they have become a serious problem at Bridget's where Metaldehyde failed to give control. The slug problem together with a build-up of onion couch (Arrhenatherum elatius) led to the trial being abandoned on this site. Slug damage has occurred on the other farms with the exception of Gleadthorpe but not so seriously as to cause crop failures.

It was recognised that a ley was a difficult starting point for direct drilling due to the large amount of vegetation to be killed and the frequent need to spray twice at the beginning of the trials was due to inexperience. The importance of reducing the amount of herbage was not appreciated and many shoots were protected from the spray and continued to grow after treatment. If the quantity of vegetation is reduced, and hard grazing with a two to three week regeneration period appears to be the best way of doing this, a good kill can be obtained.

Many leys mask perennial grass weeds particularly couch (Agropyron repens), common bent grass (Agrostis gigantea) and creeping bent (Agrostis stolonifera) and these have spread in the absence of cultivation or where cultivation is limited. Crop failures, low nitrogen rates and the experimental use of blocked coulters have all helped to exaggerate the problems on the trial areas but field scale direct drilling on infested land would lead to similar results.

Rough stalked meadow grass (Poa trivialis) has been a particular problem at Rosemaund making it necessary to spray twice on occasions and was so severe in the autumn of 1966 that winter wheat could not be sown.

The grass weed problems can be avoided by direct drilling into clean stubbles. Not only can weed free fields be chosen but herbicide rates can be reduced and coulter penetration is made easier.

Broad leaved annual weeds have been kept under control by the available range of herbicides. Perennial broad leaved weeds are not a problem on any site to date but there is a tendency for these to increase under conditions of no cultivation and normal dosage rates of hormone chemicals. Spot treatment is likely to be necessary from time to time.

With the exception of High Mowthorpe shallow rotovation has given poor results due to one of two factors:-

1. On heavy soils the use of a three bladed rotovator has produced too fine a tilth for autumn sowing and the land has tended to run together during the winter.
2. In the absence of any herbicide, grass weeds have not been killed and the emerging crop has met severe competition with a consequent effect on yield.

The first problem is being tackled by the use of a two bladed rotovator to give a rougher finish and it has now become apparent that limited cultivation will need the assistance of a herbicide to give adequate weed control.

During the course of the trial period the relative significance of associated problems has changed. Initially the mechanical problem was the most important but the development of the triple disc drill has been a great step forward. At the time of writing grass weeds are a problem in some way or other on all farms. Control without some cultivation is expensive and there is a need for a more effective cheap chemical against grass weeds if direct drilling as a system is to become a practical reality.

Until a suitable chemical is developed a compromise using chemicals and limited cultivation offers the best way of reducing labour and power requirements in cereal production.

Acknowledgements

I wish to thank my colleagues on the five Husbandry Farms for their work in the field under difficult conditions and their assistance in the preparation of this paper; the Statistics Department at Rothamsted Experimental Station for analysis of the trial data and to Plant Protection Limited for the loan of drills without which the work could not have been carried out.

References

ARNOTT, R.A. and CLEMENT, C.R. (1966) The use of herbicides in alternate husbandry as a substitute for ploughing. Weed Res. 6 (2) 142-157.

HOOD, A.E.M. (1965) Ploughless farming using "Gramoxone". Outl. Agric. IV 286-294.

JEATER, R.S.L. (1966) Agronomic aspects of direct drilling. Proc. 8th Brit. Weed Control Conf. 3 874-883.

RUSSELL, E.W. (1966) The soil problems of minimum tillage. Proc. 8th Brit. Weed Control Conf. 3 890-893.

WHYBREW, J.E. (1965) Minimum cultivations for cereals. Experimental Husbandry Farms and Experimental Horticultural Station. Sixth Progress Report, 24-25.

WHYBREW, J.E. (1968) Experimental Husbandry Farm experience with herbicides and tillage systems for cereal growing. N.A.A.S. Quart. Rev. No. 80, 154-160.

7

'Proc. 9th Brit. Weed Control Conf.1968'

APPLICATION OF HERBICIDES AS AN ALTERNATIVE TO PLOUGHING AND CULTIVATION IN SUNFLOWER AND WHEAT PRODUCTION

Zdravko Kosovac

Institute of Agricultural Research
Novi Sad, Yugoslavia

Summary In the semi arid conditions in the area of chernozem soil, the use of paraquat and prometryne as a substitute for deep ploughing in intensive sunflower production, is only possible for a limited time. Omission of ploughing for some years leads to an increase of perennial weeds, resulting in decreased yields compared with annual ploughing. However, by alternating sunflower and winter wheat, the omission of ploughing for three consecutive years did not result in any marked changes in the physical or chemical properties of the soil.

INTRODUCTION

Herbicides have already made possible substantial changes in the cultivation of sunflower and other wide-row crops. The application of herbicides has allowed intensive sunflower production without cultivation by hand, and even without cultivation between rows (Kosovac 1965.)

The increasing possibility of efficient chemical weed control has raised the question of crop production without basic soil tillage (Hood et al 1963, 1964.)

METHOD AND MATERIALS

A comparative examination was made of the following variants of basic soil tillage:-

Plough to a depth of 30 cm without herbicide
Shallow discing to a depth of 5 cm with herbicide

Tillage was carried out about a month after harvesting winter wheat prior to sunflower. The disced areas were treated, about a month later, with 1.0 kg of paraquat in 300 l. water/ha.

In both cases a pre-emergence treatment of sunflower was carried out with the following herbicides:-

prometryne 1.5 kg a.i./ha
linuron 1.0 kg a.i./ha.

During the growing period two inter-row cultivations were carried out in all plots, but no hand cultivation was done.

The same soil tillage was applied on the same areas after the sunflower harvest and removal of its stalks before winter wheat as the next crop.

Fertilizers were invariably applied in total amounts of 100 kg N_2, 80 kg P_2O_5 and 80 kg K_2O per hectare. Phosphorus and potassium fertilizers, as well as one third of the nitrogen, were applied before the basic tillage and as starter fertilizers with the seeding, while the remainder of the nitrogen was applied as topdressing with cultivation between rows.

Sunflower seeding was carried out by hand with narrow hoes, while wheat seeding was done with the classical Ferguson seed drill.

Agrochemical and physical analyses of the soil were conducted after the methods described in detail by Vučič (1964).

RESULTS

The effects of no ploughing on sunflower yields are presented in Table 1.

Table 1.

Effect of no ploughing with application of herbicides on sunflower yields

Herbicides		Seed yield - Centners/ha					
		Ploughing 30 cm			Discing 5 cm		
		1966	1967	1968	1966	1967	1968
Paraquat + prometryne 1+1,5 kg a.i./ha		36,95	24,81	25,40	35,48	24,10	21,77
Paraquat + linuron 1+1,5 kg a.i./ha		36,00	24,90	25,20	35,63	24,26	22,79
LSD	5%	1,49	2,37	3,43			
	1%	1,99	3,18	4,60			

In 1966 and 1967, no differences were found in sunflower yields. In the third year of consecutive omission of ploughing, a significantly lower yield was obtained. We consider the reason for this to be the increase of Convolvulus arvensis L., whose injurious effect on the development of sunflower crops was intensified by the extreme drought from the very start of vegetation in this year.

Table 2 shows the weed position just before harvest in 1968.

Table 2.

Effect of continued no ploughing on weed growth in sunflower crops in 1968

Herbicides	Number of weeds per m^2					
	Ploughing 30 cm			Discing 5 cm		
	Total	C.arvensis	D.sanguinalis	Total	C.arvensis	D.sanguinalis
Paraquat + prometryne 1,0 + 1,5 kg/ha	18,0	1,5	14,0	601,3	18,0	565,0
Paraquat + linuron 1,0 + 1,0 kg/ha	17,1	2,1	8,0	713,5	18,0	691,0

As a result of weaker growth of the sunflower crop under the influence of C.arvensis, there was a mass occurrence of the weed species Digitaria sanguinalis L., on unploughed land at the end of the growing period. In our opinion the very late occurrence of this weed could not have had any considerable effect on the yield.

On analysis, no differences in oil content were found between crops grown on ploughed land and those where ploughing was omitted. The yield decrease in the third year of no ploughing had no effect on the oil content in sunflower seed, but led indirectly to a reduction of the amount of oil produced per hectare.

The results of no ploughing plus herbicide application on the yield of the following winter wheat also without ploughing, are presented in Table 3.

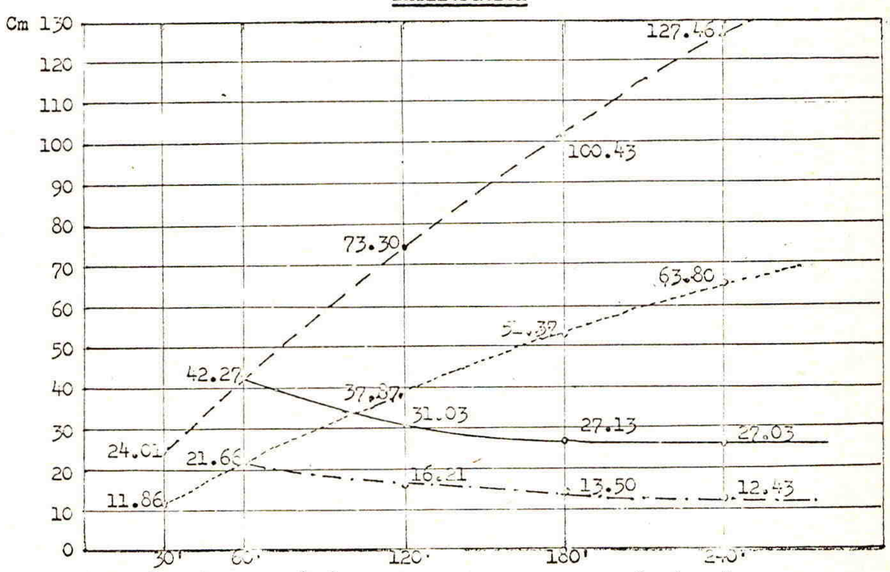
Table 3.

Effect of no ploughing on the yield of wheat following a sunflower crop

Herbicides (applied to sunflower)		Seed yield - Centners/ha				
	Ploughing 30 cm			Discing 5 cm		
	1966	1967	1968	1966	1967	1968
Paraquat + prometryne 1,0 + 1,5 kg/ha	47,90	41,90	39,33	48,20	41,83	43,84
Paraquat + linuron 1,0 + 1,0 kg/ha	48,10	42,61	38,68	47,95	42,32	41,26
LSD 5%	3, 25	2,81	3,67			
LSD 1%	4, 36	3,77	4,92			

Fig. 1.

Infiltration



Accumulated intake (cm) and instantaneous intake (cm/hour) rate.
- - - - - Oranje na 30 cm - Ploughing to 30 cm
. . . .
-.-.-.-.- Tanjiranje na 3 cm - Discing to 5 cm

The no ploughing system did not affect the yield of wheat following sunflower in any of the three years of the experiment. Surprisingly, in 1968 there was even a yield increase when ploughing was omitted for the third consecutive year, and when the weather conditions were extremely dry throughout the growing period.

All plot treatments were examined for soil moisture content throughout the season and the results indicated that there were practically no differences in soil moisture under a sunflower crop where ploughing was omitted, as compared with the moisture content where ploughing was carried out. Characteristically, no ploughing in the second and third year did not result in any difference in soil moisture content under a sunflower crop as against the same crop on ploughed land.

Water infiltration after three years of consecutive omission of ploughing and application of ploughing, immediately after the sunflower harvest, is shown in Figure 1.

Water infiltration was reduced in unploughed soil, but remained within normal limits for this soil type.

Table 4.

Moisture and physical soil properties

	Ploughing 30 cm			Discing 5 cm		
	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
Volume weight	1,26	1,25	1,25	1,30	1,28	1,26
Porosity (vol.%)	51,72	52,65	51,55	50,94	51,14	51,90
Air holding capacity	21,93	23,33	21,32	20,53	20,65	22,15
Water retention (0,33 at.)	29,79	29,32	30,53	30,41	30,49	29,75
Water permeability C-Darcy	$3,4x10^{-3}$	$4,8x10^{-3}$	$4,5x10^{-3}$	$2,4x10^{-3}$	$4,9x10^{-3}$	$3,5x10^{-3}$

Table 5.

Aggregate composition % (dry sieving)

Fraction size mm	Ploughing 30 cm				Discing 5 cm			
	0-5 cm	5-10 cm	10-20 cm	20-30 cm	0-5 cm	5-10 cm	10-20 cm	20-30 cm
> 9,52	7,13	10,34	9,00	8,39	9,83	8,82	8,85	7,03
9,52-7,00	8,56	12,85	12,51	10,38	11,96	8,67	9,43	11,71
7,00-4,76	5,71	7,50	8,28	8,10	7,50	6,26	7,60	7,36
4,76-3,36	6,37	8,48	8,77	8,27	7,42	8,15	8,59	8,86
3,36-2,00	11,28	14,50	14,38	14,74	11,74	16,86	16,00	17,54
2,00-1,00	19,24	18,64	19,64	20,84	18,49	23,63	21,98	21,76
1,00-0,50	19,55	14,22	14,74	15,63	16,94	16,50	15,67	14,47
0,50-0,25	12,90	8,24	7,91	8,37	9,97	8,10	8,03	7,25
< 0,25	9,17	5,23	4,77	5,28	6,15	3,80	4,15	4,02

In the moisture and physical soil properties analysed, no essential differences were found between soil regularly ploughed for three years and that unploughed over the same period, which is also an indication of the stability of natural properties of chernozem soil.

After three consecutive years of no ploughing, there were also no noteworthy changes in soil structure. The percentage of pulverised small particles under 0.25mm was smaller in unploughed soil, which indicates a mild positive influence of no ploughing on soil structure.

Table 6.

Chemical composition of the soil after three years of consecutive omission of ploughing

	Ploughing 30 cm			Discing 5 cm		
	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
PH/KCl	7,16	7,10	7,22	6,95	7,20	7,10
PH/H_2O	7,81	7,72	7,80	7,35	7,76	7,78
Humus %	3,09	2,98	2,44	3,60	2,36	2,00
N_2%	0,181	0,157	0,151	0,190	0,167	0,155
P_2O_5 mg/100 g	12,8	11,7	11,4	20,3	7,3	6,4
K_2O	18,9	19,2	24,2	22,70	15,20	16,70

Chemical analyses of unploughed and ploughed land after three years have only revealed noticeable differences in the phosphorus and potassium content throughout the soil profile.

DISCUSSION

The above results indicate that, intensive alternating production of sunflower and winter wheat is possible for a certain time without ploughing, with weed control by herbicides. This also means that the role of ploughing in the production of field crops can be reviewed. Until now, ploughing has been considered indispensable, because loosening and inversion of the deeper soil layer allows the physical, chemical and biological processes in the soil to be brought to an optimum state for the growing of the next crop. The results demonstrate that ploughing as applied to a normal soil type, such as chernozem, is necessary for the purpose of weed control, but that this role of ploughing can be replaced by the use of herbicides. Herbicides used for this purpose must be as efficient as deep ploughing. The present work indicates that on unploughed land perennial weeds increase after a few years. With the principal wide-row crops, this problem seems insoluble at present. It follows that on soil previously deep-ploughed, the period during which crops can be grown without ploughing must be limited to the relatively short period in which there is no build-up of perennial weeds. The results suggest that this period can be extended if wheat is followed by sunflower in a no ploughing system. This crop sequence allowed three years or more before yields dropped, compared with only two in the opposite case.

The use of paraquat as a substitute for ploughing for sunflower after winter wheat, is only partially successful, though this part is significant. Generally, weeds develop after wheat harvest and especially after shallow tillage of the stubble. In earlier practice, the need for their control was the reason why deep tillage was considered necessary. Paraquat spraying after the wheat harvest kills weeds already germinated, which makes tillage for this purpose unnecessary. However, paraquat cannot completely achieve the same efficiency of, and particularly, the duration of control as deep soil tillage. On chernozem this is confirmed by the finding that on unploughed areas treated with this herbicide,at the end of the Summer 1967, there was a much greater growth of weeds at sunflower seeding time the following Spring, than was the case on deep ploughed areas. It is possible that these weeds could be efficiently controlled until crop emergence by another treatment with paraquat, but this, apart from the question of economics, could not prevent a severe weed infestation on unploughed areas after crop emergence. Ploughing and hand cultivation of the sunflower crop can only be completely replaced by an application of paraquat in the previous Autumn, plus certain pre-emergence herbicides, which successfully control any weeds which emerge before the crop and during its growing period. Pre-emergence herbicides applied to sunflower also play a decisive role in the production of winter wheat without ploughing, because they maintain the sunflower crop practically free from weeds till the end of the growing period. This makes possible, after the sunflower harvest, a weed-free seeding and provides normal development for the wheat crop much more economically without the need for pre-emergent paraquat applications or other selective herbicides.

References

HOOD, A.E.M., JAMESON, H.R., COTEREL, R. (1963) Destruction of pastures by paraquat as substitute for ploughing, Nature. 197, 748.

HOOD, A.E.M., SHARP, D.G., HALL, D.W., COTEREL, R. (1964) The use of paraquat as an alternative to ploughing, Proc. 7th Brit. Weed Control Conf. 907-912.

KOSOVAC, Z. (1965) Uticaj primene herbicida i izostavljanja okopavanja na proizvodnju suncokreta na černozemu, Savremena poljoprivreda, 9, 743-750.

KOSOVAC, Z. (1965) Mogućnosti izostavljanja okopavanja u proizvodnji suncokreta na černozemu promenom herbicida, Zbornik radova Instituta za poljoprivredna istraživanja u Novom Sadu, 3, 187-200.

VUČIĆ, N. (1964) Water Properties of Chernozem and Chernozem-like Meadow Soil and Their Significance for Irrigation on the Irrigated Area of Bačka, Savremena poljoprivreda, 1, 3-95.