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ETHYLENE AND AUXINS AS DEFOLIANTS

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Summary Leaf fall and the processes of abscission can be accelerated both by ethylene and auxins although the two kinds of growth regulators act in opposition. These mechanisms are discussed in relation to the defoliation of tropical trees.

INTRODUCTION

The esters of synthetic auxins have now been used for chemical defoliation of tropical evergreen species for nearly twenty years. The earliest experiments for this potential use were those carried out in 1949 and 1950 in East Africa and were concerned with the attempts to defoliate areas of bush in order to render them unsuitable habitats for the tsetse fly (Holly, 1952).

The n-butyl esters of both 2,4-dichloro- and 2,4,5-trichlorophenoxyacetic acids (2,4-D and 2,4,5-T) proved to be remarkably effective in causing premature leaf fall in a large variety of trees and shrubs. The biochemical and physiological mechanisms by which this premature leaf abscission is brought about has until recently been obscure.

Under natural conditions, a leaf undergoes abscission only when the blade and petiole are yellowing and senescent or when the leaf is subjected to water or temperature or other environmental stress which induces many changes in the leaf similar to those that occur during senescence. A leaf which is green and synthetically active or non-senescent does not undergo abscission.

If the blade is removed, the petiole stump usually becomes yellow and senescent within a matter of days and separates from the stem, but the application of an auxin to the debladed stump will preserve it green and attached for many weeks. An auxin can therefore, substitute for a leaf blade in preventing abscission and much evidence is available to support the view that as long as the auxin content of a blade is high, yellowing and senescence of blade and petiole do not occur and the leaf does not fall (Addicott, 1964).

Why then, does an application of a synthetic auxin to the leaf of a tropical evergreen cause that leaf to fall prematurely ?

We now believe that the trigger which is responsible for defoliation in the auxin treated leaves is the gas, ethylene.

Four major points lead us to this thesis.

1) Some of the earliest records of the effects of ethylene on plants have reported the very rapid abscission of leaves (Crocker, 1948). Plants exposed to even a few ppm in the air can lose all their leaves by abscission in a matter of 2 or 3 days, the oldest leaves being the first to be shed. The youngest leaves which are those of highest auxin content are shed last.

2) The leaves that are shed show many of the biochemical symptoms of senescence including a loss of green colour. Indeed, ethylene gas is one of the most effective accelerators of leaf senescence.

3) Ethylene has also been detected as a natural volatile product of practically all

organs and species of plants that have been examined so far. In green plants it has been found that the youngest leaves which are highest in auxin content produce the greatest quantities of ethylene. Senescent, yellow leaves may produce practically none. Morgan and Hall (1962) were the first to show that when the natural auxin, indole-3-acetic acid, or the synthetic auxin 2,4-D, are supplied to leaves their natural ethylene production can be increased many-fold within 24 hours.

4) Although auxins stimulate the natural production of ethylene, the effects of the ethylene so produced can be overcome or negated if sufficient auxin is present in the tissue. For example, if isolated abscission zones of primary leaves of the bean (*Phaseolus vulgaris*) are exposed to ethylene, senescence of the tissue and abscission will take place more rapidly than controls in air, but if the explants are treated with 2,4-D before they are put into the atmosphere of ethylene they take longer to undergo both senescence and abscission than the controls despite the fact that they are then producing *more* ethylene than controls. Furthermore, those treated with the highest concentrations of auxin take the longest time to separate (unpublished data).

There is therefore an antagonism between auxin and ethylene in the control of the abscission process.

How do these facts help to explain the defoliation of tropical evergreens by auxins ? In the Department of Agriculture in Oxford we have studied this problem using the common evergreen shrub *Euonymus japonica*. This species is readily defoliated by spray applications of the *n*-butyl ester of 2,4-D and is a suitable test plant for studies comparable with those carried out in the tropics on tropical species (Osborne, 1958).

EXPERIMENTAL

If the 2,4-D ester at a concentration of 6.66 mg/ml in methanol is applied as a spot to the upper surface of a second year leaf, or if one half of the upper surface of such a leaf is painted with the solution of the ester, then within 4-5 days yellowing of the untreated part of the blade is apparent around the edge of the treated spot or along the edge of the treated half. The yellowing proceeds progressively so that by the 10th-14th day the whole of the untreated part of the blade, including the petiole, is yellow, while the part of the blade that received the surface auxin treatment is still green and visibl unchanged. As soon as yellowing of the untreated parts of the blade are complete the leaf is shed (Osborne and Hallaway, 1961). Whole bushes may be defoliated by this kind of droplet treatment of the leaves.

On the basis of the experiments now to be described, we propose the following model for defoliation by auxins.

Ethylene production is greatly increased in the parts of a leaf receiving auxin. The ethylene, but not the auxin, diffuses into the surrounding untreated parts of the leaf and there induces yellowing and other symptoms of senescence. Senescence of these parts of the blade and petiole initiate the processes of abscission which lead to leaf fall.

Senescence in ethylene occurs more slowly if the levels of auxin in the tissue are sufficiently high (see 1 and 4) and we propose that in the auxin treated part of the leaf, the ethylene production is counteracted by both the endogenous auxin and the high concentration of synthetic auxin which is applied. In the untreated part of a leaf the ethylene diffusing from the treated area encounters only the endogenous level of auxin which is too low to counteract the senescence inducing effects of the high ethylene levels diffusing towards them. When a sufficiently large area of the leaf has become senescent, abscission is initiated and defoliation takes place. When the leaf is shed, the auxin treated parts appear as green islands of tissue in the senescent yellow blade.

My colleague Dr. Hallaway of the Biochemistry Department, University of Liverpool and I have carried out the following experiments to verify the validity of this model for auxin induced defoliation.

Using gas chromatographic techniques, we measured the ethylene production of leaves of *Euonymus japonica* which have been treated with 2,4-D (Osborne, 1968b). The leaves of large branches were painted with the 2,4-D in methanol on one half of the blade only so that treated and untreated halves were on opposite sides of the main vein. Treated branches and untreated control branches were then stored under greenhouse conditions with their basal ends in water. At the start of the experiment and after 5, 8 and 12 days the ethylene production was measured separately in the untreated and treated halves of the 2,4-D painted leaves and also in halved control leaves. In the halves of these leaves painted with 2,4-D, ethylene production is stimulated several fold and continued to rise until the 12th day when leaf fall commenced.

Table 1.

Production of ethylene by 2,4-D treated and untreated halves of leaves of *Euonymus japonica* in which one half of the blade is painted on the upper surface with n-butyl ester of 2,4-D, 6.66 mg/ml in methanol

Time after treatment	mμl/C_2H_4/g fresh wt/hr		
	Untreated control leaves	Treated leaves	
		2,4-D-treated half	Untreated half
0 day	1.86	-	-
5 days	-	11.97	5.35
8 "	-	20.20	10.45
12 "	1.10	52.30	12.70
	Naturally senescent yellow leaves 1.98		

The rise in the level of ethylene obtained for the untreated parts of the leaf can probably be attributed to the diffusion of the gas from the 2,4-D treated halves. Halved leaves from the control branches kept in the greenhouse and from naturally senescent yellow leaves showed no rise in ethylene production during the 12 days of the experiment.

If the ethylene produced by the auxin treated part of the leaf acts as the trigger for senescence and abscission then removal of ethylene should reduce this abscission acceleration. We find that this is so if branches which have had one half of each leaf painted with the 2,4-D are enclosed in large containers over either distilled water, or over 0.25M mercuric perchlorate in 2.5M perchloric acid (this combines with ethylene in the ambient air to form a ethylene-mercuric perchlorate complex) we find that senescence and abscission of the leaves over the mercuric perchlorate is delayed.

Table 2.

Effect of removal of ethylene from the ambient air on the speed of abscission of leaves of *Euonymus japonica* which had been painted on one half of the blade with n-butyl ester of 2,4-D in methanol (6.66 mg/ml). Treated branches in vessels in air, or vessels containing 0.25M mercuric perchlorate in 2.5M perchloric acid to absorb ethylene

Time after treatment	% Abscission In air	% Abscission Over mercuric perchlorate to remove ethylene
12 days	0	0
13 "	16	0
17 "	47	0
20 "	68	0
22 "	79	10
25 "	100	37
27 "	-	47
29 "	-	74
33 "	-	100

Removal of the ethylene from the environment of the 2,4-D treated leaves reduces the speed of defoliation.

If the proposed model for defoliation is correct then an application of the auxin to the whole surface of the leaf should counteract the abscission accelerating action of ethylene when branches are enclosed in an atmosphere of the gas. The antagonism between ethylene and auxin can be readily demonstrated.

Control branches, and branches bearing leaves that have been painted over the whole upper surface with 2,4-D, are enclosed in separate but similar glass vessels containing ethylene at 500 ppm in air. Defoliation of the controls is complete by the 5th day but the leaves painted with 2,4-D do not start to fall until the 12th day.

Table 3.

Effect of application of n-butyl ester of 2,4-D in methanol (6.66 mg/ml) to whole of upper surface of leaves of *Euonymus japonica* upon their subsequent speed of abscission in ethylene 500 ppm

Time after treatment	% Abscission 2,4-D	% Abscission Control
3 days	0	0
4 "	0	11
5 "	0	100
12 "	0	-
13 "	4	-
15 "	26	-
17 "	70	-
19 "	100	-

Senescent colour changes are similarly postponed. Auxin therefore antagonises the effects of applied ethylene despite the fact that the production of ethylene by the treated leaves is much greater than the controls.

Lastly, if the yellowing and senescence of the auxin treated leaves is primarily dependent upon the diffusion of the gas into the untreated parts from the edges of treated parts, then a measured volume of 2,4-D applied as one single drop upon a leaf should be less effective in inducing senescence and abscission than several smaller drops of the same total volume, for the sum of the lengths of the circumference is greater for several small drops than it is for one large drop. The results shown in Table 4 illustrate this point.

Table 4.

Effect of distribution of droplets of n-butyl ester of 2,4-D in methanol (6.66 mg/ml) on speed of abscission of treated leaves of *Euonymus japonica*

Time after treatment	% Abscission 1 x 6 µl drop	% Abscission 6 x 1 µl drops
14 days	0	0
15 "	0	25
16 "	12.5	100
19 "	50	-
21 "	87.5	-
22 "	100	-

Leaves were treated with either one 6 µl drop of the 2,4-D or six 1 µl drops. Assuming that the spots cover the same leaf area, the circumference edge of the 6 x 1 µl spots is double that of the 1 x 6 µl spot. In reality this value is actually greater for due to the effects of evaporation and speed of spread on the leaf surface, the area covered using the 1 x 6 µl drop is slightly less than that of the 6 x 1 µl drops. The results show that defoliation of leaves treated with 6 x 1 µl drops takes place more rapidly than leaves receiving 1 x 6 µl. Furthermore, yellowing and senescence of the blade occurs sooner and, as might be expected, is initially more uniform than in the 1 x 6 µl treated leaves.

Abnormally high ethylene production caused by fungal infections of leaves or by treatment with chemicals like 2-chloroethanephosphonic acid which breaks down in the leaf to liberate ethylene (Cooke and Randall, 1968) all lead to defoliation. We may conclude that any treatment which enhances the biosynthesis, or causes the local ethylene levels in the leaf to increase will be a potentially effective method of defoliation (Osborne, 1968a).

We propose therefore that auxin induced defoliation practised on tropical vegetation results from the senescence and abscission induced by enhanced ethylene biosynthesis within treated parts of the leaf.

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RECENT ADVANCES IN STUDIES OF THE MODE OF ACTION OF THE BIPYRIDYLIUM HERBICIDES

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Summary The mechanisms whereby diquat and paraquat are reduced in photosynthetic tissues of plants to give rise to their stable free radicals are reviewed. The reoxidation of the bipyridylium free radicals gives rise to hydrogen peroxide. Flax cotyledons damaged by the herbicides show many symptoms which occur more slowly in senescence. The chlorophyll A/B ratio is reduced, Photosystem II is lost before Photosystem I and we have demonstrated an oxidation of unsaturated lipids in the cell. Preliminary results of an electron microscopic study of damaged tissues are presented. Chloroplasts have been isolated from sugar beet leaves after treatment with herbicidal quantities of paraquat and when leaching of the material during preparation is prevented the amount of paraquat present is in the proportion of 1 molecule to 100-200 chlorophyll molecules. This ratio is related to the size of the basic photosynthetic unit.

INTRODUCTION

Aspects of the mode of action of the bipyridylium herbicides paraquat and diquat were last reviewed at this conference by Calderbank in 1964. Since this time more evidence has accumulated indicating that the herbicides can be reduced in photosynthetic systems and their competitive inhibition of NADP reduction indicates that they interact with Photosystem I (Zweig 1965, Davenport 1963). This position accords with the redox potentials of the herbicides (diquat -349 mV and paraquat -446 mV).

The reduction of these compounds gives intensely coloured free radicals which are stable in the absence of oxidising conditions. In the presence of oxygen however, a rapid reaction ensues and hydrogen peroxide is formed. No intermediate radicals can be detected in this reoxidation (Farrington 1968). In fact hydrogen peroxide has been detected in chloroplast preparations after photoreactions involving paraquat and diquat (see Calderbank 1968). Mees (1960) showed that oxygen is necessary for herbicidal activity, indicating that the reoxidation stage rather than free radical formation gives the phytotoxic product.

We have attempted in this work to examine the sequence in which the phytotoxic symptoms appear and to study the damage which takes place in the chloroplasts of treated plant material. In some ways this is similar to what happens during senescence, though the herbicidal action is very rapid in comparison. In addition experiments are described where attempts have been made to measure the quantity of paraquat which reaches the chloroplasts of plants following a herbicidal treatment. The amount found can be related to the size of the "photosynthetic unit".

METHOD AND MATERIALS

The work relating the effects of diquat and paraquat on pigment levels, photosynthetic electron transport and membrane breakdown was carried out using flax (Linum usitatissimum var. Red Wing) cotyledons floated upon 10^{-4}M solutions of the herbicide under constant illumination. Chlorophyll and phaeophytin levels were measured spectrophotometrically in acetone solution according to MacKinney (1941) and Vernon (1960). The isolation of chloroplasts for photosynthetic electron transport studies was carried out by a method based on that of Arnon et al. (1956).

Reduction of ferricyanide was measured to indicate the activity of the Hill reaction (Photosystem II) according to Jagendorf and Margulies (1960) and the activity of Photosystem I was determined by ascorbate oxidation with the addition of monuron to inhibit Photosystem II (Davenport and Dodge).

Lipid peroxidation was followed by measuring the formation of malondialdehyde, a breakdown product of polyunsaturated fatty acid hydroperoxides, by the 2-thiobarbituric acid reaction (Wilbur et al. 1949, Heath and Packer, 1965).

Sugar beet (Beta vulgaris var. Suttons Improved) were used in the measurement of quantities of herbicide reaching the chloroplasts, after a treatment just sufficient to kill (Baldwin et al. 1968). The plants were grown on a 16 hour day at about 22°C and used when they had 6-8 mature leaves. After treatment with C^{14} paraquat dichloride solutions chloroplasts were isolated in a sucrose-glycerol density gradient (Leech 1963), by the polyethylene glycol method of Clendenning et al. (1956) or after freeze drying the leaf material, by a heptane-carbontetrachloride density gradient (Stocking 1959). The amount of radioactivity in the chloroplasts prepared by these methods was assayed by liquid scintillation counting after combustion of the pellet by the oxygen flask method.

RESULTS

After treatment with the herbicides flax cotyledons change from bright green to a darker green dull appearance, which ultimately changes to brown as the plant disintegrates. Cotyledons floated upon a solution of herbicide do not desiccate in the usual way. When the pigments are examined it is seen that there is a loss of chlorophyll A, which is converted to phaeophytin A, and that this leads to a reduction in the chlorophyll A/B ratio. Chlorophyll B is affected only slightly (Table 1).

Table 1.

Changes in chlorophyll levels after paraquat treatment of flax cotyledons

Time Hours	chlorophyll content 0	14	mg. per g. fresh weight 24	36
Chlorophyll A	1·40	1·25	1·05	0·5
Chlorophyll B	0·5	0·5	0·5	0·3
Ratio chlorophyll A/B	2·8	2·5	2·1	1·7

The rate of change of the chlorophyll A/B ratio under conditions of senescence, when the cotyledons were detached and floated upon water in the same way as the herbicide treatments were made is shown in Table 2.

Table 2.

Change in ratio of chlorophyll A/B during senescence of detached flax cotyledons

Time days	0	7	11	15	20
Ratio chorophyll A/B	2·7	2·6	2·1	1·9	1·7

Chloroplast preparations from cotyledons treated with diquat and paraquat for various periods showed that the Hill reaction (Photosystem II) was more sensitive than Photosystem I, and under the experimental conditions ceased completely within 24 hours, as shown in Table 3. The time of cessation of the Hill reaction is a function of temperature and Table 4 shows that damage is slower at lower temperatures.

Table 3.

Changes in photochemical activity of chloroplasts isolated from paraquat treated cotyledons

Time hours		Percentage of initial rate 6	12	16	18	19	24	30	36
Ferricyanide reduction	PS II	86	60	35	12	0	-	-	-
Ascorbate photoxidation	PS I	75	54	-	41	-	26	15	0

Table 4.

The effect of temperature on the loss of ability to photoreduce ferricyanide after paraquat treatment

Temperature °C	Time for complete loss of activity hours
10-12	30
16-17	28
20-21	24
23-25	19

Table 5 shows the peroxidation of the lipids of detached cotyledons after a paraquat treatment, as shown by the amount of malondialdehyde formed. It can be seen that there is a rapid increase.

Table 5.

Increase in lipid peroxidation during paraquat treatment of detached flax cotyledons

Time hours	Malondialdehyde level (percentage increase)
6	8
12	12
18	22
30	56
36	80
42	130

The amount of paraquat which reaches the chloroplasts of sugar beet leaves after a herbicidal treatment is shown in Table 6. The influence of the isolation medium is clearly seen.

Table 6.

The amount of paraquat in the chloroplast fraction of sugar beet leaves

Isolation medium	% paraquat in chloroplasts	Molecular ratio $\frac{\text{chlorophyll}}{\text{paraquat}}$
sucrose buffer	5·6	1500
	5.3	2800
	2.5	4100
	4·5	2000
Polyethylene glycol 4000	14·0	1350
Heptane - CCl_4	10·5	175
	18·9	100

DISCUSSION

Photosynthetic tissue is rapidly affected by the bipyridylium herbicides. Mees (1960) gives data indicating that broad bean leaf discs show a depression of respiration after only 3 hours of diquat treatment, and the discs form melanin and blacken more rapidly. Flax responded more slowly (Mees, 1959). Many of the changes that we have recorded here are seen in a few hours after treatment.

There is a similarity with the changes taking place in senescent tissues, where chlorophyll A is more susceptible to breakdown than chlorophyll B, and the ratio chlorophyll A/B falls, but this process normally takes many days. Thus the herbicide treatment considerably increases the speed of degeneration (compare Table 1 and 2). Treatment of the cotyledons with monuron, a general photosynthetic inhibitor, reduces the speed at which the chlorophyll A is lost.

It has been noted however that the ability to photoreduce ferricyanide is lost from untreated chloroplasts very rapidly, and Photosystem I has been shown to be very stable, and will survive heat treatment and sonication (Davenport and Dodge). Although the herbicides interact with Photosystem I loss of Photosystem II activity occurred before that of Photosystem I.

The oxidation of lipids by isolated chloroplasts has been studied by Heath and Packer (1965), who concluded that it was a light dependant reaction. In the normal plant cell a protection mechanism must be present to prevent damage taking place. The lipids in the plant cell are constituents of membranes which regulate the osmotic stability of the system. Thus the changes in malondialdehyde that we have shown indicate that after paraquat and diquat treatment a rapid upset of membrane integrity is possible, and this may well explain the speed at which symptoms of damage can be seen.

We have recently obtained electron micrographs of cotyledons treated with the bipyridylium herbicides and these show shrinkage of the cytoplasm from the cell wall and gross enlargement of the mitochondria, as well as the production of osmiophilic granules or plastoglobuli (Lichtenthaler,1968) in the chloroplasts. The formation of these granules again demonstrates the similarity between the damage caused by the herbicides and that which takes place in senescence. Many of the effects described may be secondary to the reaction which damages the leaf tissue cells. Once damage, perhaps to a membrane, is caused the breakdown of the tissue follows the normal pattern seen in ageing and dying cells. The relationship between hydrogen peroxide and damage has still to be elucidated, and the reason why catalase, which is present in plant cells, does not prevent damage by destroying the peroxide is intriguing. Unpublished results show that catalase in photosynthetic tissue is present to only a small extent in the chloroplast, and this is confirmed by Gregory (1968).

Table 6 indicates that paraquat can be leached out of chloroplasts by aqueous solutions, and in fact 90% can be removed in three aqueous washings. Up to 20% of the paraquat used to treat a leaf reaches the chloroplast, and this indicates that there are between 100-200 molecules of chlorophyll present to every herbicide molecule. Molecules of chlorophyll are known to work together as aggregates, though estimates of the size of this basic unit, or quantasome, vary from between 230 and 2,500 chlorophyll molecules (Park and Biggins, 1964; Izawa and Good, 1965). Whichever figure is taken it appears that there is more than enough herbicide to interact with each quantosome. Furthermore these results confirm that the proposed mechanism of photosynthetic reduction of the herbicide is possible, for paraquat does reach the chloroplast.

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A PRELIMINARY INVESTIGATION OF THE EFFECT OF TWO PLANT FACTORS ON SIMAZINE TOXICITY

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Summary Seeds of swede (cultivar Bangholm), Marrow stem kale, white mustard (cultivar English White), wheat (cultivar Jufy 1) and pea (cultivar Big Ben) were graded according to weight into two or three categories. These were sown in soil containing a series of simazine concentrations. In all species, the seedlings arising from the heavier seeds tolerated higher concentrations of simazine than those from the lighter seeds.

Seedlings of wheat, white mustard and Polygonum lapathifolium (pale persicaria) at different stages of development were exposed to a series of simazine concentrations in solution culture. Four-leaf stage of white mustard and 5-leaf stage of pale persicaria were more tolerant to simazine than the cotyledon stage. However, in wheat the 1-leaf stage was more tolerant than the 4-leaf stage. These results are discussed.

INTRODUCTION

The influence of soil and environmental factors on the performance of soil-applied herbicides has been the subject of numerous investigations and has been shown to be of considerable importance in regard to both activity and selectivity of these materials (Hartley 1964; and Holly 1964). Among plant factors, inter-specific or varietal differences have been widely investigated but intra-varietal differences have not received much attention. The present study was undertaken to investigate the effect of seed size and the stage of development within a variety on simazine toxicity to seedlings.

METHODS AND MATERIALS

1. The effect of seed weight on simazine toxicity.

The species tested were swede (cultivar Bangholm), Marrow stem kale, white mustard (cultivar English White), wheat (cultivar Jufy 1) and pea (cultivar Big Ben). Seeds of each species were graded into two or three sizes by sieving. The 1000-seed weights of test samples of each grade are listed in Table 1.

The seeds were sown in soil to which a range of doses of simazine had been applied and incorporated. Swede, kale and white mustard were sown ½ in. deep and wheat and peas, 1 in. deep. The treatments were arranged in randomised blocks with three replicates. Each species formed a separate experiment.

The plants of swede were harvested 18 days, wheat 21 days, white mustard 22 days, kale 23 days and peas 25 days after sowing, and the dry weights of the shoots determined.

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Table 1

Weight of 1000 seeds, grams

Seed Grade	Swede	Kale	White Mustard	Wheat	Pea
Large	3.48	5.88	7.14	55.2	404.4
Medium	-	4.12	4.74	-	-
Small	2.48	2.56	3.00	24.8	166.0

2. The influence of stage of development of plants on simazine toxicity.

White mustard seedlings were grown in Hoagland's solution (Hoagland and Arnon, 1950) until they reached cotyledon (fully expanded), 4-leaf or 6-leaf stage, pale persicaria until cotyledon, 2-leaf or 5-leaf stage and wheat until 1-leaf, 2-leaf or 4-leaf stage. Samples of seedlings were taken at this time for dry weight measurements. The remainder were transferred to Hoagland's solution containing a range of concentrations of simazine (technical grade). Three seedlings were grown per culture. Each species was treated as a separate experiment and replicated three times. The treatments were arranged in a split-plot design with the stages of growth in the main plots and the simazine concentrations in the sub-plots.

After 72 hours the herbicide solution was removed and the roots of the plants rinsed several times in water before returning them to fresh Hoagland's solution for a further period of 7 days. After this time the plants were harvested and the dry weights of shoots determined.

RESULTS

1. The effect of seed weight on simazine toxicity.

The shoot weights are recorded in Table 2 (a, b and c).

Table 2

The mean shoot dry weight (grams)of kale, swede, white mustard, wheat and pea raised from seed of different weights sown in simazine-incorporated soil

(a)

Treatment	Swede		Kale			White Mustard		
Simazine a.i.oz/ac	Large seed	Small seed	Large seed	Medium seed	Small seed	Large seed	Medium seed	Small seed
Control	0.13	0.10	0.28	0.19	0.17	0.35	0.29	0.22
0.30	0.09	0.05	0.21	0.18	0.10	0.34	0.21	0.17
0.48	0.07	0.02	0.15	0.12	0.05	0.25	0.14	0.10
0.77	0.02	0.01	0.08	0.06	0.03	0.14	0.04	0.02
1.20	0.01	-	0.04	0.03	0.01	0.08	0.01	0.01

(b)

Treatment	Wheat	
Simazine a.i.oz/ac	Large seed	Small seed
Control	0.22	0.13
0.5	0.20	0.09
1.0	0.16	0.07
2.0	0.11	0.05
4.0	0.08	0.03

(c)

Treatment	Pea	
Simazine a.i.oz/ac	Large seed	Small seed
Control	0.91	0.69
4.0	0.71	0.18
8.0	0.47	0.12
16.0	0.32	0.09
32.0	0.27	0.08

In all species plants from heavier seeds had larger shoot weights than those from lighter seeds, at all application rates.

ED_{50} values (the dose causing 50% reduction in shoot weight) for each replicate were estimated from graphs of shoot dry weight as a % of untreated plants plotted against the logarithm of the rate of simazine, on arithmetical probability paper. An analysis of variance was performed on the ED_{50} values which are listed in Table 3.

Table 3

The mean ED_{50} values for the test species, oz/ac.

Seed Grade	Swede	Kale	White Mustard	Wheat	Pea
Large	0.46	0.47	0.69	2.34	10.17
Medium	-	0.55	0.43	-	-
Small	0.30	0.34	0.44	1.39	0.96
LSD	0.14	0.11	0.15	0.04	0.68

With all species the ED_{50} for large seeds was significantly greater than for small seeds.

2. The influence of stage of development of plants on simazine toxicity.

The shoot weight increment during the experimental period is given in Table 4.

Table 4

The mean shoot dry weight increase (grams) during the 10 days following the commencement of the simazine treatment

Treatment	White Mustard			Pale Persicaria			Wheat		
Simazine ppm	Coty-ledon stage	4-leaf stage	6-leaf stage	Coty-ledon stage	2-leaf stage	5-leaf stage	1-leaf stage	2-leaf stage	4-leaf stage
Control	0.19	0.75	1.30	0.08	0.66	1.43	0.29	0.60	2.26
0.025	0.12	-	-	0.07	-	-	-	-	-
0.05	0.07	0.74	1.04	0.06	0.44	1.19	-	-	-
0.10	0.03	0.58	0.67	0.03	0.18	1.00	0.19	0.24	1.10
0.20	0.01	0.19	0.63	0.01	0.09	0.58	0.16	0.13	0.66
0.30	-	-	-	-	-	-	0.14	0.07	0.41
0.40	-	0.08	0.35	-	0.02	0.22	0.13	0.04	0.28
0.50	-	-	-	-	-	-	0.11	0.04	0.21

The ED_{50} for each stage of growth was calculated as described earlier using the shoot dry weight increase over the 10-day experimental period as the measure of growth. These ED_{50} values are listed in Table 5.

With white mustard a concentration of simazine 3 - 4 times higher is required to cause a similar growth reduction at the 4-leaf and 6-leaf stages than at the cotyledon stage. In pale persicaria the ED_{50} for the cotyledon stage is not significantly different from that of the 2-leaf stage, but the ED_{50} for the 5-leaf stage is about twice that of the younger stages. The ED_{50} for the 1-leaf stage of wheat is 2 - 3 times greater than that for the 2-leaf and 4-leaf stages.

Table 5

ED50 values of simazine for white mustard, pale persicaria and wheat at different stages of growth

Species	Stages of Growth		ED50 ppm
White Mustard	Cotyledon		0.04
	4-leaf		0.15
	6-leaf		0.17
		LSD =	0.09
Pale Persicaria	Cotyledon		0.08
	2-leaf		0.07
	5-leaf		0.16
		LSD =	0.02
Wheat	1-leaf		0.26
	2-leaf		0.08
	4-leaf		0.11
		LSD =	0.07

DISCUSSION

In all species tested, seedlings from the heavier seeds seem to be able to withstand significantly higher rates of simazine than plants from lighter seeds. The differences found were usually in the order of 1.5 to 2.0 times in favour of the larger seed size but in pea the differential was about 10 times. This difference is probably related to the amount of food reserves in seed of different sizes and duration of seed support of the seedlings. On the basis of these results it appears the use of graded seed would lead to greater precision in biological assays for simazine and probably other photosynthetic inhibitors.

When seedlings at different stages of development are exposed to simazine, it appears that the early stages of white mustard and pale persicaria are the most susceptible to simazine, whereas in wheat the youngest stage (1-leaf) is the most resistant.

The anamolous position of wheat may be associated with seed size. The large seeded wheat may still be able to draw on seed reserves even at the 1-leaf stage and thus gain protection from simazine in the same way that feeding of glucose through severed leaf tips conferred protection to barley plants exposed to simazine (Moreland et al, 1959). In this experiment the oldest wheat plants tested were in the 4-leaf stage, but if bigger plants were included the ED50s may have increased again well after seed support had ended. Indeed the ED50 increased from 0.08 ppm at the 2-leaf stage to 0.11 ppm at the 4-leaf stage but this increase was not significant. This point needs further investigation, but if it were so plants from seeds with larger food reserves would have the dual advantage of longer protection from simazine and thereby attaining a greater size and tolerance during this period.

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SOME FACTORS INFLUENCING THE ACTIVITY OF FOLIAGE APPLIED MCPA AND MCPB IN VICIA FABA

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Summary The results presented show that, *in vitro*, MCPB inhibits oxidative phosphorylation of excised root tissue to a greater degree than MCPA. This reversal of the normal *in vivo* susceptibility pattern may be partly due to limited absorption and translocation of MCPB in the whole plant. Fixation of MCPB in isolated cuticles has been demonstrated and may be a factor limiting the rate of *in vivo* absorption. The role of beta-oxidation is uncertain since investigation of herbicide residues in plants treated *in vivo* and *in vitro* with MCPB have revealed the virtual absence of MCPA in all regions of the treated plants. It is uncertain, at present, whether this reflects the absence of the beta-oxidase system or an inadequate movement of the substrate to the sites of conversion.

INTRODUCTION

It has been previously reported that in *Vicia faba*, the activity of MCPA is related to a relatively high rate of foliar absorption and efficient translocation throughout the plant (Kirkwood, Robertson and Smith, 1966, Robertson and Kirkwood, 1967, Kirkwood, Robertson and Smith, 1968). The inactivity of MCPB is apparently related to a high level of accumulation in the treated leaves restricting movement of the herbicide to the sites of action, or sites of beta-oxidation. It has been suggested that fixation of MCPB in the treated leaves may result primarily from physical adsorption in leaf tissues, though inhibition of metabolic processes such as translocation also appears to be involved. The present paper is a progress report on the mode of action of these two compounds and results are presented which suggest that selective activity may be due to several factors which include differentials in cuticle penetration, cuticle/epidermal fixation, translocation, cellular and mitochondrial absorption.

MATERIALS AND METHODS

The MCPA and MCPB used in these experiments was formulated as the sodium salt, and ^{14}C-labelled in the carboxyl groups. Specific activities were 2.0 and 6.0 mc/mM, respectively.

1. Cuticle penetration studies

Cuticles were isolated from the abaxial surfaces of bean leaves by stripping with cellotape. The isolated cuticles were supported on Oxoid membrane filters, placed between agar discs of 2mm thickness and diameter 8mm (upper) and 14mm (lower) respectively (Darlington and Cirulis, 1963). The system was then assembled on planchettes and treated with 0.02ml of 3.25×10^{-3}M ^{14}C-labelled MCPA and MCPB (0.65uc) using an Alga micro-syringe pipette. To minimise dehydration, the planchettes were placed on filter-paper in petri-dishes to which 0.2ml of water were added and then placed in a growth cabinet. After a treatment period of 22 hours, the experiment was dismantled and the component discs placed in vials containing 15ml dioxan-based scintillation liquid. The radioactivity of each vial was determined using a Packard Tri-carb Scintillation Spectrometer (Model 3375). The efficiency of cuticle-binding of MCPA and MCPB was determined by washing the cuticles in water using mechanical shakers for a total period of 30 minutes before radioassay.

2. Translocation studies

Bean plants were treated *in vivo* with 2.5×10^{-3}M MCPA and MCPB by vacuum infiltration of the last expanded pair of leaflets. Whilst the exact radioactive and herbicidal dose were unknown, an attempt was made to standardise the dose by standardising the vacuum period and leaf area treated. Replicate plants were harvested at one, three, twelve, twenty-four and forty-eight hours after treatment. Each plant was divided into four regions, viz. shoot apex, shoot, root and treatment leaves. The latter were washed with 50ml quantities of 0.3M sucrose, twice, for a total of four minutes. After drying overnight in an oven at 50°C, the samples were combusted using an oxygen flask (Kalberer and Rutschmann, 1961, Jeffay and Alvarez, 1961). The $^{14}CO_2$ evolved was absorbed in 15ml of 14% methoxyethanol-ethanolamine solution and aliquots of 1ml transferred to a dioxan-based scintillation liquid for radioassay using the Packard Tri-carb Scintillation Spectrometer.

3. Residue studies

2.5×10^{-3}M ^{14}C-labelled MCPB (0.65uc) was applied to the last expanded pair of leaflets by vacuum infiltration, or to four rubber rings attached by lanolin to the adaxial surface. The plants were harvested after a seven day treatment period, divided into the four regions, shoot apex, shoot, root and treated leaves and the appropriate material from six replicate plants bulked. Extractions were carried out according to the procedure of Fawcett et al (1959) and the extract esterified using 14% Boron Trifluoride-Methanol, the mixture being heated for 2 minutes on a steam bath with occasional swirling of contents. The mixture was allowed to cool and 25ml of 2% sodium sulphate added to quench the reaction. The phenoxy-ester was partitioned into the pentane layer, 5ml being injected into a 10% Apiezon L stainless steel column. The Pye 107/74 GLC was operated at 200°C and the electron-capture detector at 250°C. Oxygen-free nitrogen was used as the carrier gas at a flow rate of 60ml per minute. The detector was supplied with a 47-60v positive pulse with a pulse period of 150uS. The effluent was monitored for radioactivity using a flow monitor or fraction collection system.

Analysis of bean tissue vacuum-treated <u>in vitro</u> with nonradioactive MCPB was analysed in a similar manner.

4. Gas exchange analysis

CO_2 -free air was passed through air-tight plastic bags containing three replicate plants treated with 1.0uc doses of ^{14}C-labelled urea, 2.5×10^{-3}M MCPA and MCPB. The $^{14}CO_2$ evolved was absorbed in 14% methoxyethanol/ethanolamine and 1.0ml aliquot was radioassayed by scintillation spectrometry.

5. Studies on oxidative phosphorylation of isolated bean tissues

The uptake of oxygen and accumulation of ^{32}P were measured in isolated bean tissue by the method of Wojtaszek (1966). The experiments were carried out at 25°C ($\pm$ 0.5) in manometric vessels of a Gilson Differential Respirometer. Uniformly thin discs were incubated in the reaction medium containing the appropriate concentration of herbicide and $K_3{}^{32}PO_4$ equivalent to 0.5uc. An equilibration period of half an hour was allowed prior to the experimental run of three hours during which readings were taken at 10 minute intervals. On completion of the experiment, the washed tissue from each flask was dried under infra-red light on aluminium planchettes and assayed for radioactivity using a Tracerlab gas-flow counter.

RESULTS

1) Cuticle penetration studies

A comparison of the penetration of 2.5×10^{-3}M ^{14}C-labelled MCPA and MCPB at a range of surfactant concentrations can be seen in Table 1.

Table 1. The effect of surfactant concentration on the penetration of ^{14}C-labelled herbicides at 25°C (Mean of 4 replicates).

HERBICIDE	COMPONENT	Distribution of ^{14}C (%) % SURFACTANT 0	0.05	0.5	1	5
	Upper disc	54	25	32	32	23
MCPA	Cuticle	10	12	15	14	13
	Lower disc	36	63	53	55	64
	Upper disc	44	34	42	38	40
MCPB	Cuticle	19	30	18	38	23
	Lower disc	32	36	39	23	36

The results demonstrate that penetration of MCPA was enhanced by all concentrations, particularly 0.05 and 5%, whereas MCPB was little affected. The level of cuticle/epidermal fixation of ^{14}C-labelled MCPB was considerably higher than in the case of MCPA. The results of a further experiment to determine the proportion of herbicide firmly bound to the cuticle/epidermis are shown in Table 2.

Table 2. The proportion of bound ^{14}C-labelled MCPA and MCPB in isolated cuticles.

HERBICIDE	COMPONENT	Unwashed	Distribution of ^{14}C (%) 6x5 min*	1x30 min*
	Upper disc	46.0	50.0	34.0
MCPA	Cuticle	8.3	0.7	0.7
	Washings	-	16.0	17.0
	Lower disc	46.0	32.0	47.0
	% bound	-	4.2	3.9
	Upper disc	56.0	54.0	50.0
MCPB	Cuticle	28.0	3.5	5.6
	Washings	-	10.0	13.0
	Lower disc	13.7	32.0	32.0
	% bound	-	15.9	30.1

* washing regime

These results show that washing removed considerable quantities of herbicides from both sets of cuticles but a greater proportion remained on the cuticles treated with MCPB. The method of washing influenced the results for MCPB but had no effect on those for MCPA.

2) Translocation studies

Results showing the distribution of vacuum-infiltrated ^{14}C-labelled MCPA and MCPB throughout the treated plant are shown in Figure 1. Considerable translocation of both herbicides was observed, a greater proportion of MCPB than MCPA being moved from the treated leaves.

3) Residue Analysis

Typical traces of methyl esters of MCPA and MCPB are shown along with the reagent blank in Figures 2a,b,c. The follow[illegible] peak in the MCPA trace has been shown to have the same RF as 2,4-D and may be regarded as a contaminant. There was evidence of MCPA contamination of the MCPB sample and this contaminant, present in a ratio of 1:18, served as an internal marker. Analysis of ring-treated, in vivo and in vitro vacuum-infiltrated plants demonstrated that little or no beta-oxidation occurred in treated plants or tissues. Indeed, the ratio of MCPA to MCPB detected in each region was always less than that of the standard sample. This suggested that some metabolism of MCPA occurred in the MCPB treated plants or tissues. Results are presented in Figure 2d showing the distribution of radioactivity in the effluent gas from an MCPA-treated sample. Clearly the ^{14}C-label remained attached to the MCPA molecule during the treatment period; similar results were obtained for MCPB.

4) Gas exchange analysis

The results of gas exchange analysis are shown in Figure 3. These verify that loss of $^{14}CO_2$ occurred from both ^{14}C-labelled MCPA and MCPB-treated plants. The $^{14}CO_2$ loss was not significant however, since only 0.024 (MCPA), 0.033 (MCPB) and 0.052% (urea) of the applied radioactive dose was detected during a 14 day period.

5) Studies of oxidative phosphorylation

The effect of 2.0×10^{-3}M MCPA and MCPB on the uptake of oxygen is shown in Figure 4. Both herbicides inhibited oxygen uptake (P=0.001), MCPB to a greater degree than MCPA (P=0.01), and increasingly with time (P=0.01). Correspondingly, herbicide treatments reduced ^{32}P accumulation over a three hour period, MCPB inhibiting at an earlier stage than MCPA (Table 3).

Table 3. The effect of 1×10^{-3}M MCPA and MCPB on ^{32}P accumulation in bean root tissue

Treatment	Accumulation (dpm/mg)
Control	105.1 ± 32.5
MCPA	19.8 ± 5.0
MCPB	11.6 ± 2.2

DISCUSSION

The mode of action of the phenoxy herbicides has received considerable investigation during the past two decades and several mechanisms of action have been reported including inhibition of photosynthesis, translocation, respiratory metabolism and protein synthesis. Clearly the principal sites of action in individual cases may not be readily located, but they presumably include the chloroplasts, phloem vessels/companion cells, mitochondria, ribosomes and nuclei. It would seem reasonable to suggest that any region of the plant possessing these organelles may be a potential site of action. Realisation of the potential must depend upon the ability of the herbicide to reach these sites in herbicidal concentrations. This, in turn, must depend upon the efficiency of a chain of events, involving herbicide retention, cuticle penetration and translocation throughout the plant. The action of physical barriers such as cell or organelle membranes together with absorption and detoxification mechanisms combine to reduce the concentration of herbicide which reaches and accumulates in the organelles possessing susceptible physiological systems.

The results of the present investigation have demonstrated that when MCPA and MCPB are equally freely available to tissues of *Vicia faba* then oxygen uptake and phosphate accumulation are inhibited to a greater degree by MCPB than MCPA. It has been previously shown that growth of isolated tissue was similarly affected (Kirkwood, Robertson and Smith, 1968). In contrast, the in vivo activity of comparable concentrations of MCPB is negligable, consisting of necrosis of the treatment zone, and possibly slight stimulation of growth. The herbicide concentrations applied, *in vitro*, to root or epicotyl tissue probably bears little relation to the concentration reaching these regions under *in vivo* treatment conditions. Nevertheless the disparity between *in vitro* and *in vivo* results does appear to emphasise the importance of availability at the site(s) of action as a factor influencing activity of this compound.

There is some evidence that binding of MCPB within the cuticle/epidermal complex may be a factor of some importance. The results of studies with isolated cuticles show that MCPA penetrated the cuticle more rapidly than MCPB and was retained within the cuticle to a lesser degree. It is possible to explain these findings on the basis that MCPA entered via an aqueous (or lipoidal route in the presence of a surfactant), whilst MCPB followed a lipoidal route only and failed, unlike MCPA, to partition readily into the aqueous phase. Some evidence to support this hypothesis is found in the fact that MCPB is more lipid-soluble than MCPA (Dalziel, unpublished data) and less water-soluble than MCPA (MCPA 1174ppm, MCPB 48ppm, Behrens and Morton, 1963.)

The problem of cuticle/epidermal and presumably leaf tissue fixation is overcome using the vacuum-infiltration method of treatment. The results appear to demonstrate the movement potential in the absence of such barriers, though the possibility of some transport from the treated leaves in the xylem cannot be overlooked in these circumstances. This point is to be investigated using marker dyes.

The results of residue analysis suggest that the rate of beta-oxidation in *Vicia faba* is low or non existent; it is still uncertain whether this reflects an inefficient beta-oxidase enzyme system or inability of the substrate to reach the sites of beta-oxidation. Certainly the resistance of the bean to the concentration of MCPB applied would appear to conform to the beta-oxidation concept by which it was demonstrated that MCPB was inherently non-active except in species possessing a beta-oxidase enzyme (Wain, 1955, 1957, 1964). It is difficult, however, to reconcile the results of *in vivo* and *in vitro* studies on the basis of presence or absence of a beta-oxidase system. They appear to be more readily explained on the basis of availability at the site of conversion/activity.

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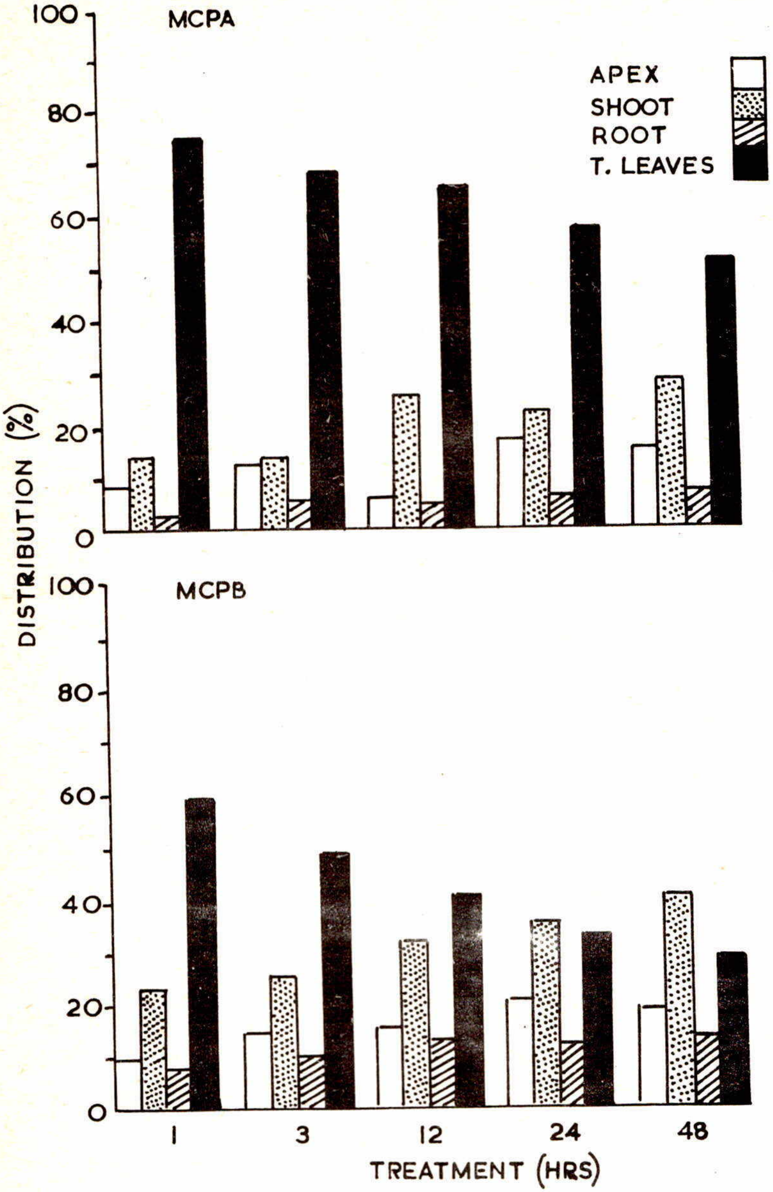

FIG. 1 THE EFFECT OF VACUUM INFILTRATION ON THE DISTRIBUTION OF MCPA AND MCPB.

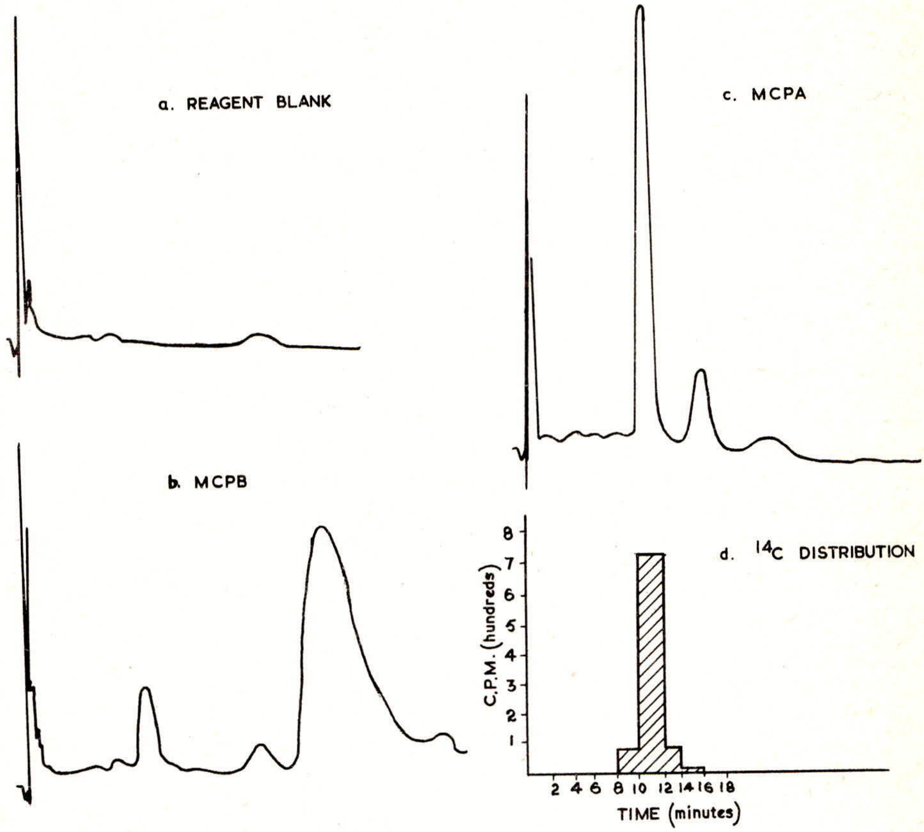

FIG. 2 GLC TRACES OF STANDARD SAMPLES OF MCPB (b), MCPA (c), AND ^{14}C-DISTRIBUTION IN AN MCPA-SAMPLE EFFLUENT (d).

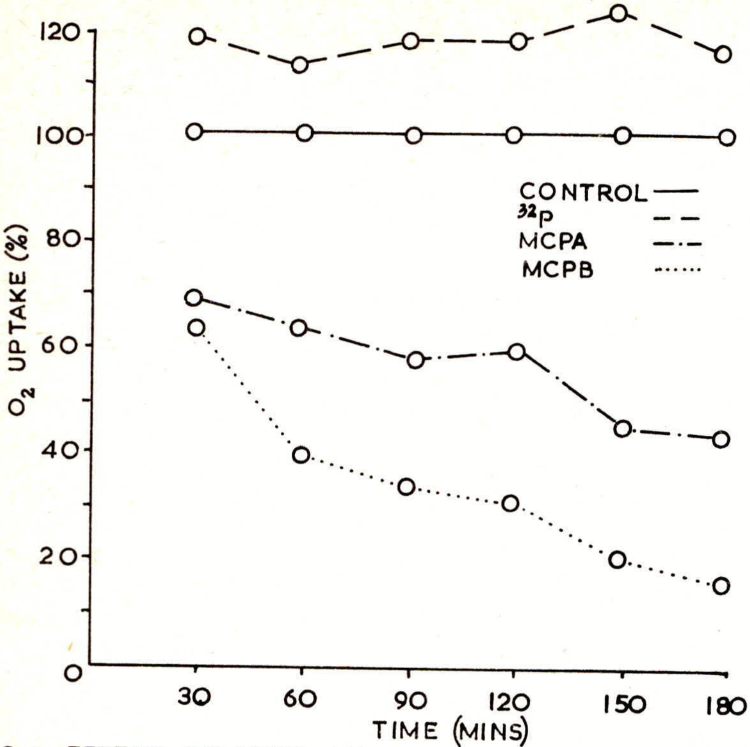

FIG.4 EFFECT OF MCPA AND MCPB ON O_2 UPTAKE BY ROOT DISKS.

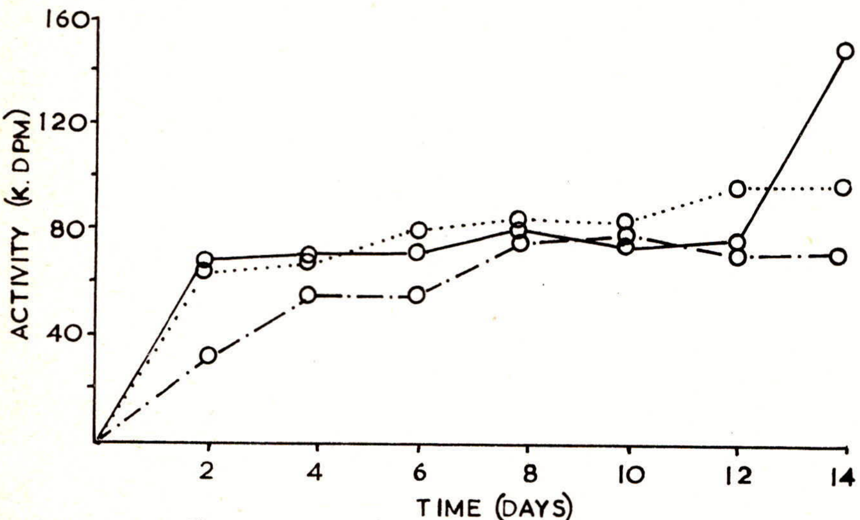

FIG. 3 LOSS OF $^{14}CO_2$ FROM ^{14}C-LABELLED UREA, MCPA AND MCPB -TREATED BEAN PLANTS.

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

THE SELECTION OF A CANDIDATE HERBICIDE; A STUDY OF STRUCTURE-ACTIVITY EFFECTS IN A SERIES OF AMINO ACID DERIVATIVES

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Summary Starting with the observed growth-regulating activity of N-phenylalanine, a group of herbicidal compounds has been developed. Highly specific requirements for activity were encountered in the series Ar.NH.X.COY in which $H_2N.X.COOH$ represents an amino acid. Maximal herbicidal effect was observed in the D-form of 2-(4-methyl-2,6-dinitroanilino)-N-methylpropionamide. The active herbicides are more toxic to seeds than to seedling plants in which they induce symptoms of scorch and chlorosis. They do not however behave as uncouplers of oxidative phosphorylation nor do they inhibit the Hill reaction. The mode of action of these herbicides has not yet been elucidated but it is thought that they may interfere with peptide synthesis. The compounds are of low toxicity to mammals.

INTRODUCTION

Carboxylic acids which induce growth regulatory, hormone-like effects when applied to the leaves of seedling plants have been described in the literature, and date back to the recognition of indole-3-acetic acid in the 1930's as a natural growth promoter. Other synthetic growth regulators that have been synthesised are listed in Figure 1. Most of the compounds are based on an aromatic nucleus with the exception of the dithiocarbamic ester disclosed by van der Kerk et al.[19].

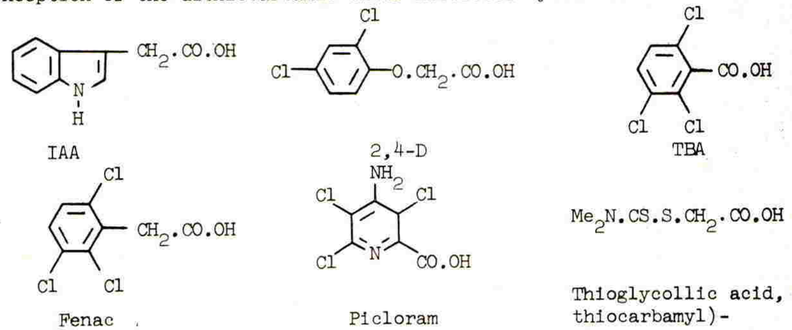
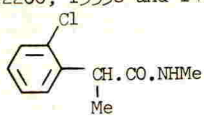


Figure 1 Growth regulators : natural and synthetic

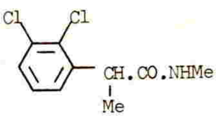
Previous experience[7,8] has been that in some cases the mono and dimethyl-amides of aralkyl carboxylic acids possess herbicidal activities which cannot be explained on the supposition that hydrolysis to the corresponding acid is occurring. Thus phenylacetic acids (I) and hydrotropic acids (II) induce auxin-like effects and

dicotyledons are most affected. This effect is optimised in the commercial herbicide 'Fenac'.

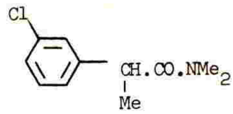
In contrast to the carboxylic acids, the derived mono and di-methylamides do not induce auxin-like responses. Herbicidal activity is predominantly a toxicity to seeds with monocotyledonous species being most sensitive. Greenhouse trials showed that pre-emergence toxicity to grassy weeds was associated with tolerance of sugar beet to both mono- and dimethylamides. The most active compounds[21] were WL 12200, 13538 and 14660.



WL 12200



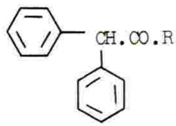
WL 14660



WL 13538

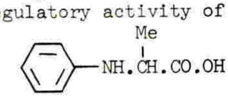
The difference in herbicidal properties between diphenyl-acetic acid (III) and its dimethylamide (Diphenamid) is well known.

R = OH, III



R = NMe_2, Diphenamid

During the routine screening of compounds for herbicidal activity our attention was drawn to the growth-regulatory activity of 2-anilino propionic acid (IV).



IV, WL 14886; 2-anilinopropionic acid

An examination of the literature showed that many 2-anilinopropionic acids and esters having a variety of nuclear substituents were known[1,3,4a,b,c,5,6,9,10,11,14,15,16,17,23]. Some work had also been done concerning the growth-regulating activity of these compounds under laboratory conditions using Avena coleoptiles[2]. There was, however, only one reference[20] to the preparation of an N-methylamide, WL 15635, related to (IV), and none to any herbicidal activity in this class of compounds.

At this point it is convenient to discuss the methods by which the herbicidal properties of compounds were assessed.

METHODS

Two categories of tests, pre-emergence and post-emergence tests, were carried out. The pre-emergence test involved spraying a liquid formulation of the test compound on to soil in which seeds of the plant species had recently been sown.

The post-emergence tests involved two types of tests, viz. soil drench and foliar spray tests. In the soil drench tests the soil was drenched with a liquid formulation containing the compound under test after the seeds of the plant species had been germinated; in the foliar spray tests seedling plants were sprayed with such a formulation.

The formulation used in the above tests consisted of 40 parts by volume of acetone, 60 parts by volume of water, 0.5 part by weight of an alkylphenol/ethylene oxide condensate available under the trade name Triton X-155, and the compound under test in varying amounts.

The seeds of the plant species were sown and allowed to germinate in steam-sterilised John Innes Compost.

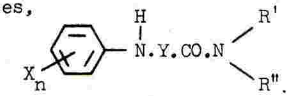
In the soil spray and soil drench tests, the sown soil and the soil bearing the seedling plants were sprayed at a volume equivalent to 50 gallons per acre and drenched at a volume equivalent to 1000 gallons per acre respectively. In the foliar spray tests, seedling plants were sprayed with a volume equivalent to 50 gallons per acre. Control tests were also carried out in which sown soil, soil bearing seedling plants, and the plants which were treated with the same compositions but containing no active compound.

All compounds were applied in two dosages equivalent to 1 and 10 kg/ha, respectively, in the soil spray and foliar spray test, and in dosage equivalent to 20 kg/ha in the soil drench test.

The herbicidal effects of the compounds concerned were assessed visually seven days after spraying the foliage and drenching the soil (post-emergence test) and eleven days after spraying the soil (pre-emergence test), and were recorded on a 0-9 scale (0 = no effect and 9 = very strong herbicidal effect). A rating 2 corresponds approximately to a reduction in fresh weight of stem and leaf of the treated plants of 25%, a rating 5 corresponds approximately to a reduction in weight of 55% a rating 9 to a reduction in weight of 95% etc.

DISCUSSION

A systematic study was therefore commenced with the view of optimising herbicidal activity in the series,



V

where $H_2N.Y.COOH$ represented an amino acid.

Since the compounds (V) may be regarded as aniline derivatives the analogy with the urea, anilide and carbamate herbicides prompted a first look at structures (V) in which X represented a chlorine atom. Compounds for test were prepared by standard procedures as outlined in Scheme I.

$Ar.NH_2$ —(Br.CHMe.CO.OEt; Heat alone or in DMF at 100°C)→ Ar.NH.CHMe.CO.OEt —(R'R"NH; Heat in EtOH at 110°C)→ Ar.NH.CHMe.CONR'R"

Scheme I Preparation of chloro and alkylanilinopropionamides

Moderate success was achieved in that 2-chloro (WL 15964), 2,5-dichloro (WL 18061) and 3,4-dichloro (WL 17227) anilino-N-methylpropionamides and the corresponding dimethylamides (WL 17246, WL 18053 and WL 17966 respectively) showed moderate toxicity to seeds and did not induce growth regulatory responses; methylamides were more toxic to monocotyledonous species and dimethylamides were more toxic to dicotyledonous species; very little post-emergence activity was seen.

Herbicidal activity was reduced by successive replacement of chlorine atoms by methyl groups and physiological effects, especially of the dimethylamides, began to resemble those of the parent carboxylic acids.

The above observations, which have been reported[22] previously and in greater detail, prompted a look at compound (V) in which the nuclear substituent X had a more pronounced electron-withdrawing effect than was exerted by the chlorine atom. The nitro group was chosen and compounds were prepared by the general procedures outlined in Scheme II.

ArCl —($H_2N.CHMe.COOH$; $NaHCO_3.EtOH$)→ ArNH.CHMe.CO.OH —($SOCl_2$)→ Ar.NH.CHMe.CO.Cl

ArCl —($NH_2.CHMe.CONR'R"$; ROH or C_6H_6)→ Ar.NH.CHMe.CONR'R"

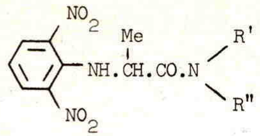
ArNH.CHMe.CO.OH —(ROH, H_2SO_4)→ Ar.NH.CHMe.CO.OR —(R'R"NH; ROH)→ Ar.NH.CHMe.CONR'R"

Ar.NH.CHMe.CO.Cl —(R'R"NH; CH_2Cl_2)→ Ar.NH.CHMe.CONR'R"

Scheme II Preparation of nitroanilinopropionamides

It became immediately obvious that special significance should be attached to a 2,6-dinitro substitution pattern.

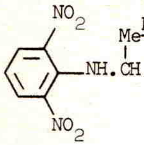
In order to establish which compound in the 2-(2,6-dinitroanilino)-propionamide series had the optimum activity, compounds (VI) were prepared from a variety of amines and the results of herbicide screening tests are given in Table 1.



VI

Table 1

Herbicidal Activity of 2-(2,6-dinitroanilino)propionamides



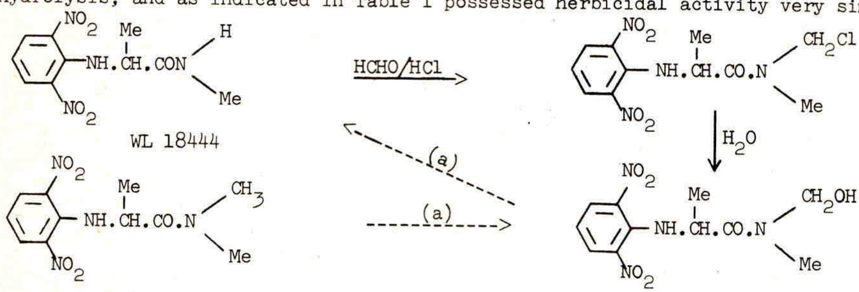
NH.CH.CONR'R" - Visual rating (0-9), seven species; maximum score 63

WL No.	R'	R"	1 Kg/Ha		10 Kg/Ha	
			Pre	Post	Pre	Post
18444	H	Me	32	37	59	52
18462	Me	Me	3	23	39	54
19382	H	Et	14	33	48	52
	Et	Et	0	26	10	43
	Me	Ph	0	15	2	23
	H	Ph	4	11	4	18
	H	CH.Me.Et	0	11	8	29
	H	$CH.Ph_2$	0	0	0	0
19472	H	$CH_2.CH=CH_2$	9	22	47	45
	H	H	0	4	18	10
20234	Me	CH_2OH	30	33	53	53
	H	C_9H_{19}	0	0	0	0
	H	$C_{18}H_{37}$	0	0	0	0
	H	NMe_2	0	15	11	27
	H	$CMe_2.CN$	0	1	13	8
	$-CH_2.CH_2.CH_2.CH_2.CH_2-$		0	7	0	18
	$-CH_2.CH_2.O.CH_2.CH_2-$		0	11	9	34

The picture revealed was fairly clear-cut. The most phytotoxic amides were those derived from the shorter chain primary alkylamines such as methylamine (WL 18444), ethylamine (WL 19382) and allylamine (WL 19472).

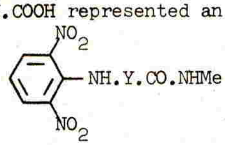
The high activity of WL 20234 (VI, R' = Me, R" = CH_2OH) would appear to be anomalous. However, this compound was made to test the hypothesis that the methylamide (WL 18444) and dimethylamide (WL 18462) could be related metabolically through a hydroxymethyl derivative (WL 20234) in a way similar to that observed between the insecticides 'Bidrin' and 'Azodrin'[18].

The amide WL 20234 was prepared by choromethylation of WL 18444, followed by hydrolysis, and as indicated in Table 1 possessed herbicidal activity very similar

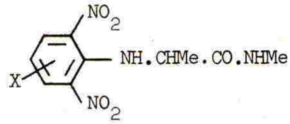


to that of WL 18444 and was more active than WL 18462. It is suggested therefore that WL 18462 is herbicidally active by virtue of biological conversion to WL 18444, possibly by way of WL 20234 (route a). Other similar biological dealkylations have been reported for aromatic ethers[12] and dinitroanilines[13].

On the basis that the preferred 2-(2,6-dinitroanilino)propionamide was the amide WL 18444 derived from methylamine the next step was to establish that α-alanine was the preferred amino acid, and a series of compounds (VII) were prepared for test in which $H_2N.Y.COOH$ represented an amino acid.



VII

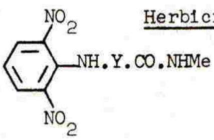


VIII

The compounds in this group and their herbicidal activities are listed in Table 2.

Table 2

Herbicidal Activity of (2,6-dinitroanilino)alkanamides



- Visual rating (0-9), seven species

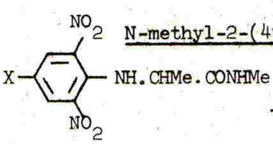
Amino-acid $H_2N.Y.CO.OH$	1 Kg/Ha Pre	1 Kg/Ha Post	10 Kg/Ha Pre	10 Kg/Ha Post
glycine	0	9	14	17
α-alanine (DL)	32	37	59	52
β-alanine	0	33	14	43
glutamic acid (L)	0	19	21	22
leucine (DL)	0	11	13	23
lysine (L)	0	0	0	3
valine (DL)	3	15	25	30
methionine (DL)	0	19	11	35
sarcosine	0	8	4	27

From these results, there was no doubt that the preferred parent amino acid was α-alanine. Having established N-methyl-2-(2,6-dinitroanilino)propionamide (WL 18444) as a preferred compound with the 2,6-dinitrophenyl configuration, α-alanine as the parent amino acid and the amide function derived from methylamine, in series (VIII) attention was turned to the effect of further substitution in the phenyl nucleus. First substituents tried were hydrocarbon groups in the 4-position. There was a significant fall off in herbicidal activity as the carbon number of the substituent increased, the cut-off point being sharp at X = ethyl.

Substitution of the 4-methyl substituent produced compounds (Table 3) showing moderate herbicidal activity with the trifluoro-methyl compound (WL 18830, VIII, X = 4-CF_3) being most active in the pre-emergence test.

Table 3

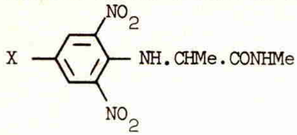
N-methyl-2-(4-substitutedmethyl-2,6-dinitroanilino)propionamides



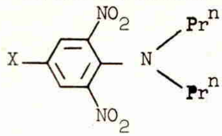
- Visual rating (0-9), seven species

WL NO.	X	1 Kg/Ha Pre	1 Kg/Ha Post	10 Kg/Ha Pre	10 Kg/Ha Post
19511	CH_3	55	48	61	55
18830	CF_3	14	14	48	24
	CH_2Cl	0	8	6	21
	CH_2OH	0	7	17	41
	CH_2OMe	5	24	36	47

The high and moderately-high herbicidal activity of WL 19511 (VIII, X = 4-Me) and WL 18830 (VIII, X = 4-CF_3) hinted that the substituent activity effects might be similar in the series IX and X. Series X contains the known herbicides, tri-



IX

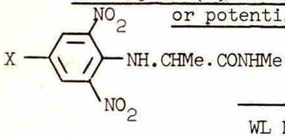


X

fluralin (X, X = CF_3), propalin (X, X = CH_3) and nitralin (X, X = $MeSO_2$) and so it became obvious that the nitralin analogue (IX, X = $MeSO_2$) should be made. This compound WL 19489 proved to be almost inactive herbicidally and similar low activity was encountered (Table 4) whenever the 4-substituent was an oxygenated function or a group (e.g. CN) which could possibly generate an oxygenated function (e.g. $CONH_2$ in this example).

Table 4

N-Methyl-2-(2,6-dinitroanilino)propionamides with an amino, oxygenated or potentially oxygenated function in the 4-position



- Visual rating (0-9), seven species

WL No.	X	1 Kg/Ha		10 Kg/Ha	
		Pre	Post	Pre	Post
19889	$MeSO_2$	0	1	0	7
	NO_2	0	2	0	17
	COOH	0	3	3	7*
	CN	0	6	9	19
	$CONH_2$	0	5	0	8
	CONHMe	0	0	0	1
	$CH=C(CN)_2$	0	4	9	10
	OMe	0	0	0	4
	NH.CO.OEt	0	0	0	4
	NH.CO.CH_3	0	8	1	13

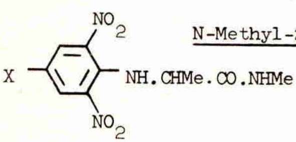
* four species only

Similarly inactive compounds resulted from the introduction of an amino function in the 4-position.

Moderate herbicidal activity resulted with a halogen atom in the 4-position (Table 5) there being little to choose in their phytotoxic effect in the pre-emergence test, although in overall activity the chloro ompound, WL 19587 appeared marginally superior. None was as active as the 4-methyl compound, WL 19511.

Table 5

N-Methyl-2 (4-halo-2,6-dinitroanilino)propionamides

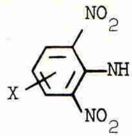


- Visual rating (0-9), seven species

WL No.	X	1 Kg/Ha		10 Kg/Ha	
		Pre	Post	Pre	Post
	F	21	18	54	36
19587	Cl	20	34	45	41
	Br	18	14	-	-
19511	Me	55	48	61	55

All compounds with a substituent in the 3-position gave a low score rating irrespective of the presence or not of an additional 4-substituent (Table 6).

Table 6



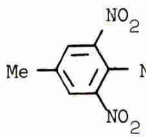
N-Methyl 2-(3-substituted-2,6-dinitroanilino)propionamides

-NH.CHMe.CO.NHMe - Visual rating (0-9), four species; maximum score 36

X		1 Kg/Ha		10 Kg/Ha	
3	4	Pre	Post	Pre	Post
Me	H	0	0	5	0
Cl	H	0	0	0	4
Me	Cl	0	0	0	0
Cl	Cl	0	0	0	3
NH.CHMe.CONHMe	H	0	6	9	11
NH.CHMe.CONHMe	Cl	0	3	0	5

Thus, indications were that the most active compound in the series was still N-methyl-2-(4-methyl-2,6-dinitroanilino), WL 19511 but as a check that conclusions reached in the WL 18444 series (4-H) were still applicable in the WL 19511 series (4-Me). other examples in the latter series having a variety of amide groups were tested (Table 7).

Table 7



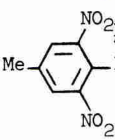
2-(4-Methyl-2,6-dinitroanilino)propionamides

NH.CHMe.CONR'R" - Visual rating (0-9), seven species

R'	R"	1 Kg/Ha		10 Kg/Ha	
		Pre	Post	Pre	Post
H	Me	55	48	61	55
H	H	0	1	0	9
H	CHMe.CO.OEt	0	0	12	1*
H	CHMe.CO.NHMe	4	5	23	14*
H	CH_2.CO.NHMe	0	13	2	24

Previously reached conclusions were substantiated in that the methylamide (WL 19511) was still the most active compound with other active compounds being derived from primary amines. A further check was made to confirm that α-alanine was still the preferred parent amino acid, and compounds listed in Table 8 were prepared and tested. The derivative of α-alanine again proved to be more active than other members of this series.

Table 8



N-(4-methyl-2,6-dinitrophenyl) derivatives of amino acid methylamides

NH.Y.CONHMe - Visual rating (0-9), seven species

Y	1 Kg/Ha		10 Kg/Ha	
	Pre	Post	Pre	Post
-CHMe-	55	48	61	55
-CH.(CH_2OH)	0	7	9	21*
-CH_2.CH_2-	2	18	14	42
-CHMe.CH_2-	4	11	31	35
-CH_2.CHMe	1	2	14	19
-CH_2-	0	5	0	23
-$(CH_2)_5$-	0	6	0	10*
o-C_6H_4	0	0	3	1*
m-C_6H_4	0	0	0	2
p-C_6H_4	0	0	0	0

* four species only

One final point required resolving and this concerned the importance of the optical configuration, if any, in determining herbicidal activity. D- and L-isomers of the more active anilinopropionamides were prepared from D- and L-α-alanines, respectively, and retention of configuration was proved by comparison of the direction of the Cotton Effect in the Optical Dispersion spectra. The results of herbicide tests are give in Table 9. The overwhelming contribution of the D-form on the herbicidal activity of the compounds is self-evident, although the effect is more pronounced in pre-, rather than post-emergence applications.

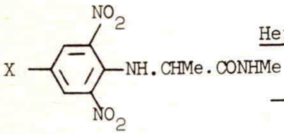


Table 9

Herbicidal Activity of D, L and DL isomers

Visual rating (0-9), seven species

X	Optical form	1 Kg/Ha Pre	1 Kg/Ha Post	10 Kg/Ha Pre	10 Kg/Ha Post
H	DL	32	36	59	52
H	D	35	31	57	52
H	L	0	19	22	36
Me	DL	55	48	61	55
Me	D	53	52	59	58
Me	L	0	14	9	29
CF_3	DL	14	14	48	24
CF_3	D	21	14	48	27
CF_3	L	0	1	0	7
Cl	DL	20	34	45	41
Cl	D	47	37	58	50
Cl	L	0	9	0	20
Et	DL	53	46	55	58
Et	D	51	51	53	58
Et	L	0	14	5	22

It is thus concluded that in compounds represented by XII, maximum pre-emergence herbicidal activity is exerted when $ArNH_2$ is 2,6-dinitro-4-toluidine, the

Ar.NH.Y.CONR'R"

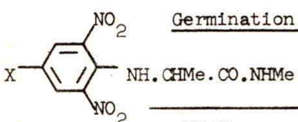
XII

amino acid is D-α-alanine and the group R'R"NH is derived from methylamine.

An indication of the powerful inhibiting effect of the D-isomers on the germination of linseed has been obtained and the dose required to cause 50% germination inhibition after 2 and 9 days was determined. The results are recorded in Table 10, together with those obtained for the natural germination inhibitor, abscisic acid, and its methyl ester.

Table 10

Germination inhibition doses for D-forms



WL No.	X	Molar conc. causing 50% inhibition of germination	
19985‡	CH_3	3.9×10^{-7}	3.5×10^{-6}
21041	C_2H_5	4.9×10^{-7}	4.4×10^{-6}
19962	Cl	2.6×10^{-6}	$>10^{-5}$
19505	CF_3	5.0×10^{-6}	$>10^{-5}$
19253	H	6.0×10^{-6}	$>10^{-5}$
Abscisic Acid		$2\text{-}3 \times 10^{-6}$	-
Methyl abscisate		2×10^{-7}	-

‡ D-isomer of WL 19511

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PARAQUAT AS AN AID TO PADDY CULTIVATION

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Summary Traditional methods of land preparation for rice consisting of two to three cultivations and taking up to 30 days to complete, were compared with minimum tillage techniques taking 10 days in which weeds were killed with paraquat followed by one cultivation.

Yields following minimum tillage were similar to normally cultivated plots but were lower if paraquat was omitted. Limited trials suggest that the method, timing and level of nitrogen application recommended for normal cultivation are also suitable for minimum tillage.

Using minimum cultivation the time and water required for land preparation is reduced, more efficient use can be made of labour, animals and machinery and the timing of land preparation is more flexible. In continuous cropping trials in which sowing followed harvest in the shortest time possible, the use of minimum tillage increased grain production over normal cultivation from 13 to 17kg/ha/day in the Wet Zone and from 18 to 22kg/ha/day in the Dry Zone.

INTRODUCTION

It has been shown by various workers that the most important effect of mechanical cultivation is to control weeds. Russel (1945) showed that on a weed-free seed-bed the yields of wheat, barley and mangold were similar, whether the land had been ploughed or not. In later work where the herbicide paraquat was used to control weeds in the absence of cultivation prior to drilling wheat, barley and kale (Hood 1963, and 1964), yields from uncultivated plots were equal to those from normally prepared plots. Recently various workers (Buenacose 1967, Hall 1966, Mabbayad 1967) have demonstrated that tillage in rice may not be essential if weeds are killed effectively with pre-plant herbicides. For a number of years in Ceylon paraquat has been used to eliminate Salvinia auriculata from water ways and infested paddy fields prior to planting. As well as killing the Salvinia the chemical also killed other weeds and it facilitated subsequent cultivation (Dias 1967). Early trials by the Department of Agriculture and Chemical Industries (Colombo) Ltd. were so promising that a formal co-operative research programme involving these bodies and Plant Protection Ltd. was established in Ceylon beginning in August 1966. A total of 28 trials on minimum tillage were carried out over 3 seasons. 13 of these, the results of which are typical of the whole, are described in this paper.

METHOD AND MATERIALS

Herbicides and application

Two herbicide treatments were used for minimum tillage trials. Paraquat* at 0.56 or 1.12kg ion/ha (both rates gave equal weed control) was used in most trials. A sequential treatment of dalapon 3.3kg a.i. followed by paraquat 0.56kg ion/ha was tried where perennial grasses mainly Panicum repens and Echinochloa stagnina were dominant (Headford 1966). This gave better control of these weeds in the absence of any cultivation (zero tillage) but when one cultivation subsequent to spraying was carried out, control given by paraquat alone was as good. Herbicides were applied in 40 gal/ac. using a hand pumped Birchmeier 'Senior' knapsack sprayer fitted with an .078 floodjet nozzle.

* Paraquat as 'Gramoxone', MCPA as 'Agroxone', dalapon as 'Dalspray', propanil as 'StamF-34'.

Layout

All sites were simple, randomised block layouts; plot size varied from 200 to 500 sq.ft.; three to four replicates.

Fertilizer

In all experiments P and K were applied at the officially recommended levels of 33kg P_2O_5 and 31kg K_2O/ha. In several experiments three levels of nitrogen were used, 0,44 and 88kg/ha. In others, the recommended level, 44kg/ha was used. In all cases N was applied 4 weeks after seeding, before heading and at heading (Rice Growing 1966).

Assessments

Number of weeds/sq.ft; ten 1 sq.ft. quadrats per replicate and fresh weight of weeds per plot taken during crop growth or at harvest. Yields were measured by reaping the whole plot having first removed one foot round the periphery.

Tillage techniques

In Ceylon, traditionally, two to three cultivations are done to kill weeds and prepare a seed bed for flooded paddy. The first cultivation is carried out either with a locally made plough pulled by bullocks, or a mould board plough, or disc or tine tiller pulled by a cagewheeled tractor, or in many cases by hand using a hoe called a mammoty. Water is then brought into the field and the land left flooded for up to two weeks after which a second cultivation is carried out. Finally after a further period of up to two weeks the field is puddled by buffaloes, human feet or cagewheeled tractor, levelled and seeded. Thus the whole operation can take 30 days or more from first cultivation to seeding.

In the basic minimum tillage technique paraquat was sprayed onto the weeds and one cultivation was carried out three days later using any of the methods described above. The field was flooded for upto seven days and then drained, levelled and seeded, the whole land preparation, including seeding, taking only 10 to 11 days. In a few experiments where the soils were sufficiently soft it was necessary only to trample the desiccated weeds into the mud and seed without further cultivation. In one series of trials seeding and transplanting was done with no cultivation whatsoever (zero tillage).

RESULTS AND DISCUSSION

Zero tillage trials

Zero tillage trials with both seeded and transplanted rice were carried out in the Wet Zone over three seasons. Yields obtained were of the same order as from normally cultivated plots (Table 1). With seeded rice desiccated weed material had to be either cut and removed or burnt to ensure good seed/soil contact. The seeder used was unsatisfactory for drained, untilled soil and stands and yields of the first crop were poor. For the second and third crops seeding was done in shallow standing water and stands and yields were comparable to those from normal cultivation.

Table 1

Effect of zero tillage and planting method on yield kg/ha (Trial H-1; Wet Zone)

Treatment	N Level (kg/ha)	1st crop	2nd crop	3rd crop
Zero tillage, transplanted	44	2,937 ab	3,475 a	4,522 cd
do do do	66	-	3,623 a	4,798 d
Normal tillage, transplanted	44	2,794 ab	2,788 a	3,578 a
do do do	66	-	3,382 a	3,902 ab
Zero tillage, seeded	44	2,424 a	2,821 a	4,063 abc
do do do	66	-	3,507 a	4,347 bcd
Normal tillage, seeded	44	3,289 b	2,944 a	3,901 a
do do do	66	-	3,495 a	4,415 bcd

Note : 1. First and third seasons. Paraquat 1.12kg ion/ha, desiccated weeds cut with sickle and removed, followed by flooding and seeding or transplanting. Second season. Dalapon @ 3.3kg a.i./ha followed by paraquat @ 0.56kg ion/ha after 3 days. Stubble then burnt and plots seeded or transplanted after flooding.
2. A Ceylon-made Johnpulle seeder was used (Johnpulle 1956). All seeded plots were treated with propanil @ 3.3kg a.i./ha 18 days after seeding. No post-crop-emergent weedicide was used in the transplanted plots.
3. a,b etc. are differences significant at 5% level according to the New Duncan's Multiple Range Test.

Minimum tillage trials

At first, attempts were made to incorporate the paraquat desiccated weeds merely by trampling them into flooded soil. This was found possible only where, as for example at B-1 (Table 2), the soil became soft on flooding. Here weed control following minimal cultivation was better than after normal cultivation (Table 2, note3). At the other site (M.I.3), the soil, even after flooding was too hard to obtain satisfactory incorporation in the first season, weed control was poor and yields were lower than from normal cultivation.

Table 2

Effect of minimum tillage, continuous cropping and level of nitrogen on yield (P & K applied at recommended levels; varieties used H-4 and H-7)

Treatment	kg/N/ha	Yield of grain (kg/ha) 1st crop B-1	1st crop M.I.3	2nd crop B-1	2nd crop M.I.3	3rd crop B-1	3rd crop M.I.3	Total for 3 crops B-1	Total for 3 crops M.I.3
Normal cultivation	0	2882bc	4642c	1700a	-[2]	943a	1212ab	5525	-
do	44	2843bc	4561bc	2215a	2817a	1011a	1406abc	6069	8784
do	88	3023c	3960ab	2444a	-[2]	908a	1151a	6375	-
Minimum tillage[1]	0	1799ab	3781a	1695	-[2]	1205ab	2012bcd	5699	-
do	44	3135c	3937a	2230a	2910a	1723c	2223d	7088	9070
do	88	2496abc	3912a	2117a	2567a	1594c	1956bcd	6207	8435

Note:- 1. Paraquat @ 0.56kg or 1.12 ion/ha.
2. No treatment.
3. In the first season differences in fresh weed weight 30 days after seeding were significant at 5% level as follows:

	kg/plot B-1	kg/plot M.I.3
Normal cultivation	30.2a	4.1b
Minimum tillage	9.2b	23.3a
Plot size (sq.ft)	384	320

In subsequent minimum tillage treatments, herbicidal sprays were followed by one cultivation to incorporate desiccated weed material using either hand hoe, rotovator or bullock drawn plough. In one such trial a minimum tillage technique using hand hoes was compared with normal cultivation and in each treatment, 3 plots were hand weeded, 3 plots were left unweeded. Weed weights following minimum tillage were similar to those after normal tillage (Table 3). Yields from minimum tillage plots were equal to those from normally cultivated plots (Table 3, note 1).

Table 3

Effect of minimum tillage and planting method on weeds and yield of grain (Variety H-4; NPK applied at recommended levels. Trial M.T.1)

Treatment	Sown or transplanted	Weeded: Fresh wt. weeds 42 days after seeding or transplanting(kg)[2]	Weeded: Yield kg/ha	Unweeded: Yield kg/ha
Normal cultivation	seeded	32.6 a	2,738	1,997
	transplanted	38.0 a	2,492	2,102
Minimum tillage	seeded	23.6 a	3,207	2,026
(paraquat 0.56kg ion/ha)	transplanted	31.0 a	2,405	1,969

Note:- 1. Differences in yield between unweeded and weeded plots, transplanted and broadcast were significant at 5% level as follows:-

Unweeded	2024kg/ha a	Normal cultivation	2332kg/ha a	Transplanted	2242kg/ha a
Weeded	2711kg/ha b	Minimum tillage	2402kg/ha a	Broadcast seeded	2492kg/ha b

2. Plot size 450 sq.ft.

Roles of paraquat, cultivation and flooding

An attempt was made to determine the relative roles of paraquat, cultivation and flooding in one trial. Assessments of weed density, made 16 and 28 days after seeding weight of weeds at harvest and of the yield of the various minimum tillage treatments suggest that paraquat, cultivation and flooding are complementary. Thus paraquat plus one good cultivation appeared to be better for weed control and yield than paraquat plus one poor cultivation which in turn was better than no paraquat and one poor cultivation. The effect of flooding was less obvious, but with poor cultivation, 7 days flooding appeared to give better weed control and higher yield than 3 days flooding (Table 4). Further confirmation of the complementary roles of paraquat, flooding and cultivation are obtained by comparing weed control and yields of all minimum tillage treatments using paraquat with minimum tillage with no paraquat, minimum tillage (1 poor cultivation) with minimum tillage (1 good cultivation) and minimum tillage with 3 days flooding with minimum tillage with 7 days flooding (Table 4 notes 5 & 6).

Table 4

Effects of paraquat, type of cultivation and period of flooding on weed incidence during the growth of the crop at time of harvest and on yields(DAS= number of days after seeding). Variety H-4, NPK applied at recommended levels.

Treatment	No. weeds/sq.ft. 16 DAS	No. weeds/sq.ft. 28 DAS	Fresh wt. weeds at harvest(gms/sq.ft.)	Grain Yield (kg/ha)
1)Normal cultivation	16(2)	30(6)	26 (24) b	3669 ab
Minimum tillage (no paraquat)				
2)1 cultivation(good)[2] 3 days flooding	16(2)	33(6)	41 (40) b	3439 ab
3)1 cultivation(good) 7 days flooding	10(2)	22(3)	24 (22) b	4395 b
4)1 cultivation(poor)[3] 3 days flooding	16(7)	29(15)	115(114)a	2544 a
5)1 cultivation(poor) 7 days flooding	15(3)	29(10)	67 (66) ab	3376 ab
Minimum tillage(paraquat 0.56kg ion/ha)				
6)1 cultivation(good) 3 days flooding	8(2)	18(3)	13 (10) b	4366 b
7)1 cultivation(good) 7 days flooding	7(1)	16(2)	19 (17) b	3970 b
8)1 cultivation(poor) 3 days flooding	15(2)	21(7)	39 (36) b	3435 ab
9)1 cultivation(poor) 7 days flooding	12(4)	27(8)	60 (58) ab	4089 b

Note:-1. Panicum repens was dominant perennial grass (numbers and wts. in parenthesis)
2. Good cultivation: total incorporation of weeds under the soil and complete submergence when flooded.
3. Poor cultivation: incomplete incorporation and partial submergence.
4. No post-crop-emergent weeding was done.
5. Differences in weed wt. between paraquat and no paraquat, and good and poor cultivation were significant at 5% level as follows:-

No paraquat 122.93 a	Poor cultivation 139.93 a
Paraquat 64.82 b	Good cultivation 47.82 b

6. Differences in yield between paraquat and no paraquat, good and poor cultivation and 3 and 7 days flooding were significant at 5% level as follows:-

No paraquat 3,439 a	Poor cultivation 3,361 a	3 days flooding 3,446 a
Paraquat 3,965 b	Good cultivation 4,043 b	7 days flooding 3,958 b

Water required for land preparation

Since minimum tillage reduces the time for land preparation from about 30 days to 10 or 11 days, there should be a corresponding saving in water requirement. An experiment carried out in the Dry Zone in Ceylon showed that even where normal cultivation was completed in the abnormally short time of 15 days the saving in water shown by the minimum tillage technique was 60% (Table 5). The implications of this are discussed later.

Table 5

Effect of minimum tillage on water required for land preparation

Treatment	Water required for land preparation (acre inches)[3]	Yield (kg/ha)
Normal (2 cultivations/puddling extended over 15 days)[1]	17.8	5,525
Minimum tillage		
Dalapon, 3.3kg a.i. followed 3 days later by paraquat 0.56kg ion/ha.	7.3	5,312

Note:-1. Cultivated with rotovator.
2. All plots treated with MCPA @ 0.83kg a.e./ha 21 days after seeding.
3. The water delivered to each plot was measured by passing it through a single V-shaped notch after the method described by Israelsen (1955).

Nitrogen requirements of minimum tillage rice

In trials on wheat, barley and kale, it has been shown that without nitrogen, yields from minimum tillage plots are often lower than those from normally cultivated plots, but that when nitrogen is added, yields from minimum tillage are similar (Hood 1963 and 1964). From the limited work done here in rice the need to add nitrogen to minimum tillage plots to obtain yields equal to those from normal cultivation is not so evident. In the first season trial at B-1, yields from minimum tillage were lower than from normal cultivation when no N was added (Table 2) but in the second and third seasons at this site, no differences in yield were obtained at zero N level between normal and minimum tillage. At two other sites, M.I.2 (Table 6) and M.I.3 (Table 2 third season) yields at the zero N level for normal and minimum tillage were similar. The tentative conclusion from these trials is that the recommended method, timing and level of N application applies equally to minimum tillage as well as to normal cultivation.

Table 6

Effect of minimum tillage on yield (kg/ha) at 3 levels of nitrogen (Variety H-4; P & K at recommended levels; trial M.I.2)

Treatment	N-levels	1st season	2nd season
Normal cultivation[1]	0	3484a	4200abc
do	44	4551b	4654bc
do	88	4220b	4913c
Minimum tillage			
Paraquat 0.56kg ion/ha	0	3487a	4033ab
do	44	3937ab	4554abc
do	88	4348b	4434abc
Dalapon 3.3kg a.i. followed by paraquat 0.56kg ion/ha	0	-	3805a
do	44	-	4696bc
do	88	-	4849c

Note:-1. Two cultivations and one puddling.

Effects of minimum tillage on rice production

At two sites (B-1 and M.I.3) harvesting of one crop has been followed in the shortest time possible by seeding the next crop to determine whether the time saved by minimum tillage can be utilised to increase rice production. The increased yield per day obtained from minimum tillage plots (Table 7) is due to the shorter time taken to grow three crops and also in this case, to the higher yields.

Table 7

Increase in productivity from minimum tillage at recommended level of N (44kg/ha)

Treatment	Days between 1st operation & harvesting 3rd crop		Yield(kg/ha)			
	Wet zone;rainfed B-1	Dry zone;irrigated M.I.3	Total 3 crops B-1	Total 3 crops M.I.3	Average/day B-1	Average/day M.I.3
Normal cultivation	495	437	6069	7784	13	18
Minimum tillage	413	406	7088	9070	17	22

Extension of minimum cultivation techniques in Ceylon

The recommended technique for Ceylon is now as follows:-

1. Spray 0.56kg paraquat ion/ha (equivalent to 2 pints 'Gramoxone'/acre).
2. After 3 days carry out one cultivation using either hand hoe, plough etc.
3. Flood field for 7 days.
4. Drain, level and seed.

In extensive demonstrations of this technique by Chemical Industries (Colombo) Ltd. personnel on farms throughout Ceylon, growth of the crop following minimum cultivation has been normal in every case and yields have been equal to or greater than those from the adjoining farmers' fields where normal cultivation was practised.

The work described above has confirmed the need for good pre-plant weed control in order to obtain maximum rice yields. Good cultivation followed by flooding is generally satisfactory for the purpose but takes time and excessive water and is often not practicable when the cultivator has poor equipment and limited time or difficult soil conditions. Particularly under these circumstances the use of a pre-planting spray of paraquat is of value in killing weeds and facilitating incorporation into the soil with the minimum of effort. Since less labour, animals or machinery are required a greater area can be cultivated with existing resources. The water saved at the time of land preparation can be utilised to cultivate more land, especially important in irrigated areas. Finally the shorter time and reduced human, animal and machinery resources needed for land preparation with minimum tillage techniques can provide greater flexibility for timing of operations and less likelihood of these being affected by adverse weather conditions.

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NEW DIRECTIONS IN WEED CONTROL RESEARCH FOR TROPICAL RICE

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Summary

Recent research on weed control in tropical rice has brought two concepts to the point of practical application. (1) The pre-emergence and early post-emergence grass control activity of phenoxyacetic acid herbicides suggests their use in combination with selective grass herbicides to increase the weed control spectrum and to permit the use of lower rates and less costly grass herbicides. Granular formulations which are easy to apply, of two such combinations, EPTC/MCPA and trifluralin/MCPA, are now commercially available for application to flooded rice shortly after transplanting. Similar combinations of nitrofen, propachlor, pyriclor with either 2,4-D or MCPA are also promising and may be developed for transplanted tropical rice. (2) Minimum tillage techniques using paraquat, pyriclor and a few other chemicals have successfully reduced tillage operations and occasionally made zero tillage feasible for transplanted rice. In the absence of perennial grasses and excessive accumlation of plant material, land preparation may also be replaced chemically in direct seeded rice.

INTRODUCTION

Two features of weed control research in tropical rice have reached the point at which they can have important practical impact and should receive additional attention from extension and development agencies. These techniques are (1) the use of phenoxyacetic acids (granular or liquid forms) at early times of application and (2) the use of non-selective chemicals for minimum tillage techniques on submerged soils. While the second is not simply a weed control practice, it derives an important part of its value from this component.

The effectivity of 2,4-D and MCPA in rice has been demonstrated repeatedly from the time of their discovery (Ryker and Brown, 1947; Van de Goor 1950: Vachhani, Chaudhry and Mittra, 1963; Vega, 1953) but the permitted timing has been found to vary from 15 days to 50 days after transplanting or sowing in order to avoid toxicity losses. It has been observed frequently, however, that early applications of phenoxy acetic acids cause no damage (Smith and Shaw, 1966; IRRI, 1964;) and that with suitable culture, especially tillage and water management, the 2,4-D or MCPA may provide as good weed control as the best combination of selective chemicals and handweeding practices. In Taiwan (Young, 1962) the use of 2,4-D in transplanted rice was observed to be satisfactory in the second crop (when temperatures are high) but resulted in injury to the first crop when sprayed before 50 days after transplanting. The studies of weed control with phenoxy acetic acids have been repeated (Moomaw *et* al, 1966) and produced variable yields but relatively consistent weed control with a single application.

In Ceylon where rice is normally broadcast sown and only about 30% of the crop acreage is weeded (Jayasekera and Velmurugu, 1966) improvements in rice yields were demonstrated by the use of PCP and propanil. In other recent studies (Gunawardena and Yogaratnam, 1968) yield improvements with chemical weed control were not demonstrated, but good control of weeds was obtained with linuron in transplanted rice and with propanil and MCPA or PCP and molinate at most locations in broadcast rice. Chloroxuron and linuron were unsatisfactory owing to phytotoxicity.

The minimum cultivation techniques developed and utilized successfully for maize in North America and for several crops in the UK and Europe have been attempted in rice with a high degree of initial success. Tests in Guyana and Malaysia (Anonymous, 1968) have demonstrated the feasibility of utilizing minimal cultivation techniques under several different conditions of culture. Trials in Ceylon (Mittra, 1968) have also shown that both direct seeded and transplanted rice can be established in this manner. In the Philippines (IRRI, 1967) results with paraquat or with pyriclor and picloram compared favourably with standard plough and harrow treatment combinations in the dry season and resulted in yields nearly double these in which no land preparation was made for transplanted rice.

METHODS AND MATERIALS

The experiments reported here were carried out using advanced management practices for tropical rice. Usually these consisted of growing the new rice variety, IR8, with moderate to high levels of nitrogen (120 kg/ha) and adequate insect protection with either 3 applications of diazinon or a combination of gamma BHC and malthion. Weed control chemicals were sprayed with a hand carried pressurized boom applicator developed at the International Rice Research Institute. In most experiments weed control ratings and dry weight of weeds were determined but principal reliance is placed on changes in grain yields resulting from weed control. Comparisons with a non-weeded plot and with a local practice or hand weeded control were usually made. Unless indicated, weed seeds were sown in the paddy just after land preparation.

Tillage practices for land preparation for either transplanted or direct sown rice were carried out with a ploughing and harrowing combination using local traditional tools: either the carabao plough or the Indian Desi plough and a comb harrow (in Philippines) or a levelling board (in Ceylon and India). Every attempt was made to maintain a shallow (5 cm) continuous flood of water in the rice paddy at all times. These careful land preparation and water control practices frequently minimize weed growth and result in reasonably high levels of weed control in untreated plots.

RESULTS AND DISCUSSION

Table 1 shows the results of rates and times of application of 2,4-D isopropyl ester. No difference in yield was obtained between times of application (as early as 4 days after transplanting) while the lower rates were less effective and even at the earliest time the highest rate (0.8 kg/ha) of application was desirable.

Table 1

Grain yield of transplanted IR8 rice treated with 2,4-D isopropyl ester and other selected herbicides 1967 dry season. IRRI.

Early application treatments (4 DAT)	Rate (kg/ha)	Late Application treatments: 2,4-D IPE (25 DAT) 0	0.2	0.4	0.8	Mean	
	0.2		5997*	6805	6126*	6309	
2,4-D IPE	0.4		5798*	7005	7134	6646	
	0.8	6721	7439	7460	7196	7365	
	Mean		6411	7090	6819		
Molinate (G)	3.0	7578	8212	7784	8535	8027	
Propanil + MCPA	3.5+0.8					6343	
2,4-D + EPTC	0.6+2.4					7324	
MCPA + HW (iX)	0.8					7619	
Handweeding (3X)						7745	$LSD_{.05}$ =
No weeding						1094*	1486 kg

*Yields were significantly lower than standard MCPA + HW(1X) or Handweeding.

Table 2 lists rice yields from a number of phenoxyacetic acid herbicides in granular or liquid combination with grass weed killers. The chemicals were applied to seedlings of 2 ages which were transplanted at the same time.

Differences in yields relative to seedling age were absent but were observed as a result of weed control provided by different forms. 2,4-D isopropyl ester and MCPA potassium salt, when applied alone produced yields not significantly different from the best treatment which was the combination of MCPA and 1 handweeding. Molinate followed by MCPA and the EPTC/2,4-D granules applied 4 days after ethylhexyl ester of 2,4-D were significantly less effective.

Table 2
Grain yield of transplanted IR8 obtained from early applications of phenoxyacetic acid herbicides to dapog and 21-day old seedlings. IRRI. 1968 dry season

Chemical and rate	Time 1/ DAT	Seedling age: 21 days (Regular)	Seedling age: 11 days (dapog)	Treatment Mean	Statistical significance at 5% level 2/
(kg/ha)		(kg/ha)	(kg/ha)	(kg/ha)	
MCPA(0.8)fb HW	25 + 35	7080	7491	7286	
Molinate fb MCPA(3+0.8)	4 + 25	6891	6972	6932	
EPTC/2,4-D(2/0.8)	4	7201	6124	6663	
2,4-D IPE(0.8)	4	6108	7124	6616	
" (0.8+0.8)	4 + 25	6652	6245	6449	
MCPA-K WP (0.8+0.8)	4 + 25	5676	6908	6292	
(0.8)	4	4966	5919	5443	
Pyriclor/2,4-D(0.2/0.5)	4	4737	5464	5101	
2,4-D amine EC(0.8+0.8)	4 + 25	4438	5132	4785	
2,4-D Isooctyl (0.8)	4	3506	4899	4203	
2,4-D amine (EC(0.8)	4	3896	4480	4188	
2,4-D Ethylhexyl(0.8)	4	4278	3548	3913	
" (0.8+0.8)	4 + 25	3980	3539	3759	
2,4-D Isooctyl (0.8+0.8)	4 + 25	4729	2666	3698	
Trifluralin/MCPA(0.7/0.4)	4	2902	3463	3182	
No weeding		1640	2173	1906	
Mean (seedling age)		4918	5134		

1/ Days after transplanting
2/ Any two means falling within the same line are not significantly different at 5% level.

Table 3 shows the results of combination of grass herbicides and phenoxyacetic acids tested with or without a uniform spray of 1.0 kg a.i./ha MCPA 20 days after transplanting. There is a marked increase in yields attributable to weed control, but in spite nearly 60% reduction in weed weight the yield increase with MCPA was only about 15% and some cases were negative. Application of MCPA or 2,4-D 3 days after transplanting also produced control of weeds including grasses that was not significantly different from the selective grass killers.

In a recently conducted Uniform International Weed Control Experiment (Table 4) results from direct sown rice in Ceylon show little response to weeding since weed seeds were not sown in the paddy and in general showed no significant yield improvement from chemical treatments over no weeding. The application of $\frac{3}{4}$ kg/ha of MCPA at 40days after sowing gave yields close to those in the best treatment in the experiment which was an applicati0n of 0.2 kg/ha of pyriclor followed by the MCPA spray.

A nearly identical result was obtained from the same experiment conducted in India with both transplanted and direct sown paddy (Manna and Chaudhry 1968).

It is apparent from these three experiments that with good tillage and water management practices the response to chemical weed control is low and that earlier application of phenoxyacetic acid than normally recommended will satisfy the requirements for weed control in so far as it can be economically justified. The use of selective grass herbicides in addition to the phenoxyacetic acid must be looked upon as supplementary. A number of these supplementary materials have shown their worth in screening and management experiments and are now being test-marketed on a trial basis as granular formulations in combination with either MCPA or 2,4-D. The principal materials involved areEPTC and trifluralin. Others will probably be developed commercially within a few years.

Table 3

Effects of herbicides with and without an MCPA spray on grain yields and weed weight of transplanted IR8 rice.

IRRI 1967 dry season

Weed control treatment	Rate of herbicide applied (a.i.)	Time of application 1/	Grain yield -MCPA	Grain yield +MCPA (1.0 kg/ha) 20 DAT	Grain Yield increase with MCPA (if over 700 kg/ha)	Decrease in Weed dry at harvest with MCPA
	(kg/ha)		(kg/ha)		(%)	(%)
Dichlobenil	2.0	2 DAT	8042	8654	-	28
Molinate	3.0	1-2 LSG	7322	8418	15	88
EPTC/2,4-D	3.0	3 DAT	7306	8345	14	-22
MCPA	1.0	3 DAT	7056	8016	14	87
2,4-D	1.0	3 DAT	6943	7988	15	77
CP-45592	4.0	3 DAT	6751	7982	18	97
CDAA	5.0	3 DAT	8295	7939	-	53
Propachlor	4.0	3 DAT	8033	7899	-	30
M-2863	0.25	3 DAT	7421	7557	-	-
Pyriclor	0.20	1 DBT	6425	7349	14	48
Propanil	3.5	1-2 LSG	6747	7201	-	73
KN_3	5.0	1-2 LSG	5252	7021	34	81
			7133	7864	(10)	58
Handweeding 2X		20 and 40 DAT	8129			
Rotary weeding + handweeding		20 and 40 DAT	8079			
MCPA + Rotary weeding	1.0	20 and 40 DAT	6326			
No weeding			2934			

1/ DAT = Days after transplanting
DBT = before transplanting
LSG = leaf stage of grasses

S.e = 530 kg/ha
LSD = 1503 kg/ha
C.V.(X) = 12%

MINIMUM TILLAGE EXPERIMENTS

Substantially more economic justification for the use of herbicidal chemicals in rice cultivation can be made if the chemical performs a part of the tillage requirement in addition to its function as a simply herbicide. The leading chemical in the development of this concept in Asian rice has been paraquat (Mittra, 1968) and a number of tests have shown favourable results.

On a fertile and deep heavy clay soil in the Philippines (IRRI, 1967) tillage was shown to be unnecessary when rice was transplanted in land that had been sprayed with 0.8 kg/ha paraquat, 5.0 kg/ha PCP or 1.0 kg/ha pyriclor + 0.2 kg/ha picloram.

Each of the chemical treatments reduced weeding labor by 200 man-hrs/ha compared with unsprayed and unplowed controls while yielding over 6000 kg/ha rough rice.

An even more forceful case for minimum tillage procedures will result if they can be combined with broadcast sowing of rice in order to eliminate the high labour requirements for transplanting at the same time that the laborious task of land preparation is minimized. If reliance must still be placed on the transplanting methods of stand establishment less advantage would seem to accrue to the reduction of the mechanical or hand power requirement for tillage.

During the 1967 dry season (Table 5) a test was conducted to examine paraquat and pyriclor rates in a "zero tillage" experiment. These chemicals and PCP in diesel oil were sprayed pre-planting and all treatments received an application of 0.8 kg/ha of MCPA 41 days after sowing. Broadcast and transplanted control plots were prepared with normal tillage practices and were sprayed with molinate at 3.0 kg/ha and followed with one hand weeding 51 days after planting. Pyriclor at 0.5 or 1.0 kg ai/ha and the PCP in diesel oil treatment resulted in yields that were as high as the ploughed, harrowed and broadcast control plots. In this test paraquat was not as effective as it had been in previous transplanted trials and the higher grain yields with increased rate suggest that even higher rates would have been advantagous for both chemicals. This is attributed primarily to the fact that the soil was unusually fertile and that weed growth was vigorous and dense. The tiller counts 22 days after planting showed normally high numbers in each chemical treatment and no serious problems in stand establishment were encounted.

Table 4

Effect of herbicide treatment on weed weight and yield of broadcast sown rice variety IR8. Maha Illuppallama, Ceylon
Wet season, 1968. Weed seeds not sown

	WEED FRESH WEIGHT		Grain
	Grasses	Broadleaves and sedges	Yields
1/	g/m²		kg/ha
1. Hand weeded twice (25 and 40 DAS)	21	160	6540
2. Hand weeded once (40 DAS)	5	145	6065
3. Hand weeded + MCPA 2/	151	45	6695
4. MCPA	55	125	6865
5. Pyriclor (0.2 kg/ha a.i., 1 DBS)	22	335	4590
6. Pyriclor + MCPA	165	60	7340
7. Molinate (3.0 kg/ha a.i., 1-2 LSG)	1	220	6270
8. Molinate + MCPA	85	20	6250
9. KN_3 (5.0 kg/ha a.i., 2-3 LSG)	50	245	6960
10. KN_3 + MCPA	385	60	7110
11. Propanil (3.5 kg/ha a.i., 2-3 LSG)	85	240	6555
12. Propanil + MCPA	95	30	6025
13. Propachlor (3.0 kg/ha a.i., 1-2 LSG)	10	210	7065
14. Propachlor + MCPA	120	110	5470
15. Paraquat (1.0 kg/ha a.i., 1 DBS(delayed)+MCPA	210	105	6975
16. No weeding	30	225	6675
			6590

1/ See Table 3
2/ MCPA was applied at 0.8 kg/ha a.i., 40 DAS

$LSD_{.05}$ = n.s
C.V.(X)% = 11

These results demonstrate that high yields can be obtained from broadcast sown rice without tillage provided a suitable herbicide combination can be applied as a pre-planting spray.

A problem sometimes encountered in obtaining good stand establishment in dense weed growth has been the failure to get firm contact between seed and mineral soil, which has led to the retention of a single tillage (Mittra, 1968) to incorporate residual organic matter.

Table 5.

Results from a minimum tillage experiment with broadcast rice in which chemical weed control was substituted for land preparation
IRRI 1967 dry season

VARIETY: IR8

Treatment number	Treatment 1/	Herbicide Rate (a.i.,)	Grain yield at 14% H_2O	Dry weed weight	Time-to-weed	Tiller count (22DAP)
		(kg/ha)	(kg/ha)	(g/m^2)	(man-hrs/ha)	(no/m^2)
1	Paraquat + MCPA	0.5 + 0.8	4067	165	-	560
2	Paraquat + MCPA	1.0 + 0.8	5180	168	-	414
3	Paraquat + MCPA	1.5 + 0.8	5856	133	-	542
4	Pyriclor + MCPA	0.25 + 0.8	6035	223	-	458
5	Pyriclor + MCPA	0.5 + 0.8	6505	150	-	482
6	Pyriclor + MCPA	1.0 + 0.8	7344	70	-	472
7	PCP-oil + MCPA	5.0 + 0.8	7342	60	-	458
8	PHB + Molinate + MCPA + HW (Broadcast control)	3.0 + 0.8	7635	33	144	412
9	PHT + Molinate + MCPA + HW (Transplanted control)	3.0 + 0.8	5407	71	106	446
10	No tillage + MCPA	0.8	1210	447	-	318

LSD = 958
CV(X)% = 12
1/ PHB - Ploughed and harrowed, broadcast. PHT - Ploughed and harrowed, transplanted
HW - Handweeded.

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WEED CONTROL IN LOWLAND RICE AT THE UNIVERSITY OF THE PHILIPPINES, COLLEGE OF AGRICULTURE

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Summary Weed control experiments were undertaken to determine the optimum weed-free period from transplanting and the effect of the duration of competition between rice and weeds on the grain yield of rice. The effect of nitrogen fertilizer on rice-weed competition was likewise determined.

With IR-8 ("Miracle Rice"), a short, stiff-strawed and high tillering variety, a weed-free condition of 20 days after transplanting was sufficient to obtain optimum yield. Longer weed-free periods did not increase grain yield considerably. Shorter weed-free periods gave very low yields. On the other hand, a 30-day weed-free period is necessary for C_4-63, a variety of medium height and tillering capacity. The response to shorter and longer than 30 day weed-free periods was similar to that of IR-8.

The critical period of rice-weed competition for IR-8 was between 20 and 30 days after planting while that for C_4-63 was between 30 and 40 days after planting. Reduction in grain yield due to weed competition increased steadily as the amount of nitrogen added was increased from 0 to 120 kg/ha.

Several promising herbicide treatments were evaluated. For lowland rice, the effectiveness of the following herbicides were demonstrated: a) Treflan-R (trifluralin plus MCPA), b) EPTC + MCPA and c) molinate followed by 2,4-D.

INTRODUCTION

Basic to the appreciation of the value of controlling weeds and to the development of a weed control scheme is the information on some aspects of competition between the weeds and the crop. In tropical areas research efforts to gather such information has been inadequate. The use of herbicides for the control of weeds in major crops has been slowly but steadily gaining acceptance in Southeast Asian rice culture.

This paper reports experiments undertaken to determine the optimum weed-free period from transplanting in lowland rice fields and the effect of the duration of competition between rice and weeds on grain yield. The influence of nitrogen on rice-weed competition was likewise studied.

Highlights of results from separate experiments evaluating promising herbicide treatments are also reported.

METHOD AND MATERIALS

The effect of the duration of weed control on the yield of the rice varieties, IR-8 (Miracle Rice) and C_4-63 was determined by keeping respective plots weed-free for 10, 20, 30, 40, 50 and 60 days after transplanting. No further weeding was done after the designated period of weed control.

To determine the effect of the duration of weed competition, the crop was allowed to compete with the weeds in respective plots for 10, 20, 30, 40, 50 and 60 days after transplanting. Plots were kept weed-free after the competition periods until harvest.

The influence of nitrogen on competition between rice and weeds was determined at five levels of exogenous nitrogen, namely 0, 30, 60, 90 and 120 kg/ha. All of the nitrogen was applied at nine days after transplanting.

All experiments were conducted at the Central Experiment Station of the University of the Philippines College of Agriculture. The soil in the experimental area is classed as Maahas clay. In all experiments plots measured either 2 x 5 m or 3 x 5 m except in one experiment where plots were 1.5 x 4 m. Three to four replications in the randomized complete block design were used in all the experiments.

RESULTS

The predominant weeds in the experimental area belong to three groups, namely: sedges, broadleaved species and grass weeds. The sedges are *Eleocharis equisitina* Presl., *Fimbristylis miliacea* (L) Vahl., *Cyperus difformis* (L), and *Cyperus iria*. *Monochoria vaginalis* (L) Presl. was the main broadleaved species. The grassweeds were mainly *Echinochloa crusgalli* (L) Beauv., and *Leptochloa chinensis*.

The effect of duration of weed control. In IR-8, the increase in grain yield over unweeded plots was 27 and 286 per cent with 10- and 20-day weed-free duration, respectively. In the case of C_4-63, the increases were 351, 559, and 748 per cent for 10-, 20- and 30-day weed control, respectively. Additional weeding beyond the 20-day duration for IR-8 and 30 days for C_4-63 appeared to have no further effect on grain yield. (Table 1).

Table 1

The effect of duration of weed control on the yield of two lowland rice varieties

Duration of Weed Control (Days after transplanting)	Var. IR-8 Grain yield (kg/ha)	Var. IR-8 % of Control	Var. C_4-63 Grain yield (kg/ha)	Var. C_4-63 % of Control
Unweeded Check	575	100	430	100
10	729	126.7	1941	451.3
20	2222	386.4	2833	658.9
30	2251	391.4	3646	847.9
40	2228	387.4	3236	752.5
50	2310	401.7	3809	885.8
60	2458	427.8	3438	799.5

The effect of duration of weed competition. Table 2 shows the effect of duration of weed competition on the yield of rice. Grain yield progressively decreased as the period rice-weed competition was prolonged. For IR-8 the yield was maximum when allowed to compete with weeds for 20 days after transplanting. An additional 10-day weed competition reduced the yield by about 339 kg/ha. This observation suggests that the critical period of weed competition lies between 20 and 30 days after planting. With C_4-63, however, the critical period is apparently between 30 and 40 days after planting.

Table 2

The effect of duration of weed competition on the yield of two lowland rice varieties

Duration of Weed Competition (Days after transplanting)	Var. IR-8 Grain yield (kg/ha)	Var. IR-8 % of Control	Var. C_4-63 Grain yield (kg/ha)	Var. C_4-63 % of Control
10	2121	693.1	2996	723.6
20	2886	943.1	2703	652.8
30	2547	832.3	2747	663.5
40	2312	755.5	2588	625.1
50	2130	696.0	2058	497.1
60	2049	669.6	809	195.4
Unweeded Check	306	100	414	100

The influence of nitrogen on competition. As the amount of exogenous nitrogen was increased the grain yield was steadily reduced. In IR-8 for instance, at 0 and 120 kg nitrogen per hectare grain yield was reduced by 72 and 95 per cent, respectively (Table 3). Yield reduction due to weeds at all levels of nitrogen was consistently higher in IR-8 than in C_4-63.

Table 3

The influence of nitrogen on the effect of weeds on the yield of two rice varieties

Treatment N, Kg/Ha	Treatment Weeded or Unweeded	IR-8 Grain yield (kg/ha)	IR-8 % reduction	Var. C_4-63 Grain yield (kg/ha)	Var. C_4-63 % reduction
0	Weeded	2706	72	2202	54
	Unweeded	760		1006	
30	Weeded	2547	78	2911	82
	Unweeded	549		548	
60	Weeded	3054	85	3368	69
	Unweeded	462		1037	
90	Weeded	3537	87	3321	83
	Unweeded	451		583	
120	Weeded	3177	95	3614	79
	Unweeded	168		760	

Table 4

The effectivness of chosen herbicide treatments for weed control in lowland rice

Treatment: Herbicide	kg/ha	D.A.T.[1]	Grain yield kg/ha	Weed weight (Dry) at harvest g/50 x 50 cm. G	S	B	Total	Weed count at harvest (50 x 50 cm) E. e.[2]	E. c.[3]
Treflan + MCPA	0.75 + 0.5	3	6207	35	4	0	39		
Handweeded (3x)	-	-	7460	-	-	-	-		
Unweeded	-	-	2994	139	28	13	234		
EPTC + MCPA	1.75 + 0.4	7	6097	5	56	0	61	72	0
Handweeded (3x)	-	-	8491	-	-	-	-	-	-
Unweeded	-	-	4530	89	47	1	137	47	17
Molinate fb 2,4-D	3, 1/2	5, 30	4845						
Molinate	3	5	1188						
Handweeded (2x)	-	-	4366						
Unweeded	-	-	796						

1/ Days after transplanting at treatment

2/ *Eleocharis equisitina*

3/ *Echinochloa crusgalli*

Field evaluation of herbicides. The best treatment observed in experiments on field evaluation of three herbicides are presented in Table 4. Like any field evaluation of promising herbicides, the aspects considered included different rates and timing of application. In previous reports (Vega, et. al., 1967) Treflan was suggested to be sprayed pre-emergence followed by a post-emergence spray of a chlorophenoxy herbicide for the control of surviving broadleaved weeds and sedges. A combination of Treflan and MCPA has since been formulated. This new formulation proved effective when applied 3 days after transplanting at the rate of 0.75 kg/ha for Treflan and 0.5for MCPA. Among the different Eptam + MCPA treatments, Eptam at 1.75 plus MCPA at 0.4 kg/ha broadcast at 7 days after transplanting also proved effective for lowland rice. This treatment was however ineffective against *E. equisitina.* This weed species persisted until harvest and is believed to cause the 2.4 ton/ha difference between the handweeded plot and the EPTC + MCPA treated plot. Full benefits from the application of 3 kg/ha molinate at 5 days after transplanting was realized only when such basic molinate spray was followed by a 2,4-D (1/2 kg/ha) application at 30 days after transplanting. After the molinate treatment about the only weed species left was *M. vaginalis.* The phenoxy spray at 30 days after transplanting controlled said species very effectively.

DISCUSSION

Competition from weeds results in reduced rice yield. While this fact is recognized by many, information on certain aspects of rice-weed competition may bring about better appreciation of the control of weeds in this crop. Moreover such information may guide research workers in developing a more efficient scheme for the control of weeds in rice.

The results indicate that a continuous weed-free condition may not be necessary for any optimum grain yield in a rice crop. This work establishes the importance of a weed-free condition from transplanting until the rice plants have produced sufficient number of tillers and a canopy of leaves such that the space between hills are shaded. Emergence of weeds was minimized in this condition.

The minimum duration of weed control which gave optimum yield varied with the two rice varieties used in the study; i.e. 20 days for IR-8 and 30 days for C_4-63. This is expected because the two varieties differ in their growth habits. IR -8 grows faster and develops more tillers than C_4-63; the former can therefore be expected to shade spaces between hills within a shorter period from transplanting. The different durations of weed control may be interpreted to simulate different lengths of residual effect resulting from the pre-emergence application of herbicides. The results therefore, indicate that a pre-emergence herbicide treatment which can gave a residual effect of about 20 days may suffice for a variety like IR-8; whereas a variety like C_4-63 would require a herbicide treatment with a residual effect of about 30 days.

Under certain circumstances, a post-emergence application of herbicides is preferred to a pre-emergence treatment. The effectivity of a post-emergence spray depends largely on the time of application. The desired time is when the susceptible stage for the weeds coincide with the resistant stage for the crop. One consideration often overlooked is the critical period of rice-weed competition; i.e. the duration of time from transplanting when rice can tolerate competition and will not reflect the adverse effects of competition in terms of reduced grain yields. The implication is, the weeds should be controlled before they do permanent damage to the crop. Results of the experiments showed that the two varieties differed in their tolerance to weed competition, indicating that IR-8 can tolerate less competition than C_4-63.

The data on the influence of nitrogen on competition also suggest the lesser competing ability of IR-8 than C_4-63. At all levels of added nitrogen (except at 30 kg/ha) the per cent reduction in yield in IR-8 was higher than yield reduction in

C_4-63. This may be due to the difference in the selection pressure utilized in developing these varieties. This implies that IR-8 was selected under "ideal" growing conditions while C_4-63. were selected under "less ideal" growing conditions. Since fertilizers (especially nitrogen fertilizers) are fast becoming a standard input in rice production it is essential to know its effect on rice-weed competition. The data obtained clearly indicate the futility of using fertilizers without controlling the weeds. It seems that in a weedy situation the addition of fertilizers favoured the weeds more than the rice.

During the years that followed the acceptance of 2,4-D as a chemical control for sedges and "broadleaved" weeds in rice, research efforts have been directed towards obtaining herbicide(s) treatments that could also control the grass weeds of rice. Within the last few years, there has been ample evidence that such herbicide(s) treatments have been found (Steele, B. 1966; Vega et. al., 1967). The three treatments outlined in table 4 are representatives of this group of herbicide(s) treatments. All the treatments have one characteristic in common they all involve a phenoxy spray either applied together with the "grass herbicide" or applied following the "grass herbicide". A formulation that contains both kinds of herbicides (for grass weeds and for sedges and dicot weeds) is anticipated to be effective when the sedges and the dicot weeds are either emerging or will emerge very shortly after the application of the herbicide. In situations where this does not happen a follow-up spray of a phenoxy herbicide may be necessary.

Weed control by means of herbicides in the rice growing areas of Southeast Asia have more problems than the efficacy of the herbicide. The economics of herbicide application is an important consideration. An example on hand is the herbicide treatment making use of molinate and 2,4-D. This treatment has been amply demonstrated to be effective. The cost of the chemical and its application is, however, almost prohibitive and farmer's inability to shoulder the cost prevents its widespread use in the Philippines.

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WEED CONTROL ON A SWAZILAND RICE AND SUGAR CANE ESTATE

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Summary Earliest weed control methods in rice employed hand hoeing and applications of PCP. Aerial application of propanil now gives excellent weed control under paddy conditions in Swaziland and has been a major factor in increasing rice yields. Extension of "upland" irrigated rice systems will cause increased difficulty in weed control and a number of screening trials have been carried out with alternative herbicides but with little immediate success. Work to date on chemical and cultural methods for the control of wild rice (*Oryza punctata*) are noted. Comment is made on chemical control of weeds in irrigated sugar cane, 2,4-D is effective and most commonly used because of its low cost but its several disadvantages will result in the use of other herbicides, such as diuron, becoming increasingly important.

RICE

The agricultural project of the Commonwealth Development Corporation known as Swaziland Irrigation Scheme planted its first rice under paddy conditions in 1951. This first planting of 80 acres was hand sown into a dry seed bed. The present acreage, 2,788 acres of paddy and 801 acres of upland rice, is being extended by further development of overhead sprinkler and slope flooding under "upland" conditions. Weed control problems now fall into two parts. That where water in paddies allows for weed control and that under "upland" (non-flooded) conditions.

In general yield reduction due to weeds only becomes serious after two or three years of cultivations from virgin land. Weed control until 1960 on older lands was by fallowing, irrigating and cultivating prior to planting, by hand weeding and water control with some use of PCP at 3 lb/ac applied by knapsack or tractor mounted equipment to young seedlings. In 1959 a cultural method of weed control was attempted and was used on old lands in 1960 and 1961. Dry paddies were flooded to a 4 in. depth prior to weed seed germination and pre-germinated rice seed aerially sown into the water. The several disadvantages are that weed control is only reasonably good, a delay of 24 hours in seeding due to weather conditions unsuitable for flying results in loss of the seed as it can no longer be handled without injury to the emerging radicle and young plants are not firmly rooted and wave action in the paddies washes them to the leeward bank necessitating reseeding. Control measures have to be taken against a Brachiopod, *Triops granarius*, and a snail, *Lanistes ovum*, both of which feed on the emerging radicle and coleoptile. Malathion at $\frac{1}{2}$ lb a.i./ac controls the former pest but no practical control system has been found for the latter. These two pests are not a problem where rice seed is drilled into a dry seed bed.

Propanil. Plot and field trials with propanil (as STAM F34) in 1961 gave promising results and since 1962 every crop has received this treatment. Rice is grown in monoculture and after harvest the stubble is burnt and the seed bed prepared by discing during the dry winter. Seed is combined drilled with fertilizer and paddies flushed with water to promote germination. A second flush is given before propanil application to encourage active growth of weeds, primarily *Echinochloa* holubii and Leptochloa chinensis. About 18 days from first irrigation when weeds are at the 3 to 4 leaf stage, an aerial treatment of propanil at 3.6 lb/ac in 8.3 gallons water is made. Droplet size and distribution of the sprayed solution is checked against dyed spray deposits on paper strips. Further weed germinating is controlled by the permanent flooding of paddies to about 4 in. depth of water 1 to 2 days later. Water depth is gradually increased to 6 in. until 3 weeks before harvest when paddies are drained.

Weed control is excellent and has been the greatest single factor responsible for increased rice yields. Over the estates as a whole average yields increased from 1100 lb rough rice per acre in 1959/60, when the weed problem on the estate was at its height, to 3789 lb/ac average for the 3 years 1964-66. In replicated trials in 1966 yields in a single season were depressed from 4000 lb in propanil treated plots to 2,250 lb rough rice/ac in plots with no weed control.

Field scale trials have been carried out with different rates and spray volumes of STAM F34. The most consistent results with least phytotoxicity have been obtained in aerial application with 3.6 lb/ac propanil in 8.3 gallons water. Propanil at 3.6 lb/ac in 4.2 gallons water, STAM F34 neat at 1 gallon/ac and a specially formulated low volume material, STAM LV10 at 1 gallon/ac have either shown poorer weed control or greater phytotoxicity. Work with LV10 is promising, however, and would lower costs of application. Good results have also been achieved using 2 lb/ac propanil at 10 days after the flush for germination. Weeds are at the 2 leaf stage and susceptible to the lowered rate of propanil. Because rice plants are too small at this stage to be inundated with water, as in the normal method of preventing further germination of weed seeds, should such germination occur a second application of 2 lb propanil is required. Although STAM F34 gives excellent weed control it can be improved upon and in replicated plot trials with knapsack application treatment of STAM + a confidential additive gave significantly better ($P = 0.05$; c. of V = 11.7%) results than STAM alone. Manufacturers advised that the high cost of the additive did not make its commercial production a possibility.

The limitations of propanil are its sensitivity to low termperatures and the absence of residual effect which requires action to be taken after application to control further germination of weeds. In paddies this is done by flooding but Bluebonnet 50, the variety grown on the estate, is still too small at the optimum time of spraying weeds to be inundated without some setback. Although there is need for a selective pre-emergence herbicide with residual action of 5 to 6 weeks to allow rice to tiller and canopy before inundating under paddy conditions, this need is greater under "upland" conditions where, subsequent to propanil application, no weed control by flooding is possible. Furthermore, populations of weeds tolerant to propanil are more likely to build up under non-paddy conditions.

Linuron. In 1966/67 encouraging work was carried out in knapsack trials (100 gallons water/acre) with linuron (as Afalon 50% WP). Application was 8 days after the water flush for germination and rice seedlings were emerging. Propanil at 3.6 lb/ac was applied to other plots 8 days later. All rates of linuron 0.5, 0.75 and 1 lb/ac a.i. caused scorch of the emerged coleoptiles but no apparent setback in further growth of the rice. All treatments gave good weed control while differences between treatments were small. Rice yields from treated plots were significantly better than the untreated control and the 1 lb a.i. linuron treatment better ($P = 0.05$; C. of V = 8%) than that of propanil. In 1967/68 this work was extended and knapsack application (37 gallons water/ac) of 7 rates of linuron 4 days after flushing were compared with the standard treatment 22 days after flushing. Visual assessment of weed population was made at time of propanil application, Table 1. Half the plots in the 1.5 lb/ and 2 lb a.i. per acre treatments had no weeds at all but phytotoxicity and die back of rice was pronounced at this treatment rate. However counts (16 x 3' lengths of row) of strong healthy tillers taken in each treatment 45 days after germination showed little difference between treatments. Numbers of grasses and rice plants per square foot are tabled together with the mean yields of the 4 replicates for each treatment. Sedge population (Cyperus difformis) was also markedly reduced at the 2 lb a.i. level. Overall impression was that $\frac{3}{4}$ lb a.i. would be the expected rate for field operations.

Table 1

Pre-emergence application of linuron to rice

linuron a.i./ lb/acre	Weed cover assessment at 22 days (10 = 100% cover)	Numbers of plants per ft^2 at 45 days		Yields rough rice lb/ac
		Grasses	Rice tillers	
0.25	5.75	11.6	20.8	3,220
0.38	4.00	12.1	19.7	3,010
0.5	3.00	3.04	16.9	4,311
0.75	1.50	0.39	20.5	4,791
1.0	1.50	0.82	16.1	4,356
1.5	1.00	0.07	16.7	4,560
2.0	0.63	0.04	14.9	4,537
propanil 3.6 lb	(8.25)	1.46	16.5	3,623
untreated control	7.00	24.10	17.1	2,467

s.e. of a single observation 753.2 lb/ac rough rice C. of V. 19.4%

During 1965 and 1966 aerial applications of linuron in 10 gallons of water per acre were also made. Results were conflicting and somewhat disappointing. In 1965 aerial application of $\frac{1}{2}$ lb and 1 lb a.i. linuron, both applied in 10 gallons water/ac pre-emergence and very early post-emergence (crop and weeds), caused a definite but mild phytotoxic effect at both rates especially in the post emergence 1 lb/acre rate. The crop, however, recovered. At a different site 1 lb a.i./acre was applied from the air at the same spray volume and no phytotoxicity was recorded. In the following year marked phytotoxicity was recorded with some death of rice seedlings following the 1 lb/acre a.i. and 10 gallons of water pre-emergence application and caused an 18% reduction in yield compared with propanil treatments. In the same year at a different site aerial applications of $\frac{1}{2}$, $\frac{3}{4}$, 1 and $1\frac{1}{4}$ lb/ac a.i. linuron caused no phytotoxicity although coleoptiles were just emerging through the soil surface when sprayed. In both trials weed control was good and at the site where no phytotoxicity was recorded increases of 900 lb rough rice per acre were achieved over untreated control. The interest in linuron was sustained by the absence of any other commercially available selective pre-emergence herbicide for rice weeds and the high cost of propanil at 81/- per acre compared with 26/- for linuron.

Subsequent work with the mini-logarithmic sprayer indicates that, under local conditions, Bluebonnet 50 has an acceptable degree of tolerance to linuron applied early post-emergence, at least to 15 days after germination but not to 26 days, at rates up to $1\frac{1}{4}$ lb a.i./ac. Combination of $\frac{3}{4}$ lb a.i. linuron and 2 lb a.i. propanil per acre have not caused phytotoxicity to newly emerged rice and it is this type of mixture which is currently being evaluated for application about a week after emergence of the rice coleoptile. At the present time the lack of understanding of conditions which evoke phytotoxic symptoms in rice following some applications of linuron precludes its large scale use.

Other pre-emergence herbicides. Work by the Swaziland Department of Agriculture (1964/65) indicated, in small plot trials with knapsack sprayers (30 gallons water/acre), that prometryne, Rowmate (3,4- and 2,3-dichlorobenzyl-N-methylcarbamate), Ordram (molinate), Glenbar (O,S-dimethyl tetrachlorothioterephthalate) and BV 207

(1-(3-chloro-4-methylphenyl)-3-methylpyrrolidin-2-one) as pre-emergence treatments compared favourably with propanil post-emergence. The first 4 materials and one other, Tok (nitrofen) were investigated by the estate in 1965/66 using 5 gallons of spray solution per acre to replicated 2 acre plots as pre-emergence aerial application.

Table 2 gives a generalised description of the control based on weed population counts taken 18 days after treatment. Only grasses through to the 5 leaf stage, and hence considered to be surviving weeds, were counted and 24 yard square quadrats were taken for each treatment. No treatment gave satisfactory weed control and where this was best it was also associated with the greatest phytotoxicity to rice. When propanil was applied 20 days after treatment all rice plants in the Rowmate plots were killed, indicating interaction of carbamate and propanil.

Table 2

Comparative effect of 5 herbicides 18 days after pre-emergence aerial application to rice

Injury rating 0 = no effect 10 = complete kill

Herbicide Applied after flushing	lb/ac a.i.	Weed control	Phytotoxicity to rice
Glenbar	1	0	0
	3	1	0
Prometryne	$1\frac{1}{2}$	4	2
	2	6	1
Molinate	3	1	0
	5	2	0
Rowmate	3	2	2
	6	5	4
Nitrofen	2	1	0
	4	3	0
Applied before flushing			
Prometryne	$1\frac{1}{2}$	2	0
	2	4	3
Molinate	3	1	0
	5	2	0

Recent trials with pre-emergence herbicides have been extended to post-emergence treatments with a view to their possible combination with propanil treatments. Ramrod (propachlor) Sindone B (1,1,4-trimethyl-6-isopropyl-5-indanyl ethyl ketone + 7-indanyl isomer) and OCS 21693 (methyl 2,3,5,6-tetrachloro-N-methylterephthalamate) have shown little or no phytotoxicity in very early and late post-emergence treatments, (2 days and 21 days after coleoptile emergence), at rates higher than that necessary for weed control. Rice has been more sensitive to post-emergence treatments of BV 201 (1-(3,4-dichlorophenyl)-3-methylpyrrolidin-2-one), Tok and GS 14260 (terbutryne).

Sedges Where necessary control of *Cyperus difformis*, *C. iria* and *C. distans* is achieved by applying 0.75 lb a.e. MCPA in $2\frac{1}{2}$ gal water/ac by aircraft 6-8 weeks after planting. Paddies are drained just before spraying and reflooded within a few days.

Canals and drainage lines. Effective suppression of weeds, mainly *Paspalum distichum* and *Echinochloa pyramidalis* in canals and drainage lines is being achieved by the use of 2.5 lb a.i. dalapon and 2.25 lb a.i. aminotriazole mixture per acre.

Wild rice A major weed problem currently under investigation is the control of Oryza punctata (Kotschy). This "wild rice" species successfully competes with commercial varieties and has a shorter period of maturity. The seed also displays a dormancy of at least 12 months. Cultural control as bare fallow or pastures and by cultivating and keeping paddies flooded during the non cropping months are being tested. Burning the stubble of the rice crop only kills wild rice seed on the soil surface. Crops other than rice do not yield well on our paddy soils and irrigation layouts and this rice monoculture precludes the initiation of a non-selective gramin-aceous herbicide programme. O punctata does, however, develop a mesocotyl at seed depths below $\frac{1}{4}$ in. whilst in Bluebonnet 50 this seldom occurs unless the seed is sown to a depth of greater than 1 in. By careful preparation of the seed bed and control of seed depth at planting it is possible that selective chemical control may be achieved by the use of a non water soluble herbicide. High seed rates would minimise yield reduction due to the inevitable loss of some plants of the commercial rice crop. This approach is being investigated.

SUGAR CANE

The estate experience and field trials of both S.I.S. and C.D.C.'s neighbouring estate, Mhlume (Swaziland) Sugar Co. arebriefly described. Estate practice has been restricted, almost exclusively in the past 10 years, to the use of 2,4-D amine at $3\frac{1}{2}$ lb a.e./ac. Application has been by knapsack or tractor mounted rig or where conditions are suitable by aerial application in as low as $2\frac{1}{2}$ gallons spray solution per acre. Very satisfactory weed control follows pre-emergence application but residual effect is limited to 6 weeks and one or more hand weedings are required before cane canopies some 6 to 8 weeks later. One major factor in favour of this herbicide is its low cost, 21/- per acre for material. Disadvantages are the insufficiently long residual effect, requirement of moist soil conditions at time of spraying, setback of certain cane varieties (N.Co. 376) to post-emergence sprays, restricted use during the cotton growing season and the increase in population of weed species tolerant to these levels of 2,4-D, for example Panicum maximum. Other phenoxy herbicides, such as butyl isopropyl ester and the glycol ester of 2,4-D give 14 days longer residual effect but their use has not been justified on a comparative cost basis with the amine.

Of other herbicides screened, diuron at 3.2 lb a.i./ac (cost 110/-), atrazine at 3.2 lb a.i./ac (93/-) and bromacil at 0.8 lb a.i./ac (54/-) offer the greatest potential for local usage. Bromacil must be used with caution for severe phytotoxicity and setback to the cane is likely if application rates are not carefully controlled. Atrazine has also been successfully used at rates of 2 lb a.i./ac on sandier soils but it appears that Digitaria sanguinalis and Urochloa panicoides are somewhat tolerant of atrazine treatments. Most interest centres on diuron, which has shown itself to be a useful broad spectrum herbicide for pre- and post-emergence treatments in irrigated cane lands. Heavy overdoses of diuron to young cane have produced no apparent phytotoxicity.

Cyperus esculentus and C. rotundus are at present limited but potentially serious weed problems on the estates. Gosnell and Thompson (1967) have shown that linuron (2 lb a.i.) and diuron (3.2 lb a.i.) gave good control of C. esculentus and post-emergence sprays of 7.2 lb a.i. 2,4-D control of C. rotundus. Best control of both species was achieved by spraying with paraquat at 0.5 lb a.i./ac at the commencement of flowering with an increased effect by the addition of 2 lb a.i. 2,4-D control of C. rotundus. Best control of both species was achieved by spraying with paraquat at 0.5 lb a.i./ac at the commencement of flowering with an increased effect by the addition of 2 lb a.i. 2,4-D amine to the spray. Local experience is that a mixture of 0.8 lb a.i. diuron and 0.25 lb a.i. paraquat per acre provides excellent control of *C. esculentus* where treatment has been carried out in the shade of canopied cane.

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WEED CONTROL IN RICE IN CEYLON

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Summary

Of the 1.5 million acres of paddy in Ceylon, only about 30 per cent is in fact weeded. Methods of stand establishment determine largely the success achieved with different methods of weed control. Chemical weed control using MCPA at 0.75 lb a.i. per acre and propanil at 3 lb a.i. per acre, was similar to hand weeding and raised yields of rice two fold under irrigated culture, compared to the unweeded control. Chemical weed control also offers the greatest promise in the case of rainfed rice. A pre-emergence application of PCP at 4 lb a.i. per acre followed by post-emergence application of propanil at 2 lb a.i. per acre gives very effective control. The semi-dry method of rice culture is full of promise, provided weeds can be controlled chemically. The use of paraquat could help to effect considerable economy in water use, and make double or even treble cropping in a year feasible.

INTRODUCTION

Rice cultivation in Ceylon covers an area of approximately 1.5 million acres. During the period 1954-56 to 1964-66 rice production in the island increased by about 55 per cent, giving an average annual rate of growth of about 5 per cent. In relation to the substantial increases in inputs, e.g. fertilizer use increased by about 400 per cent during the period, and loans granted for paddy cultivation by over 100 per cent, the response in terms of increased yields must be considered inadequate. While this may be attributed to many factors, one reason for the slowness to achieve anticipated yields in spite of a gradual spread of improved techniques of culture, is the failure to adopt, in conjunction, proper measures of weed control in rice fields, (table 1). A recent estimate put the total extent in fact weeded at 30 per cent of the total cultivated extent.

Table 1.

Spread of improved techniques of culture, and extents weeded in '000 acres, 1960 - 64.

	Maha (N.E. Monsoon season)					Yala(S.W. Monsoon season)				
Cultural practice	1959/60	'60/61	'61/62	'62/63	'63/64	1960	1961	1962	1963	1964
Transplanted in rows	26.5	24.6	33.7	37.2	43.8	6.6	12.2	13.7	12.6	13.5
Transplanted, but not in rows	99.0	85.8	106.0	120.5	135.8	23.3	22.9	42.5	39.7	52.7
Row seeded	32.3	25.4	28.3	28.3	16.4	22.6	13.2	23.8	20.2	16.9
Total transplanted or row seeded	157.8	135.8	168.0	186.1	196.2	52.6	48.4	80.1	72.7	83.1
Extent weeded, weedicides used, and crop harrowed	231.9	227.9	297.8	383.3	336.6	146.2	150.5	205.5	226.9	188.7

Source: Administration reports of the Director of Agriculture, Ceylon.

Crop losses due to weed competition have been estimated at 15-20 bushels per acre, and total losses at around 15 million bushels per year. The early stages of growth of the crop appear to be the most sensitive to weed competition. Failure to control weeds during the first three weeks, reduced yields by as much as 75 per cent in rainfed rice, and 50 per cent in irrigated rice (Jayasekera and Velmurugu 1966).

CULTURAL PRACTICES IN RELATION TO WEED CONTROL

Rice in Ceylon is grown largely under lowland mudded culture as irrigated rice, and to a limited extent under rainfed conditions as upland rice. With irrigated rice, preparatory tillage is in itself an accepted method of weed control. Careful tillage and complete inversion of the furrow slice is followed by submergence. Clean weeding of bunds and irrigation channels removes another troublesome source of weeds. The use of standing water purely for weed control purposes, however, becomes of doubtful importance in broadcast or row sown cropw, as the germinating paddy will not take standing water, and during this period both paddy and weeds will grow alike. Finally when the crop does take standing water, the weeds are ahead and will offer the crop severe competition. Standing water is more useful for a transplanted crop to which it can be applied earlier. Water alone seldom provides adequate control and very often has to be combined with either mechanical or chemical methods.

Rainfed rice is usually seeded prior to the onset of the monsoon. Rainfall immediately after seeding promotes the germination of the crop, as well as a prolific growth of weeds. Suitable chemical methods including pre-emergence and post-emergence treatments, give adequate control of weeds. Mechanical weed control becomes difficult due to heavy rain thereafter. Thus it is clear that the method of stand establishment determines to a large extent the measure of success that can be achieved with the different methods of weed control.

WEED CONTROL IN IRRIGATED RICE

In irrigated rice, sowing is preceded by puddling of the soil. This cultural operation destroys surface vegetation and provides a clean seed bed for sowing. Chemicals can be used to control all subsequent weed growth, but their efficacy is reduced whenever rain occurs immediately after spraying. Another difficulty would be the complete drainage of fields prior to application, particularly in ill drained areas.

An experiment to compare the efficacy of propanil, MCPA and handweeding with the unweeded control in influencing weed populations and rice yields was laid out on the University fields at Peradeniya, on 1.3.68 using the variety IR8. The design was a randomized block with four replications, and the plot size was 300 sq.ft. Propanil was sprayed at 3 lb a.i. per acre 14 days after sowing, and MCPA was sprayed at 0.75 lb a.i. per acre at 28 days after sowing. The major weed species found in the experimental plots in decreasing order of density were Fimbristylis miliacea. Vahl; Isachne globosa O'ktze; Cyperus iria. L; Echinocloa stagnina Beauv; Ischaemum rugosum salisb; Monochoria vaginalis Presl; Pistia stratiotes. L; and Echinochloa colonum Link.

The degree of weed control measured in terms of weed dry weights 60 days from sowing (period of maximum tillering) and again at 95 days from sowing (heading), together with the final yield at harvest is shown in Table 2. A covariance analysis between the yield of rice and weed weights at heading showed that these were significantly correlated (r=0.76) while the weed weight at tillering was not highly correlated. All weed control methods used were superior to the control and raised yields two fold compared to the control. There was no significant different between chemical control with either propanil or MCPA and hand weeding.

Table 2.

Mean Weed weights per sq. ft. in grams at tillering, and heading, and final yields of rice in bushels per acre.

Treatment	Weed weight per sq. ft. at tillering	Weed weight per sq. ft. at heading	Adjusted yields of rice in bushels per acre
Control	13.8	24.4	36.0
Hand weeded	3.1	4.5	84.2
Propanil	0.5	0.6	86.8
MCPA	1.9	5.2	92.3

S.D. = 0.01   L.S.D. 34.0 bushels.   Coefficient of variation = 7.9%

RAIN FED RICE

In rainfed rice water does not play a significant role in weed control. Rainfall soon after seeding promotes prolific weed growth. Graminaceous weeds predominate, particularly Echinochloa colonum Link, an annual grass that closely resembles the rice plant in the early stages. Soil conditions are also not suitable for the effective use of mechanical methods of weed control. Chemical weed control offers the greatest promise. Research carried out at the Dry Zone Research Station, Maha Illupalama suggests that a pre-emergence application of PCP followed by a post-emergence application of propanil gives very effective control. Of several dosages and combinations of the two chemicals tested, the most optimum dosage and combination appeared to be 4 lb a.i. of PCP followed by 2 lb a.i. of propanil. (Jayasekera and Velmurugu 1966).

WEED CONTROL AND WATER ECONOMY IN RICE PRODUCTION.

As early as 1912, Briggs and Shantz (1914) observed that the water requirement of rice was not much higher than that of rye and lower than that of many other plants. This was confirmed later by many Indian workers. Senewiratne suggested that only soil saturation is required for better growth and development of the rice plant. Standing water is a luxury, and confers only marginal benefits chief of which is weed control, which can be achieved also by other means. It is customary practice in Ceylon to flood paddy fields after the plant is established and to gradually increase the depth of flooding as the plant grows. Nearly two acre feet of water are utilized for land preparation and 1 acre foot is used per month of irrigation (Senewiratne and Appadurai 1966). All available evidence suggests that a saturated soil is desirable, that standing water helps to control weeds, but there is no justification for growing rice in flowing water. Chemical weed control points to the desirability of preparing the land dry, sowing ungerminated seed, and impounding the water into the field as the rains get heavier. This semi-dry method of rice culture will no doubt help to minimize the extravagant use of water and thus help to extend the area under cultivation.

MINIMUM TILLAGE WITH PARAQUAT

Paraquat a total weed killer, is increasingly becoming popular for destroying all weeds present in a paddy field soon after harvest. The use of the chemical helps to eliminate 2 ploughings or muddings, and effects considerable economy in the water used in land preparation. The use of paraquat has resulted in yield increases of 15-20 bushels per acre. (Dias 1966), and promises to make double or treble cropping in a year a realizable aim.

CHEMICAL WEED CONTROL AND COSTS.

High costs, particularly foreign exchange costs, have been the chief limiting factors to the wide spread use of chemicals for weed control in Ceylon. For irrigated rice the cost of using propanil amount to Rs.56/= per acre, while for rainfed rice the combined use of PCP and propanil costs around Rs.76/= per acre. Yield increases of 6-8 bushels per acre could offset these costs. Incidental benefits of chemical weed control also include an economy in water use, and a saving in time and labour. Costs will decline with wider use and this is the current trend in Ceylon.

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CONTROL OF MIMOSA PUDICA L.(SENSITIVE PLANT) ON RICE FIELD BUNDS

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Summary The Chemical control of *Mimosa pudica* L. infesting rice field bunds was attempted using esters of 2,4,5-T and 2,4-D and also the amine of 2,4-D at two levels of application, (2+1) and (2+1+1) l./ac for esters and (3+1) and (3+1+1) l./ac for amine in two and three weekly doses. 2,4,5-T ester was the most effective, while 2,4-D ester did not suppress the lateral shoots. 2,4-D amine was not at all effective. Mechanical cutting produced vigorous regrowth within a month. It is concluded that two applications of 2,4,5-T ester at (2+1) l./ac would be sufficient to give a good control of the weed with complete kill and without any regrowth for over a year.

INTRODUCTION

Mimosa pudica L. the sensitive plant, is a troublesome spinescent, perennial weed of tropical rice field bunds and irrigation channels. Cultural methods of control such as cutting the plant to the stumps or burning have not been effective. Being on rice field bunds and channels, ploughing down or up-rooting with "mummatti" (spades) is not possible. Hence the scope of herbicides for the control of this weed was investigated.

Paul (1947) advocated good tillage for the control of *M. pudica* in pastures. Early investigations in Malaya suggested mechanical means as more economical than herbicides (Anon, 1950). Buckley (1951) recommended periodical mechanical tearing out of the weed in pastures as more successful than 2,4-D.

Investigations in Jamaica (Anon, 1953) proved that judicial combination of mechanical and chemical methods such as application of 2,4,5-T, alone or preferably in combination with 2,4-D after "billing" (a light cutting with machete), would be the most useful in controlling *M. pudica*.

Trials with 2,4,5-T alone or in combination with 2,4-D have shown the former to be the best on several occasions (Kasasian,1963 and Anon, 1953), whereas 2,4-D alone does not give consistently satisfactory results (Jagoe and Johnston 1949, Buckley, 1951 and Ripema, 1965).

METHODS AND MATERIALS

The details of the trials are as follows:
Location: Rice field bunds, Agricultural College, Madurai, India.
Plot size: 16 ft x 6 ft; Treatments: Eight; Replications: Four.

Treatments (units refer to commercial products)	No. of sprayings	Total a.i./ac applied
I. 2,4,5-T ester at 2+1 litres per acre	Two	1.2 kg
II. 2,4,5-T ester at 2+1+1 " " "	Three	1.6 kg
III. 2,4-D ester at 2+1 " " "	Two	0.9 kg
IV. 2,4-D ester at 2+1+1 " " "	Three	1.2 kg
V. 2,4-D amine at 3+1 " " "	Two	2.4 kg
VI. 2,4-D amine at 3+1+1 " " "	Three	3.0 kg
VII. Mechanical cutting upto ground surface	(once)	
VIII. Untreated control		

Spraying interval: Weekly. Spray volume: 100 gal per acre.

Spraying was undertaken when the plants were showing vegetative growth, after the monsoon showers. No surfactants were used.

Monthly observations were recorded adopting the score card technique and all the scorings were done by the same person to avoid any personal variability. The mean scores (value) of the four replications were taken into account for rating the efficacy of the treatments.

RESULTS

(1) Immediately after spraying: The folding up of the leaflets and the bending down of the whole leaf at the pulvinus were noted. The folded leaves regained the normal position in about 3 to 5 minutes in the hot sun. However, it was observed that the leaves began to lose their sensitivity gradually about 3 hours after the spray. The night position of the leaflets and the leaf was also affected; the leaflets tended to remain open instead of being folded up together; the petioles of the leaves did not bend down, unlike in the normal leaves.

(2) First week after spraying: In about 3 days after spraying, the loss of sensitivity of the leaves and leaflets was pronounced and within 7 days, loss of sensitivity was complete. Yellowing and scorching of the leaflets, dropping of the inflorescence heads and epinasty of the growing shoots were observed.

(3) Second week after spraying: The entire leaves started dropping off in 2,4,5-T ester treatments while in treatments with 2,4-D ester the leaflets began to drop off with partial dropping of leaves; with 2,4-D amine the leaves and leaflets were still intact, though a little yellowing was noted.

(4) One month after spraying: In 2,4,5-T ester, irrespective of the dosages, the symptoms of drying of the plant were very severe, with all leaves dropped off, growing tip burnt, stem partly dried and flowers shed. The higher dose (2+1+1 l./ac) of 2,4-D ester was slightly effective, yet the scorched leaves were still adhering to the stem, growing tip not burnt completely and stem remained green. In 2,4-D amine, the leaves showed tip burning only. The growing tips were slightly burnt. The plant almost appeared like an untreated plant. The cultural treatments promoted fresh regrowth on the stumps within a month after cutting.

(5) Subsequent observations: Monthly observations were made for four months after the treatments were initiated. The rating of the efficacy of herbicides was done and presented in Table 1.

Table 1.

Rating of herbicide efficacy on mimosa

(Mean values of four replications)

	December, 1966					January, 1967					February, 1967					March, 1967				
	*LV	GT	LS	ST	T	LV	GT	LS	ST	T	LV	GT	LS	ST	T	LV	GT	LS	ST	T
Score	1	3	4	2	10	1	3	4	2	10	1	3	4	2	10	1	3	4	2	10
Treatments.																				
I.	1	3	4	1	9	1	3	4	1	9	1	3	4	2	10	1	3	4	2	10
II.	1	3	4	1	9	1	3	4	1	9	1	3	4	2	10	1	3	4	2	10
III.	1	2	1	0	4	1	2	1	1	5	1	2	1	1	5	1	2	0	1	4
IV.	1	2	3	1	7	1	2	3	1	7	1	2	3	1	7	1	2	1	1	5
V.	0	1	1	0	2	1	1	0	0	2	1	1	0	0	2	1	1	0	0	2
VI.	1	1	1	0	3	1	1	1	1	4	1	1	1	1	4	1	1	1	1	4
VII.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VIII.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* LV = leaves; GT = growing tip; LS = lateral shoots; ST = stem; T = total

Treatments As listed above.

Scorings:

Leaves = all dried up - 1; no drying at all - 0.
Growing tip burnt = complete - 3; partly - 2; slightly - 1; not burnt - 0.
Lateral shoots suppressed = complete - 4; partly - 2; slightly - 1; not - 0.
Stem drying = complete - 2; partly - 1; no drying - 0.

DISCUSSION

To summarise the observations, the leaf drying was seen in most of the herbicide treatments except in lower doses of 2,4-D amine. However, the effects of 2,4,5-T ester in scorching and killing the leaves were quick and visible within a week. Comparing the formulations of 2,4-D, the esters were noted to be slow in action while the amines proved ineffective.

The effects of 2,4,5-T ester were marked. The plants were completely killed within two months of spraying. There was no regrowth of the plants even a year after spraying. The dosages did not materially alter the efficacy of the herbicides. These observations are in conformity with the investigations on this weed in Trinidad (Kasasian, 1963).

At higher doses (2+1+1 l./ac), 2,4-D ester was somewhat effective, but the effect was not persistent. The lower doses (2+1 l./ac) were not effective in checking the growth of lateral shoots, despite the inhibition of the activity of growing tips. The stems in both cases remained partly green throughout. This is similar to the findings elsewhere also where 2,4-D has not found favour in the control of Mimosa in grass lands (Jagoe and Johnston, 1949), pastures (Buckley, 1951) and rubber plantations (Riepma, 1965) in Malaya.

2,4-D amine proved the least effective among the three herbicides tried. Even the yellowing and scorching of the leaves were slow. The suppression of lateral shoots and inhibition of the activity of the growing tips were poor. The stems remained almost green throughout.

The mechanical removal of the shrub, by cutting to ground level was of no use as fresh shoots had grown vigorously from the cut stumps within a month.

It is concluded that application of 2,4,5-T ester at 2+1 litre per acre is best for the control of Mimosa pudica.

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WEED CONTROL IN COTTON

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Summary At Henderson Research Station on deep reddish brown clay, long-season broad-spectrum weed control will only be achieved by using combinations of the selective herbicides at present available. Either nitralin or trifluralin should be used preplanting, and incorporated, to control monocotyledonous weeds while control of dicotyledonous weeds should be achieved by pre- or post-emergence applications of chemicals such as prometryne and fluometuron. Post-emergence application of these chemicals may be preferable as, in some cases, they should control any monocotyledonous weeds that survive the reduced rate of application of the aniline group. However, under tropical conditions there is a danger of the soil becoming and remaining too wet for timely application. Herbicide problems on cotton soils showing a high silt fraction are discussed.

Optimum quantities of each herbicide have not yet been determined for all Rhodesian conditions but the suggested herbicide-combination technique should reduce the risk of crop phytotoxicity particularly on the lighter soils.

INTRODUCTION

Cotton had limited economic prospects in Central Africa, until the introduction of effective pest control measures, since when acreages planted to this crop have increased rapidly. Chemical weed control is now common practice on the Rhodesian cotton crop and, with the establishment of a weed control team at the Henderson Research Station in conjunction with work at Gatooma Research Station, this subject has recently been studied fairly intensively.

Cotton has usually been grown on the heavier soils and so far research has been limited to these soils. However, a large increase is foreseen in the cotton acreage on the sandy soils and future research will include work on these soil types. In the 1967/68 season, there were a number of cases of serious crop damage on these soils, caused by the application of a selective herbicide.

The weed spectrum of Rhodesia is extensive and varies from area to area, but it was decided that the initial programme of investigation should be limited to the following weeds of the highveld (above 3,000 ft):-

Rottboellia exaltata is a tall annual grass with the capability of germinating at any depth from 6 inches. The plant is a major problem on heavy soils below 4,200 ft and as this is the highest altitude for economic cotton production, it is widespread in most cotton fields. It does not appear as a problem on the sandy soils.

Eleusine indica is a widespread annual grass common on sandy soils.

Nicandra physaloides is a tall, fast growing annual dicotyledonous weed of major importance and commonly found on highly fertile soils at higher altitudes.

Acanthospermum hispidum is a noxious dicotyledonous weed in many areas, germinating late in the season and growing on all soil types. Its occurence as a serious weed is limited to areas of low fertility or low rainfall.

METHODS

The results reported in this paper were obtained in the four seasons 1964/65 to 1967/68 at Henderson Research Station. The trials were designed to study crop tolerance and in no cases were the weeds allowed to compete with the crop but an attempt was made to assess accurately the weed control attained. R. exaltata and A. hispidum do not occur normally in any quantity at Henderson Research Station and the results quoted prior to the 1967/68 season do not indicate the control of these weeds. In the 1967/68 season, R. exaltata was sown on the trial area. No variable dosage treatments were included in these trials as other trials had indicated optimum herbicide levels for weed control and these were the levels normally applied.

RESULTS

The following sequence of trials were carried out on a deep reddish brown clay. No significant reductions in crop yield due to the herbicides were recorded.

1964/65

Treatments were:-

ametryne	1.5 lbs a.i. per acre pre-emergence
prometryne	1.5 lbs a.i. per acre pre-emergence
dacthal	6.75 lbs a.i. per acre pre-emergence
diuron	1.6 lbs a.i. per acre pre-emergence
desmetryne	1.5 lbs a.i. per acre pre-emergence

Prometryne proved the most effective, followed by ametryne on a weed spectrum of predominantly mixed dicotyledons, but with some grasses.

1965/66

Treatments were:-

prometryne	1.5 lbs a.i. per acre pre-emergence
CIPC	1.4 lbs a.i. per acre pre-emergence
trifluralin	1.0 lbs a.i. per acre preplant incorporated
fluometuron	2.8 lbs a.i. per acre per-emergence
norea	1.8 lbs a.i. per acre pre-emergence

CIPC and norea showed poor results compared with the other herbicides. The weed spectrum on this trial was again mixed, but with grasses, particularly Setaria spp., predominating.

1966/67

Treatments were:-

prometryne	1.5 lbs a.i.	per acre pre-emergence
trifluralin	1.0 lbs a.i.	per acre pre-plant incorporated
fluometuron	2.8 lbs a.i.	per acre pre-emergence
fluometuron	2.8 lbs a.i.	per acre post-emergence at 1st pair of true cotton leaves.

All the herbicides were partially successful in this trial. However, trifluralin gave poor control of broad-leafed weeds, while fluometuron, post-emergence, failed to control germinated grasses. The weed spectrum was predominantly N. physaloides with a light infestation of the grasses E. indica and Setaria spp.

These trials in addition to other screening trials carried out indicate the following grouping of herbicides according to weeds controlled.

R. exaltata

trifluralin
nitralin

E. indica

trifluralin
nitralin
prometryne
fluometuron

N. physaloides

Most cotton herbicides screened with the exception of trifluralin and nitralin which had a very limited effect.

A. hispidum

fluometuron
prometryne

In the final trial it was decided to assess certain combinations of the herbicides and to obtain more information on R. exaltata, seed of which was sown in the trial area.

DISCUSSION

In all the trials reported, the weeds were removed before they could affect the crop. No one method of assessing weed control in these trials was found satisfactory because the weed spectrum varied over the experimental areas but the following conclusions are justified.

1. Control of R. exaltata was only regularly achieved by the application of trifluralin or nitralin.

2. Broad-leafed weed control was best achieved by fluometuron and prometryne, the former gave longer persistence. Prometryne, however, was slightly more effective on R. exaltata and when applied post-emergence was very effective on most weeds including R. exaltata (Henderson Research Station, 1967/68).

Table 1

Cotton herbicide trial 1967/68
Treatments and crop yields

Herbicide	Rate lbs a.i. per acre	Method of application	Mean wt. of seed Cotton in lbs/acre
1. Fluometuron	2.8	pre-emergence	3101
2. Prometryne	1.5	pre-emergence	2892
3. Trifluralin	1.0	pre-planting, incorporated	2487
4. Nitralin	1.13	pre-planting, incorporated	2650
5. Trifluralin + fluometuron	0.5 1.6	pre-planting, incorporated pre-emergence	2901
6. Nitralin + fluometuron	0.56 1.6	pre-planting, incorporated pre-emergence	2871
7. Trifluralin + prometryne	0.5 1.0	pre-planting, incorporated pre-emergence	2910
8. Nitralin + prometryne	0.56 1.0	pre-planting, incorporated pre-emergence	2559
9. Nitralin + fluometuron	0.56 1.6	(tank mix, pre-emergence (and lightly incorporated	3037
10. Ametryne	1.5	pre-emergence	2689
11. Ametryne + prometryne	0.75 0.75	tank mix - pre-emergence	2716
12. Control Handweeded	-	-	2372

cv = 16.2%
LSD (p=0.05) N.S.

Table 2

Cotton herbicide trial 1967/68
Weed Control achieved

Treatment No.	% Survivors of *R. exaltata* compared with control: 1st weeding (after 20 days)	2nd weeding (after 40 days)	3rd weeding (after 90 days)	% Survivors of other weeds (mainly dicots) compared with control: 1st weed.	2nd weed.	3rd weed.
1	67	100	61	7	16	17
2	51	64	92	3	10	19
3	5	3	7	30	92	57
4	17	6	21	34	64	62
5	11	14	22	1	10	14
6	35	19	32	25	21	41
7	11	15	33	1	7	13
8	20	27	50	8	26	67
9	53	25	31	6	31	19
10	72	100	97	2	12	28
11	59	98	62	1	6	35
12	100	100	100	100	100	100

The 1967/68 results show the success achieved with the combinations of two herbicides, trifluralin followed by a pre-emergence spray of prometryne or fluometuron. Unfortunately at this stage there do not appear to be good prospects of a successful single-application soil-incorporation technique, as other trials at Henderson

Research Station (Richards & Franklin, 1968) have shown the detrimental effect of fluometuron and herbicides of similar activity. Further experimental work will have to be carried out on the above combinations to suit various weed infestations, while on sandy soils the lower rates applied in a combination may permit the use of herbicides which to date have proved phytotoxic to the crop at the levels previously required for satisfactory weed control.

A large percentage of Rhodesia's cotton crop is grown on soils of high silt content that causes 'capping' and poor water penetration. Mechanical cultivation is therefore necessary on these soils, particularly in a dry season. The use of trifluralin and nitralin permit this soil movement without loss of weed control. Broad-leafed weed control can be achieved in the row by a banded application of fluometuron or prometryne. At a later stage, if necessary, a post-emergence spray may be applied to the 'between row' area. This treatment will control most of the weeds that have escaped cultivation, and any plants of *R. exaltata* that have survived the reduced rates of application of trifluralin or nitralin.

However, two problems arise with regard to post-emergence application that require further study.

(a) Under subtropical conditions, weeds rapidly outgrow the cotton plant making directional spraying difficult if not impossible and so far, no selective post-emergence herbicide has proved successful.

(b) On the heavy soils, prolonged rainy periods may prevent the use of wheeled implements on the land for relatively long periods, delaying directed post-emergence applications beyond the optimum time. This problem does not arise on sandy soils which are manageable within a few hours of heavy rainfall.

From the cost aspect, these combinations will be more expensive unless banded applications can be made. Excluding application costs, which will vary according to whether the application is made in conjunction with another operation (discing, planting etc.) or not, costs of chemicals would be as follows using trifluralin as a basis at 100 units per acre (1968 prices).

Trifluralin	1.0 lbs a.i. per acre	100
fluometuron	2.4 lbs a.i. per acre	120
prometryne	1.5 lbs a.i. per acre	115
trifluralin +fluometuron	0.5 lbs a.i. per acre) 1.6 lbs a.i. per acre)	130
trifluralin +12 in. band of fluometuron	0.8 lbs a.i. per acre	90

No mention has so far been made of perennial weeds resistant to the various herbicides mentioned. On dryland, *Cyperus esculentus* is only one of immediate importance. This weed is undoubtedly increasing and the reduction in mechanical cultivation brought about by the use of herbicides is likely to accelerate this increase. However, post-emergence applications of MSMA have given promising results on this species on the Henderson Research Station. On irrigated areas other perennials, in addition to *Cyperus* spp., will adapt themselves to the prevailing conditions and their control has to be planned at an early stage to prevent a major problem developing. Ample labour by European standards is available on Rhodesian farms and it is possible to remove resistant weeds by hand cultivation or spot herbicide application.

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WINTER APPLICATION OF RESIDUAL HERBICIDES BEFORE COTTON

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Summary Residual herbicides selective to cotton such as diuron and fluometuron, applied in winter at adequate rates, produced effective weed control during winter and after crop emergence, without affecting the yield. In late winter, on emerged weeds, spraying a mixture of amitrole with ametryne, prometryne, fluometuron or diuron, achieved good to excellent control of the weeds on the seedbed followed, with the two latter compounds, by a marked residual effect; no serious crop injury was recorded.

INTRODUCTION

The Israeli climate is characterized by a mild and rainy winter and a hot and dry summer. These conditions are ideal for summer crops, but during the rainy winter, it is often difficult to carry out at the right moment the necessary cultivation for weed eradication and seedbed preparation. Trials on sorghum have shown (Horowitz 1964, 1967) that a herbicide with residual and selective properties, such as atrazine, could be applied in the winter before planting and the rains will slowly leach the compound into the soil. Most annual weeds germinating in the winter as well as summer weeds appearing amidst the crop, were efficiently controlled by a single winter treatment to such an extent that winter or summer cultivation became actually unnecessary.

Because control of winter weeds and proper seedbed preparation are critical for cotton the same approach as for sorghum has been tried. At first, various herbicides recommended for pre-emergence in cotton were applied, at higher rates, on weed-free soil in winter. These treatments were given much earlier than the preplant application of diuron tried by Hamilton et al. (1966). In a following stage residual herbicides were combined with foliar-acting compounds thus extending the application on emerged weeds.

This paper summarizes the main results of the experimental work carried out from 1964 to 1967. The various experiments may be grouped into two series: a) winter treatments given on clean soil, before or at the beginning of the rain season; b) late winter treatments applied on a developed weed population, 2-3 months before the cotton was planted.

METHODS AND MATERIALS

All sprayings were applied with a knapsack sprayer fitted with Tee-Jet nozzles at a spray-volume of 400 l/ha. Cotton (var. Acala 15-17) was planted in April in rows 96 cm apart and sprinkler-irrigated immediately afterwards.

The winter treatments at Kefar Meccabi, Barqay and Usha, were applied on 25.XI.1965, 30.XII.1965 and 16.XI.1966 respectively, on weed-free soil surface. The total precipitation following the treatments were 375 mm, 293 mm and 610 mm respectively. The late winter treatments, at Ginnegar and Sedot-Yam, were sprayed on 1.III. 1967 and 120 mm of rain fell after the treatment. At Ginnegar, ridges had been prepared in December and were covered in February by a dense vegetation of 10-30 cm height; the height of the nozzle was determined from the top of the ridge. Cotton was planted on the ridge after removing its top. At Sedot-Yam, the field was infested with many weeds, some of which reached 1-1.2 m; the nozzles were placed 30-40 cm above the weed canopy.

All treatments were replicated four times on plots of four rows wide (the two central rows were picked for yield determinations) and 20 m long. At Kefar Meccabi and Barqay, each 20 m plot was sub-divided in two subplots 10 m long, one weeded and the other left untouched (= unweeded) until three months after planting, when the whole field was cleaned. At Usha, Ginnegar and Sedot-Yam, the whole experimental field, including controls, was cleaned $1\frac{1}{2}$ months after planting.

RESULTS

The work on winter treatments started in winter 1964/65, when various residual herbicides were applied in December in comparison to the usual 2,4-D + dalapon treatment (0.8 + 3.0 kg/ha) given in February. The best control of winter weeds and of summer weeds up to two months after cotton emergence was achieved by diuron and fluometuron; the prometryne-treated plots were re-infested during the winter, especially by Umbellifereae and the trifluralin-treated plots, by Solanum villosum and Cruciferae. The 2,4-D + dalapon application killed the sprayed weeds but failed to prevent new emergence in early spring.

In the following year, 1965/66, experimental work dealt mainly with diuron, trifluralin and fluometuron, and in 1966/67 ametryne was added. The main data are presented in Table 1.

Emergence of cotton was normal, but in treatments with diuron and fluometuron at higher doses, typical herbicidal injury - chlorosis and partial necrosis - appeared on the cotyledons and first leaves of the cotton plants. In all cases, the symptoms were only temporary and did not appear on the new foliage formed 1-2 months after emergence. No herbicide treatment produced a significantly lower yield than the weeded control. The cotton yield was markedly affected by the extent of the weed infestation during the first months of growth as shown by a comparison of weeded and unweeded control plots at Kefar Maccabi, where summer weed infestation was heavy; at Barqay, however, with lesser infestation, the difference between both controls was only of about 10%.

The first experiment on late winter treatments was carried out at end of February 1966. The weeds, about 10-15 cm in height, were sprayed with mixtures of amitrole 2.5 kg/ha with diuron, fluometuron or prometryne at the doses used in the winter applications. The combination of amitrole with diuron or prometryne produced a clean seedbed, while the effect with fluometuron was slower and less complete. For comparison, amitrole alone caused a general discoloration but killed only small seedlings, 2,4-D + dalapon gradually produced a good control and paraquat achieved an excellent control. These three contact treatments had no residual effect on summer weeds; the best weed control during the growth period of the crop was achieved with amitrole + fluometuron followed by the mixtures with prometryne and diuron.

In the following year, 1967, the three residual herbicides previously tested and also ametryne were applied in mixture with amitrole at two locations; the results are summarized in Table 2.

Table 1

Effect of winter treatments on weeds and cotton

Treatment kg/ha		Winter weeds before planting (1)	Summer weed (1) after regrowth 1st irrig.	Summer weed (1) after 2nd irrig.	Cotton yield as % of control on plots weeded	Cotton yield as % of control on plots unweeded
Kefar Maccabi 1965/66 (2)						
Diuron	0.9	1.1	1.6	0.4	158	156
	1.4	0.4	1.0	0.5	154	165
	2.8	0	0.9	0.6	180	161
Trifluralin	0.9	2.9	0.9	1.4	152	155
	1.4	2.2	0.2	0.1	162	160
	1.8	0.9	0.6	0.6	175	175
Control		4.4	3.7	4.2	135	100
Barqay 1965/66 (3)						
Diuron	0.9	0.9	1.7	1.4	104	98
	1.4	0.2	1.6	0.5	103	106
	2.8	0	1.5	0.6	109	99
Fluometuron	2.4	0	1.1	0.2	101	107
	3.6	0	1.0	0	106	100
	4.8	0	0.2	0	105	109
Control		3.7	2.2	2.2	110	100
Usha 1966/67 (4)						
Diuron	1.4	0.6	0.1	0	98	
	2.1	0.2	0	0.1	108	
	2.8	0.1	0	0	104	
Fluometuron	2.4	1.0	2.5	1.1	99	
	3.2	1.1	1.7	0.5	104	
	4.0	0.6	2.0	0.2	109	
Ametryne	1.5	1.2	2.7	0.4	98	
	2.0	1.4	2.6	1.1	97	
	2.5	1.1	2.7	1.2	103	
Control		1.9	2.7	0.9	100	

(1) Visual rating from 5=weediest plot to 0=free of weeds.
(2) Winter weeds mainly Cruciferae; yield of unweeded control, 100%= 2870 kg/ha; all herbicide treatments sign. (1%) to control.
(3) Yield of control, 100%= 4260 kg/ha; no significant differences.
(4) Control sprayed with paraquat before planting; yield of control 100%= 3650 kg/ha; no significant differences.

Increasing the dose of amitrole in the mixture, generally increased the herbicidal effect on the weeds present. This was specially clear at Sedot-Yam where the prevailing weeds were volunteers of cereals reaching 1-1.2 m in height, although the overall control was insufficient because of the size of the weeds. At Ginnegar, the cleanest seedbed was produced by the mixture of diuron, prometryne and ametryne. The persistence of the residual effect of ametryne and prometryne was brief, while diuron and fluometuron gave a good control of summer weeds (Amaranthus spp., Portulaca oleracea, Solanum villosum etc.). Temporary herbicidal injury in cotton was recorded on diuron and fluometuron plots, but yield was not affected as noted previously.

In none of the experiments could phytotoxic residues be found affecting the following crop.

DISCUSSION

For efficient and long-lasting control of winter and summer weeds in cotton fields, only very persistent herbicides can be taken into account. Assuming that their decomposition by chemical and biological pathways is a function of concentration and time (cf. reviews of Hartley, 1964; Upchurch, 1966) the dose to apply in winter, several months before planting, should be several-fold the rate recommended for pre-emergence. Ametryne and prometryne at rates up to three times those used in pre-emergence, were not persistent enough in November-December spraying, in agreement with published data (Hocombe et al., 1966, Rodgers, 1968). More efficient weed control was achieved by fluometuron and diuron, which are both persistent compounds, and especially so the latter. However, comparing Barqay 1965/66 and Usha 1966/67 experiments (Table 1) it appears that the rainfall following the treatment have considerable influence. Heavy rains, as in winter 1966/67 decreased the residual activity of fluometuron, while outstanding control was produced by diuron. The obvious difficulty in practice is that rainfall pattern cannot be predicted at the time of herbicide application. Thus, for early winter applications, diuron at a rate double that for pre-emergence, appears preferable, while fluometuron which is leached more readily and somewhat less persistent (Shahied & Andrews, 1966) seems better suited for mid-winter spraying.

Trifluralin is a widely used herbicide for cotton and, if properly incorporated, very persistent (Currey & Cole, 1967). However because of its lack of activity against Cruciferae which often constitute the bulk of the winter weed population, the application of trifluralin in winter appears justified only in fields heavily infested by perennials such as Sorghum halepense (Y. Klefeld, in preparation).

Experiments carried out in Israel and elsewhere have shown that winter cultivations and seedbed preparation might be replaced by a single chemical treatment, but it has not yet been proved that this replacement is desirable, except for particular situations such as heavy soils in areas with high rainfall. Many cotton growers in Israel prefer to combine cultivations in early winter with a chemical seedbed preparation applied 2-3 months before planting. If the soil surface is weed-free at that time, the previously mentioned herbicides can be applied. On emerged weeds, however, the effect of these residual herbicides which act mainly through the soil, will be inadequate. On the other hand, paraquat + diquat or 2,4-D + dalapon are effective against the existing weed population but no residual action can be expected after the cotton is planted.

Following promising preliminary experiments, various mixtures of residual herbicides with amitrole were tried. The herbicidal effect of amitrole alone was slow and inadequate, but mixtures had a remarkable foliar activity (see Table 2). The combination appears to be synergistic and similar mixtures have been used especially in fruit crops and against perennials (Strijkers & Braeckman, 1963). In our

Table 2

Late winter treatments on established weeds before cotton

G = Ginnegar (1) and S-Y = Sedot Yam (2)

Treatment	kg/ha	Winter weeds before planting (3) G	Winter weeds before planting (3) S-Y	Summer weeds (3) G	Summer weeds (3) S-Y	Injury rating on cotton (4) S-Y	Cotton yield as % of control S-Y
Diuron 1.1 + Amitrole	0.6	1.6	4.3	0.1	0.2	2.1	123
	1.2	0.4	3.1	0.2	0.4	1.2	112
	2.5	0.2	1.0	0.9	0.2	2.1	109
Fluometuron 2.4 + Amitrole	0.6	1.2	2.8	0.1	0.4	3.0	113
	1.2	1.1	2.1	0.2	0	3.0	107
	2.5	1.1	1.5	0.4	0.1	2.2	123
Prometryne 1.5 + Amitrole	0.6	1.4	3.0	2.2	1.5	0	106
	1.2	0.6	1.9	2.2	1.5	0	105
	2.5	0.2	1.8	1.5	1.0	0.2	103
Ametryne 1.5 + Amitrole	1.2	0.7	1.8	3.5	1.7	0	114
	2.5	0.6	1.5	3.4	1.2	0.5	106
Paraquat 0.4 + Reglone 0.2 (Control)		1.2	1.1	2.0	1.7	0	100

(1) Spraying on preformed ridges; weeds up to 30 cm.
(2) Spraying on flat surface; weeds up to 1.2 m. Yield of control 100%=3520 kg/ha; no significant differences.
(3) Rating as in Table 1. Summer weeds assessed $1\frac{1}{2}$ months after planting; at Ginnegar assesment on top of the ridge.
(4) Visual estimation $1\frac{1}{2}$ month after planting; scale from 0=no injury to 5=complete discoloration and necrosis.

case, excellent control of annual weeds up to 20-30 cm in height has been produced while the effect of the residual component persisted. Combinations with diuron or prometryne had a stronger acute effect than those with fluometuron, possibly because of the specific formulation of each herbicide entering into the mixture. Concerning the rates to apply, the present recommendation is that the dose of the residual compound depends on the time remaining until planting and the dose of amitrole is a function of the development of the weeds.

No phytotoxic residue was reported after the various cotton experiments, even on the diuron-treated plots. As the cotton was irrigated, it is probable that the degrading activity of soil micro-organisms was continuous throughout the whole growing season. Similarly, in irrigated cotton fields in the U.S.A., no carry-over was found after diuron even after repeated applications.

An interesting point is the absence of serious permanent herbicidal damage to the cotton plants, although the safety margin of diuron, fluometuron, prometryne or ametryne is quite narrow when sprayed in pre-emergence. This observation could be related to the reduced toxicity often recorded on incorporated preplanting treatments.

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FLUOMETURON AND TRIFLURALIN FOR WEED CONTROL IN EGYPTIAN COTTON FIELDS

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Summary Preliminary tests with fluometuron in 1964, '65 and '66 warranted further trials amounting to 9500 feddans during the past two seasons. The application of fluometuron either pre-emergence or post-sowing at 3 lb/feddan resulted in satisfactory weed control without phytotoxicity. Weed control during early growth resulted in seed cotton yields estimated at 25 and 24.8 percent over normal hand-hoeing in 1966 and 1967 respectively. In a few cases where wheat followed fluometuron-treated cotton slight residue damage occurred.

Trifluralin applied presowing incorporated at 1 lb/feddan in large-scale trials in 1967 either alone or with fluometuron was most effective against summer annual weeds and yield increases were evident. Outstanding results were obtained using a trifluralin-fluometuron combination, where trifluralin was incorporated pre-sowing at 1 lb/ feddan, followed by fluometuron applied pre-emergence at 0.9 - 1.8 lb/ feddan. Trifluralin with the lower rates of fluometuron reduces the possible injury to rotational crops.

INTRODUCTION

Hand-hoeing is the common practice for weeding in Egyptian cotton fields where annual weeds are the most dominant and perennials are relatively less widespread. Winter annuals emerge before or with cotton, while summer annuals invade cotton fields later when hand-hoeing is not feasible due to the dense growth of cotton. Previously, summer annuals were removed by hand for use as cattle feed. Now, with the wide use of poisonous insecticides, weeds are no longer used for such a purpose and so left to harbour harmful pests, particularly cotton, leaf and boll worms.

The potential chemical weed control in Egyptian cotton fields has been considered of particular interest with the increasing shortage in hand-labour. Cornish-Bowden (1966) demonstrated the advantageous use of fluometuron (Cotoran) against broad-leaved weeds in irrigated cotton without phytotoxic effects. The same author showed that trifluralin (Treflan) gave good control of many grassy weeds. The object of the present work was to evaluate the justification and effectiveness of chemical weed control with fluometuron and trifluralin.

METHODS AND MATERIALS

The present work was carried out in 3 successive seasons comprising two proper experiments, one in 1965 and another in 1966. Extensive trials and wide-scale demonstration applications in 1966 and '67 are included. Two new herbicides, Cotoran (fluometuron : N- (3-trifluoromethylphenyl)-N'N' dimethylurea) and Treflan (trifluralin : alpha, alpha, alpha - trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine) were evaluated.

1965 Experiment:- The experiment was laid down at Sakha Experimental Station on a clay loam soil. Cotton seeds, variety Giza 45, were used. Sowing date was 31st March. The layout consisted of seventy-two experimental plots with twelve treatments of fluometuron at 2, 2.5, 3, 3.5 and 4 lb/feddan. Hand-picking of seed cotton took place on 20th September. Wheat, annual clover (barsim), broad beans and flax followed the crop for the determination of any residual herbicide effect.

1966 Experiment: This experiment was carried out at Gemmaiza Experimental Station on a clay soil. The variety Menoufi was used and sowing took place on March 15. The lay-out consisted of 36 experimental plots of six treatments. Fluometuron at 3 lb/feddan was used without hand-hoeing or with one late hand-hoeing eleven weeks from sowing. Hand-picking of seed cotton was done on September 18.

Throughout the experimental work of 1965 and '66, cotton seeds were sown by hand in each experimental plot on six ridges in holes 20 cm. apart. Cotton plants were thinned to two plants per hole. Each treatment was replicated six times in plots of 21 m^2. The appropriate dose of the herbicide for each plot was sprayed at a volume of 400 l/feddan with a knapsack sprayer. Two different applications were used, the first as post-sowing before irrigation, and the second as pre-emergence, 4 days after sowing, with watering. Hand-hoeing (4 times during the season) as well as untreated and unweeded controls were included. Annual winter weeds were assessed during the first week of June, while summer annuals were assessed one week before hand-picking. Values of fresh weights of weeds per plot were assessed as percentage weed control. Seed cotton yield in each plot was obtained and considered in the results.

Fluometuron large-scale trials in 1966: For the determination of the extent to which fluometuron could be recommended for further use, the application in 1966 was extended to some 4000 feddans. Three quarters of this area belonged to official farms, while the rest was scattered in 440 demonstration fields in 15 different provinces. As the herbicide was not available at a convenient time, the application was carried out as a post-sowing spray at rates of 3 lb/feddan with 200-400 l. spray volume. Seed cotton yield prodced from 700 treated feddans was evaluated.

Fluometuron extensive use in 1967: The treated area in the second year amounted to some 5500 feddans, again spread over a wide number of farms and provinces. Fluometuron was used at the same rate as in 1966. The application was modified as in most cases the ridges were irrigated about 2 weeks before sowing, followed by spraying and watering. Weeds present after the pre-sowing irrigation were either removed by light hand-hoeing or left for chemical effect. In a treated area of 600 feddans scattered in 275 demonstration fields the mean of seed cotton yield was computed. Throughout the work in 1966 and '67 the herbicide treatment was applied to different cotton varieties as restricted in the different zones.

Trifluralin large-scale trials in 1967: For the first time, Treflan was included in extended trials in an area of 900 feddans on official farms. It was used as pre-sowing spray at 1 lb/feddan, with 200-400 l. water. Mechanical incorporation took place a few hours after treatment.

Raising ridges, sowing seeds and watering were then carried out.

Trifluralin-fluometuron combinations in 1967: This combination was used in field-scale trials at Sokha Experimental Station. Trifluralin was used in the same way as described previously. Fluometuron then followed as a post-sowing application at two different rates, 0.9 and 1.8 lb/feddan. Data were obtained concerning percentage weed kill, average number of open bolls per plant and weight of seed cotton (kg/21 m^2 plot).

RESULTS

Fluometuron (previously known as C 2059) in a preliminary test proved to have noticeable effect against weeds in cotton. Hence, more attention was given to its further use.

Throughout the experimental work in 1965 and '66, the dominant annual winter weeds were, *Beta vulgaris*, *Melilotus indicus*, *Chenopodium* spp., *Cichorium endivia*, *Sinapsis juncea* and *Sochus oleraceae*. The prevailing summer annuals were, *Dinebra retroflexa*, *Echinochloa colonum* *Corchorus olitorius* and *Portulaca oleraceae*.

Results of the present work are shown and discussed as follows:

1965 and '66 experiments - Data presented in Table 1 show the effectiveness of fluometuron

Table 1

Effect of fluometuron on annual weeds and seed cotton yield (1965)

	% Weed Kill WA[1]	% Weed Kill SA[2]	Seed Cotton Yield (kg/plot)
Post-sowing			
2 lb/feddan	66	14	4.183
2.5 "	72	19	4.450
3.0 "	87	52	5.083
3.5 "	93	60	5.316
4.0 "	99	74	5.466
Pre-emergence			
2 lb/feddan	81	28	4.683
2.5 "	86	37	4.526
3.0 "	99	68	5.166
3.5 "	100	75	5.433
4.0 "	100	87	5.666
Hand-hoeing	36	24	4.833
Check	--	--	1.800
	L.S.D.	(P = 0.05)	0.673

1 WA = Winter annual weeds.
2 SA = Summer annual weeds.

The pre-emergence application was found to be of slight preference to the post-sowing. All herbicidal treatments were of distinct superiority to normal hand-hoeing in the control of annual winter weeds that grew before June. As for summer annuals that grew from June to September, acceptable control was found with rates exceeding 2.5 lb/

feddan. In the present work no phytotoxicity was noticed. The proportional increase in seed cotton yield evidently appeared with rates ranging from 3 to 4 lb/feddan. A slight injurious effect was noticed only on wheat plants where the seeds were sown without working the soil after cotton harvest, especially with the highest rate of 4 lb/feddan.

In the 1966 experimental results as presented in Table 2, a slight advantage can be noticed with the pre-emergence treatment when one hand-hoeing was included.

Table 2

Effect of fluometuron on annual weeds and seed cotton yield (1966)

	% Weed Kill		Seed Cotton Yield
	WA[1]	SA[2]	kg/plot 21 M^2
Post-sowing			
3 lb/feddan	97	55	3.133
3 lb/feddan + 1 Hand-hoeing	97	60	3.158
Pre-emergence			
3 lb/feddan	99	58	3.733
3 lb/feddan + 1 Hand-hoeing	99	64	3.775
Hand-hoeing	25	29	2.916
Check	--	--	1.128
L.S.D. (P = 0.05)			1.000

1 WA = Winter annual weeds.
2 SA = Summer annual weeds.

Taking into account all aspects, it was concluded that fluometuron as a new herbicide showed sufficient promise to warrant further use in larger trials.

Fluometuron large-scale trials in 1966: The result of the previous work encouraged the extensive use of fluometuron in 400 feddans. The mean yield of seed cotton was obtained from 677 treated feddans of the total 4000 feddans treated with fluometuron. In comparison with the mean yield of the untreated adjacent fields, it was found that the herbicide application resulted in an increase of 25%. The treated fields yielded 735 kg/feddan compared with 586 kg/feddan produced from normally hand-hoed fields.

Fluometuron extensive use in 1967; The mean seed cotton yield per feddan was calculated in a treated area of 535 feddans scattered in 275 demonstration fields in 10 different provinces. The average yield in the treated fields was 950 kg/feddan with an appreciable increase of 189 kg. (24.8%) over that produced from the normally hand-hoed fields.

Although weeds were well controlled, the growers were not entirely convinced at keeping the chemically treated fields out of hoeing. The mean number of hand-hoeing was 1.59 for the treated fields compared with 3.69 for the untreated. Hence, the average cost was reduced by 56.8% as a result of the herbicidal application.

Throughout the period of extensive use of fluometuron, during 1966 and '67, the following rotational winter crops grown in the treated soil developed normally, provided that thorough ploughing and heavy watering preceeded. In a very few cases, a slight injury not exceeding 0.05% was observed on wheat plants. However, the yield was not affected. It should be noted here that broad-beans (*Vicia faba*) yielded better in the soil previously treated with Cotoran. This phenomenon seems to be worthy of further study.

Trifluralin and Trifluralin-fluometuron combination in 1967: In four different locations, data were taken from fields trials. The results are presented in Table 3.

Table 3

Effect of herbicidal treatment on annual weeds and cotton production 1967

	% Weed Kill WA	% Weed Kill SA	No. of open bolls (per plant)	Seed Cotton Yield (Kg/plot)
Site 1				
Trifluralin (1 lb/f.)	65	92	18.8	6.93
(Trifluralin (1 lb/f.) + (Fluometuron (0.9 lb/f.)	98	100	19.6	7.89
(Trifluralin (1 lb/f.) + (Fluometuron (1.8 lb/f.)	100	100	22.9	8.26
Hand-hoeing	36	21	12.9	3.93
L.S.D. (P = 0.05)	--	--	1.2	0.99
Site 2				
Trifluralin (1 lb/f.)	68	98	17.1	5.48
(Trifluralin (1 lb/f.) + (Fluometuron (1.8 lb/f.)	100	99	18.5	5.47
Hand-hoeing	44	28	9.2	3.72
L.S.D. (P = 0.05)	--	--	2.4	0.70
Site 3				
Trifluralin (1 lb/f.)	57	92	18.0	4.88
Fluometuron (3 lb/f.)	98	63	17.8	5.04
Hand-hoeing	34	26	9.8	3.18
L.S.D. (P = 0.05)	--	--	2.05	0.07
Site 4				
Trifluralin (1 lb/f.)	62	94	17.8	4.14
(Trifluralin (1 lb/f.) + (Fluometuron (1.8 lb/f.)	97	99	17.0	4.21
Hand-hoeing	38	32	5.4	2.47
L.S.D. (P = 0.05)	--	--	3.4	1.00

The pronounced effect against winter annuals was distinct in all treatments including fluometuron. Trifluralin appeared to be mostly effective against summer annuals. Outstanding results were gained with the use of trifluralin-fluometuron combination. In the present work, trifluralin (1 lb/feddan) was used pre-sowing incorporated into the soil, followed by fluometuron application at pre-emergence (0.9 and 1.8 lb/feddan). Little difference was found between the two rates of fluometuron used. Therefore, an appreciable result can be accomplished by the use of fluometuron at a relatively low rate (0.9 lb/feddan) provided it is applied following trifluralin incorporated pre-sowing. It is quite clear that all herbicidal treatments were superior to hand-hoeing as a traditional practice in cotton fields. The dignificance in the average number of open bolls per plant as well as the average seed cotton yield per plot is evident. All values obtained from the herbicide treatments differed significantly from hand-hoeing values.

DISCUSSION

The fact that acceptable control using fluometuron alone was only found with rates exceeding 2.5 lb/feddan in 1965 may be due to the short residual effect with the lower rates. In this connection Cornish-Bowden (1966) stated that of the pre-emergence treatment, the higher rate (5 lb) of fluometuron was successful in controlling weeds for 9 weeks without damaging the crop. The slight residue effect noted on wheat plants following fluometuron-treated cotton might be the result of misapplication.

In the 1967 trials, trifluralin appeared to be most effective against summer annuals. Arle and Hamilton (1963) found trifluralin controlled annual weeds for extended periods when applied to the soil before the summer weeds germinated. The same authors noted that it is most effective on grassy weeds and this is supported by the work of Kempen (1965).

Throughout the trials, the evidence for increased seed cotton yield as a result of herbicidal use can be explained by the lack of competition from weeds during the early stages of crop development. Similar gains in yield have been reported by other workers, Harris (1964) reported that pre-and post-emergence herbicides used without cultivation produced 572 pounds per acre (26.3%) more than that obtained by more traditional methods. Goyne (1966) found that crops grown on land treated with trifluralin yielded 1200 lb. more seed cotton than crops on untreated land.

As a result of the present work it can be concluded that both fluometuron and trifluralin can be accepted as effective herbicides in Egyptian cotton fields. The most appreciable effect is obtained using the trifluralin-fluometuron combination in two applications. Trifluralin at 1 lb/feddan as a pre-sowing treatment, incorporated into the soil, followed by fluometuron applied as a pre-emergence treatment at 0.9 lb/feddan. The outstanding results gained using herbicide combinations has been reported before. Frans (1967) demonstrated that a combination of trifluralin pre-sowing, and diuron pre-emergence, caused no crop injury and resulted in better control of weeds than was obtained with either component alone.

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NOREA PLUS MSMA (HERBAN*-M), A NEW HERBICIDE COMBINATION SELECTIVE IN COTTON

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Summary A need for improvement over pre-emergence weed control methods in cotton has led to the development of a new post-emergence herbicide combination known as Herban-M. This formulation is a liquid suspension containing 1.6 pounds of technical norea and 3.3 pounds of MSMA plus surfactant per U.S. gallon. This herbicide combination is the result of years of experimentation in the United States, Europe, Latin America and Africa.

Experiments indicate that Herban-M is an effective post-emergence weed killer with pre-emergence residual activity in the soil. Herban-M is selective to young cotton in directed and semi-directed sprays. This formulation of norea and MSMA plus surfactant gives better weed control than either material alone and it kills many resistant weed species. Herban-M performs under a wider range of climatic conditions than either material alone. Two applications one week apart in young cotton, before the first bloom stage, gave the best results. Recent field trials in sugarcane and coffee gave promising results.

INTRODUCTION

During recent years great advances have been made in the development of new herbicides for cotton. Pre-emergence herbicides alone often fail to give the complete control of weeds and grasses desired by farmers. When this happens, a post-emergence herbicide is needed. Norea is especially desirable for this use since it is safer to tender cotton than many other herbicides. The need for improvement of cotton weed control methods has led to progress through herbicidal combinations. One of the more notable combinations is a selective post-emergence herbicide known as Herban-M.

Herban-M is a liquid suspension of 3-(hexahydro-4, 7-methanoindan-5-yl)-1, 1-dimethylurea (norea) and monosodium acid methanearsonate (MSMA) plus surfactant. This formulation contains 1.6 pounds of technical Herban (norea) and 3.3 pounds of MSMA per U.S. gallon (3.78 litres). Herban-M has been found most effective in controlling small annual weeds in young cotton. Weed control with the mixture has been consistently better than with the single components. Present recommendations and registration cover only directed applications. We will present for your consideration data on the effects of directed, semi-directed and topical or overhead sprays of Herban-M, and its components, norea and MSMA.

METHODS AND MATERIALS

Field studies were initiated in various Experiment Stations in the United States in 1964 and 1965. Further tests were conducted in Brazil, Colombia and Mexico in 1966. In 1967 and 1968 field trials were extended to the following additional countries: Australia, Egypt, Guatemala, Nicaragua, Peru, Rhodesia, South Africa, Spain and Thailand. Both small plot experiments utilizing hand application equipment and field-size trials with conventional aerial and tractor equipment were used in these tests. Small plot experiments were randomized blocks with two to four replications. Single and split applications were tried in most countries.

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Two years of intensive tests were conducted at the Hercules Experimental Farm in the United States in 1964 and 1965. The major weed species were stinkgrass (Eragrostis), purslane (Portulaca), pigweed (Amaranthus), and nodding spurge (Euphorbia). Weeds in these tests emerged with the cotton. Four replicates of applications were made to cotyledon stage and first true-leaf stage cotton. Rates employed and results are listed in Tables 1 and 2.

Field experiments were conducted in Brazil in 1967. These tests were made under adverse conditions with weeds and grasses 20 to 60 centimeters high and cotton 15 to 25 centimeters tall. Overhead treatments were made on a40 to 50 centimeter band over the cotton and weeds. A Hudson knapsack sprayer regulated to 26 p.s.i. pressure with 8004-E nozzles was used. Three hundred cubic centimeters of solutions were used per 10 square meters (300 litres per hectare). Overhead applications were made on March 14, 1967 and on March 20, 1967. No data were recorded for phytotoxicity to cotton because none of the treatments caused significant injury. Rates employed and results are presented in Table 3. Four replications were used in these tests.

Similar experiments were conducted in 1967 and 1968 with Herban-M formulations in Australia, Mexico, Nicaragua, Peru, Rhodesia, Spain and South Africa. Plot sizes varied from 25 to 100 square meters with 3 to 4 replicates and randomized block designs. Constant pressure knapsack sprayers and tractor applicators fitted with T-jet flat fan 8004 and 8004-E nozzles were used with 300 to 400 liters per hectare of water. Visual ratings of cotton tolerance and weed control were taken after overhead, semi-directed and directed post-emergence applications were completed.

RESULTS

The 1964 and 1965 tests conducted by Hansen (1965) in the United States indicated that a combination of 1.65 kg of norea (Herban 80 percent) and 1.82 kg of MSMA per hectare gave good weed control up through the cotton first true-leaf stage. This mixture was also tolerated by the cotton with a non-directed spray. Larger and older weeds were too resistant for adequate control with a single application. Visual ratings indicated that the mixture was more selective to cotyledon cotton than first true-leaf cotton (Tables 1 and 2).

In the 1967 Brazilian trials conducted bu James (1967) two overhead applications were needed to give satisfactory weed control results. (Table 3). Considering the adverse conditions under which these tests were made the results were very encouraging. Norea plus MSMA and surfactant gave considerably better post-emergence weed control than MSMA plus surfactant alone. There were only slight differences between treatments which received 1.5, 2.0 or 3.0 kg/ha of norea. These experiments indicate that 1.5 kg/ha of norea in combination with MSMA would be recommended for future applications.

Norea and MSMA combinations were further evaluated in 1967 and 1968 in Rhodesia, South Africa and Spain. In these tests, all post-emergence herbicides were semi-directed or directed to the weeds. Two applications spaced 5 to 7 days apart gave consistently better than 80 percent control of grasses and broadleaf weeds in all replicates. Similar tests were conducted in Mexico in 1968, differing in that post-emergence overhead treatments were made with the new Herban-M formulation. Two broadcast sprays of five litres per hectare of Herban-M per application in 200 litres of water per hectare per application produced better than 85 percent weed control under varying temperatures and sunlight conditions.

Table 1

Weed control and tolerance in cotyledon cotton with norea and MSMA combinations

Weed control and crop tolerance rating
(0 = no effect; 10 = complete kill)

Treatment (kg/ha)		Average weed control		Average cotton tolerance
Norea 80% wp	MSMA	Grasses	Broadleafs	
0	0	0	0	0
0	0.91	2	2	0
0	1.37	3	4	0
0	1.82	3	4	0
0.83	0	6	4	0
1.65	0	9	9	0
2.48	0	9	9	0
0.83	0.91	8	6	0
0.83	1.37	9	7	0
0.83	1.82	8	8	0
1.65	0.91	10	7	0
1.65	1.37	9	8	0
1.65	1.82	10	9	1
2.48	0.91	10	8	1
2.48	1.37	10	9	0
2.48	1.82	10	9	0

Table 2

Weed control and tolerance in first true-leaf cotton with norea and MSMA combinations

Weed control and crop tolerance rating
(0 = no effect; 10 = complete kill)

Treatment (kg/ha)		Average weed control		Average cotton tolerance
Norea 80% wp (Herban)	MSMA	Grasses	Broadleafs	
0	0	0	0	0
0	0.91	2	0	0
0	1.37	3	4	0
0	1.82	2	5	0
0.83	0	6	8	0
1.65	0	7	9	1
2.48	0	9	9	0
0.83	0.91	7	8	1
0.83	1.37	7	9	1
0.83	1.82	7	9	1
1.65	0.91	9	9	1
1.65	1.37	9	10	2
1.65	1.82	8	9	2
2.48	0.91	8	9	0
2.48	1.37	9	10	1
2.48	1.62	10	10	2

Table 3

Weed control in 15 to 25 centimeters cotton with norea and MSMA combinations in Brazil

Weed control rating
(0 = no effect; 10 = complete kill)

Treatment (kg/ha)		Average weed control two weeks after treatment	
Norea 80% wp (Herban)	MSMA	One application	Two applications
0	0	0	0
0	1.4	2	4
1.0	1.4	4	7
1.5	1.4	5	8
2.0	1.4	3	8
3.0	1.4	4	8

DISCUSSION

Rumberg, Engel and Meggitt (1960) reported that temperatures below 60°F tended to retard the action of the methanearsonates while temperatures above 65°F tended to increase their effectiveness. Widiger (1967) concluded that high temperatures and full sunlight were important to the favourable action of MSMA. The Herban-M results from Mexico and other areas indicate that it gives more consistent results under varying climatic conditions than MSMA alone.

Herban-M gives good to excellent control of the following weeds and grasses: pigweed (*Amaranthus retroflexus*), ragweed (*Ambrosia trifida*), sandbur (*Cenchrus*), purple nutsedge (*Cyperus rotundus*), crabgrass (*Digitaria sanguinalis*), barnyard grass (*Echinochloa crusgali*), goose grass (*Eleusine indica*), stink grass (*Eragrostis*), morning glory (*Ipomoea*), panic grass (*Panicum*), purslane (*Portulaca oleracea*), yellow foxtail (*Setaria lutescens*), Johnsongrass (*Sorghum halepense*), cocklebur (*Xanthium*). Herban-M gives poor to fair control of the following weeds: Bermuda grass (*Cynodon dactylon*), curley dock (*Rumex crispus*), teaweed (*Sida spinosa*), and dandelion (*Taraxacum*). McWhorter (1968) reports that this mixture of norea and MSMA is effective and is now being used throughout the southern cotton rainbelt zone of the United States.

Herban-M is a liquid suspension of norea (Herban) and MSMA based on the results of these and other combination tests in the United States, Europe, Latin America and Africa. These studies show that Herban-M kills on contact and leaves a residual for later germinating weeds and grasses. It controls a wide range of grass and weed species, and is selective to young cotton in directed and semi-directed sprays. Herban-M gives better weed control than either norea or MSMA alone. It also performs under a wider range of climatic conditions than either material alone. Weed control effectiveness depends upon timing of applications. Earlier sprays give broader spectrum control. Five litres per hectare of Herban-M in 300 litres per hectare of water for each application give best results. Two applications one week apart in young cotton before the first bloom stage gave the best results in these tests. Recent trials in tropical sugarcane and coffee gave promising results.

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FIELD TRIALS WITH HERBICIDES APPLIED TO COTTON IN MOZAMBIQUE

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Summary

Field trials with pre-emergence herbicides applied to cotton were conducted on four different types of soil occuring in the cotton belt of Mozambique. Fluometuron was the herbicide showing the broadest range of selective doses; applications at 2.50 to 3.00 kg/ha gave the best results. Prometryne at 1.50 kg/ha, noruron at 4.00 kg/ha and diuron at 1.60 kg/ha proved to be effective too, although their selectivity to cotton depends in a greater degree on the texture and organic matter content of the soils to which they are applied.

INTRODUCTION

The use of herbicides to control weeds in cotton is a practice of comparatively recent introduction in Mozambique. However, in view of the scarcity and rising costs of manpower, two correlated factors becoming more and more hampering every day, cotton growers were compelled to adopt chemical methods of weed control to reduce labour costs.

Research and experimentation on herbicides undertaken in other countries has reached an advanced stage; but seeing that ecological conditions, coupled with the diversity of the weed flora typical of the different local zones, could not fail to influence performance, results recorded abroad must be checked locally before the use of particular products can be recommended.

In order to provide cotton growers with advice about the herbicides best suited to the different ecological regions occuring in the cotton belt of Mozambique, trials were carried out with the main products considered as selective to cotton.

The results obtained are briefly discussed in this paper.

METHODS AND MATERIALS

The trials were carried out at the Experimental Stations of Maniquenique, Mutuali and Nampula, during the campaigns of 1965/66 and 1966/67.

Soils at Maniquenique are of alluvial origin, medium organic matter content, clay texture, slightly acid reaction; at Mutuali they derive from the granitic-gneissic complex, are rich in organic matter, sandy-clay-loam in texture and of slightly acid reaction; those of Nampula are of granitic origin, sandy-clay-loam texture, medium organic matter content and neutral reaction. In a different site of this Station the trials were laid-out on a soil with the same characteristics but very poor in organic matter.

The herbicides under trial were prometryne, a mixture of prometryne + simazine (40:15), noruron, linuron, fluometuron, diuron and trifluralin. The dosage, given in terms of a.i. kg or l/ha, appears in table 1. Treatments were pre-emergence in relation to cotton and to weeds. Application made with nozzles tee jet flat spray No.80.03, at 2.8 kg/cm^2 pressure, was carried out overall. Trifluralin was applied one day before sowing and immediately incorporated into the soil by two passes, at right angles, of a double disk harrow. The other herbicides were applied one day after cotton was sown.

A partially balanced lattice square design was chosen for the trials, the plots area being 45 m^2. A control plot, hoed in the traditional way of the region where the trials were taking place, was included, and it served as a comparison term for assessing the results obtained with the treatments.

Cotton was sown under raingrowth conditions. However, in none of the trials did an interval more than six days intervene between the herbicide application and the first rains.

The control index of each plot was determined 30 days after the cotton was sown. This index is to be understood as the percentage of weeds controlled by the herbicide.

Some days before the flowering of cotton started, species resistant to each herbicide were duly identified, after which all the plots were handhoed.

RESULTS

Average yields of seed cotton are given in table 1, as well as the weed control index attained by the herbicides in the different soils on which trials were carried out.

In all the types of soil under trial prometryne at 1.50 kg/ha was found to be effective and the yields did not differ significantly from those obtained from the control plot. When the rate was increased to 2.00 kg/ha a better control of the weeds was achieved, but the yields did not derive any benefit from it; in some cases this dose proved to be toxic to the cotton, a fact responsible for the significant production drop recorded at Mutuali.

On clay, as on sandy-clay-loam soils rich in organic matter, 1.65 kg/ha of the mixture prometryne + simazine (40:15) was not successful in eliminating the weeds, but when applied at an increased rate of 2.47 kg/ha significantly higher yields resulted. Both rates were found to give place to similar yields if applied to sandy-clay-loam soils with a medium organic matter content. In the same type of soil, but poorer in organic matter, 2.47 kg/ha were injurious to cotton and responsible for significant yield losses.

With nururon at 4.00 kg/ha yields significantly identical to those of the control were obtained in all the four types of soil. When the rate was increased to 5.60 kg/ha there was observed, in some cases, a tendency to lower yields, without corresponding beneficial effects in weed control.

On sandy-clay-loam soils rich in organic matter, even when treated with the highest doses of 1.25 kg/ha, linuron had no control effect, and the cotton plants were literally overtopped by weeds. Significantly lower yields resulted. On clay soils, less rich in organic matter, as on sandy-clay-loam soils of medium organic matter content, a sufficiently effective control was achieved by this herbicide, whether applied at 0.75 or 1.25 kg/ha. The yields here equaled those obtained from the control. Nevertheless, the organic matter content was low, a rate of 1.25 kg/ha was excessive, with the result that plants, and consequently yields, were adversely effected.

Fluometuron revealed a high selectivity to cotton and was not influenced by difference of texture or organic matter content of the soils to which it was applied. The rate of 2.40 kg/ha was considered sufficient. When increased to 3.20 kg/ha this dose did not enhance production improvement.

Without affecting the cotton plants or the yields, diuron at 1.60 kg/ha showed effectiveness in weed-killing; but where the dose was raised to 3.20 kg/ha and applied on sandy-clay-loam soils, poor in organic matter, its effect was injurious to cotton.

At a rate of 0.48 kg/ha trifluralin was not effective in controlling weeds on sandy-clay-loam soils rich in organic matter; good results were nevertheless recorded where the same dose was applied to these type of soils with a lower organic matter content.

Table 1

Production of cotton seed (kg/ha) and control index of weeds, attained herbicides in four types of soil

		Production				Control index			
		Clay	Sandy -	clay	- loam	Clay	Sandy -	clay	- loam
Herbicides	Rate a.i./ha	medium org. mat. cont.	rich org. mat. cont.	medium org. mat. cont.	poor org. mat. cont.	medium org. mat. cont.	rich org. mat. cont.	medium org. mat. cont.	poor org. mat. cont.
Prometryne	1.50	430	1440	1530	1640	53	53	42	70
	2.00	420	1250	1500	1720	70	78	52	65
Prometryne)	1.65	450	1210	1530	1640	75	63	40	70
+ Simazine)	2.47	610	1470	1620	1480	65	80	55	68
Moruroa	4.00	600	1480	1500	1660	65	70	32	63
	5.60	460	1280	1580	1540	65	78	38	70
Linuron	0.75	500	980	1470	1660	43	0	28	63
	1.25	480	950	1570	1330	63	8	35	73
Fluometuron	2.40	480	1350	1530	1710	70	55	48	78
	3.20	410	1420	1550	1890	83	78	50	75
Diuron	1.60	450	1280	1440	1980	70	53	28	75
	3.20	450	1360	1660	1660	70	58	62	58
Trifluralin	0.24		710	1390			8	28	
	0.48		700	1580			8	20	
	0.96				1660				55
	1.92				1560				73
Control		500	1380	1600	1810				
L.S.D. (P=0.05)		±160	±170	±186	±259	±6	±9	±8	NS

Table 2.

Susceptibility of some weeds to the pre-emergence herbicides under trial

Species	Pro-me-try-ne	Prom. + Sima-zine	No-ru-ron	Li-nu-ron	Fluo metu ron	Diu ron	Tri-flu-ra-lin
Acalypha segetalis Nuell Arg.	x	x	x	0	0	0	0
Acanthospermum hispidum DC.	0	x	x	0	x	x	0
Amaranthus spinosus L.	x	x	x	x	xx	x	xx
Argemone mexicana L.	xx	xx	xx	x	x	x	xx
Boerhaavia diffusa L.	x	x	0	x	0	x	x
Brachiaria deflexa (Schum.)C.E. Bubb. ex Robyas	0	x	x	x	x	x	x
Brachiaria isachne Stapf.	x	x	x	x	x	0	x
Cardiospermus halicacabum L.	xx	xx	0	0	xx	xx	xx
Chenopodium album L.	xx	xx	xx	xx	xx	xx	xx
Cissampelos sp.	x	xx	xx	xx	x	xx	xx
Commelina benghalensis L.	0	0	0	0	0	0	0
Corchoras trilocularis L.	x	x	0	0	x	x	0
Cyperus rotundus L.	0	0	0	0	x	x	0
Dactyloctenium giganteum Fisher et Schweickerdt	xx	xx	x	0	0	0	0
Digitaria adscendens (H.B.K.) Henrard	0	0	0	0	0	0	xx
Eleusine indica (L.) Gaertn.	0	0	x	xx	xx	xx	xx
Eragrostis aethiopica Chiov.	x	x	xx	x	x	x	xx
Eragrostis arenicola C.E. Hubbard	x	x	xx	xx	xx	x	xx
Euphorbia hirta L.	xx	xx	x	xx	0	x	xx
Gynandropsis gynandra (L.) Brig.	0	0	0	0	x	0	x
Hybanthus enneaspermus (L.) F. Muell	0	0	0	0	0	0	0
Ipomoea sp.	0	0	0	0	x	x	x
Jacquemontia sp.	0	0	0	0	0	0	0
Leptochloa panicea (Retz) Chwi	x	x	0	0	x	x	xx
Leucas sp.	0	0	0	x	x	x	x
Mollugo nudicaulis Lam.	x	x	0	0	xx	0	0
Mucuna sp.	0	0	0	0	0	0	0
Ocimum americanum L.	0	x	x	0	x	x	0
Oxalis semiloba Sond.	xx	xx	xx	0	xx	xx	xx
Panicum maximum Jacq.	xx	xx	xx	0	x	0	xx
Phyllanthus nummulariaefolius Poir.	x	x	0	x	x	xx	x
Portulaca oleracea L.	xx	xx	xx	0	xx	x	xx
Ricinus communis L.	xx	xx	xx	x	xx	0	0
Stylochiton sp.	xx	xx	0	0	0	xx	xx
Sonchus cleraceus L.	xx	xx	xx	xx	xx	xx	0
Sorghum verticilliflorum Stapf.	xx	xx	0	0	xx	xx	xx
Urochloa mosambicensis (Hack) Dandy	xx	xx	0	xx	xx	xx	xx
Vernonia cinerea Less.	0	xx	xx	x	x	0	0
Thesium sp.	xx	xx	0	0	0	xx	xx
Tragus berteronianus Schult.	xx	xx	x	xx	x	xx	xx
Tribulus terrestris L.	x	x	xx	x	xx	0	xx
Trichodesma zeylanicum R. Br.	0	0	0	0	0	0	0
Tridax procumbens L.	0	x	x	xx	xx	xx	0

0 - null effect   x - slight herbicide effect   xx - effective control

In table 2 the weeds found to infest cotton during the trials are indicated, as well as the herbicide effect on them. The criterion was followed that, when a given weed was absent from a plot treated with a certain herbicide, but was present in other plots, this implied that the weed had been controlled by the product. It may happen that this criterion is not absolutely correct, as the absence could have been caused not by the effect of the herbicide but by the fact that the weed was actually absent from the plot.

At Maniquenique (clay soils, medium in organic matter content) the prevailing weeds were Cyperus rotundus L., Commelina benghalensis L., Amaranthus spinosus L., and Acalypha segetalis Muell. Arg. Cyperus was not killed by either of the herbicides under trial, although the highest doses of fluometuron and diuron had a greater effect on this weed's populations and retarded their growth. The same null effect of all the products was observed in connection with Commelina benghalensis, while Amaranthus spinosus was effectively controlled by fluometuron and trifluralin and only slightly affected by the other herbicides when applied at the highest rates. Acalypha segetalis resisted fluometuron and diuron action, but showed signs of susceptibility to prometryne, the mixture of prometryne + simazine (40:15) and to noruron.

Results from Mutuali (sandy-clay-loam soil, rich in organic matter content), where the main weeds were Digitaria adscendens (H.B.K.) Henrard, Acanthospermum hispidum DC., Tridax procumbens L., Eleusine indica (L.) Caertn. and Ocimum americanum L. show that Digitaria adscendens was effectively controlled by trifluralin and Tridax procumbens by the highest doses of diuron, fluometuron and linuron. Plots to which the mixture prometryne + simazine and prometryne had been applied alone, were the only ones where Eleusine indica dominated. Acanthospermum hispidum and Ocimum americanum were not controlled by trifluralin, prometryne and linuron.

At Nampula (sandy-clay-loam soils, medium to poor in organic matter content) the dominant weeds were Corchorus trilocularis L., Digitaria adscendens (H.B.K.) Henrard Tridax procumbens L., Commelina benghalensis L., and Jacquemontia sp. A slight control was revealed by prometryne, the mixture of prometryne + simazine, fluometuron and diuron on Corchorus trilocularis., Digitaria adscendens infested, in a greater or less degree, all the plots, and trifluralin was the only product to show effectiveness in this case. Tridax procumbens was controlled by diuron, fluometuron and linuron. Commelina benghalensis was unaffected by all the herbicides and so was Jacquemontia sp.

DISCUSSION

Whenever the doses shown in table 3 were applied, cotton yields were significantly similar to those obtained from the control plots, in which eradication was made by handhoeing. No complete control was however achieved during the period extending from sowing to the beginning of the flowering of the cotton, by any of the herbicides tried.

It must be stressed however that, provided the dosage was suitable for the soil type to which it was to be applied, herbicides retarded the growth of the less resistant weeds, and cotton was consequently allowed to develop without being considerably affected by competition. When the herbicide action began to fade and weeds resumed their normal growth, all the plots were handhoed and cotton, already sufficiently developed, easily dominated the weeds that emerged latter.

In Mozambique, the more advanced growers - the ones more readily expected to apply herbicides to their crops - generally grow cotton in extensive areas. Variations, sometimes considerably marked, of texture and organic matter content are likely to occur within their fields. This implies the elimination of those

Table 3

Doses (a.i. kg or l/ha) at which pre-emergent herbicides did not affect cotton yields

Herbicides	Clay medium org. mat. cont.	Sandy - clay - loam: rich org. mat. cont.	Sandy - clay - loam: medium org. mat. cont.	Sandy - clay - loam: poor org. mat. cont.
Prometryne	1.5	1.5	1.5	1.5
Prom. + Simaz.	2.5	2.5	1.7- 2.5	1.7
Noruron	4.0	4.0	4.0	4.0
Linuron	0.8-1.2	-	0.8-1.2	0.8
Fluometuron	2.4	2.4	2.4	2.4
Diuron	1.6	1.6	1.6	1.6
Trifluralin	-	-	0.5	0.5

herbicides with a narrower range of selective doses, and their use must be discarded. This is the case with the mixture of prometryne + simazine (40:15) and linuron, with which small variations in soil texture and organic matter content, or even in the application rate, may cause effects ranging from poor weed control to the destruction of cotton plants.

Fluometuron was the herbicide showing best selectivity to cotton, the plant being not affected by variations, however marked, in doses or types of soil. Prometryne, noruron and diuron, with a small range of suitable dosage rate will have to be used under more precise conditions. Trifluralin has been tried at rates too low to allow its selectivity to be adequately assessed.

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A PRELIMINARY EVALUATION OF COTTON HERBICIDES FOR PEASANT FARMING IN NORTHERN NIGERIA

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Summary The effects of herbicide applications on the yield of seed cotton and hand labour for weed control were measured in experiments at sites throughout northern Nigeria. The importance of the correct timing of herbicide applications to take effect during the period of greatest labour demand in the peasant holding as a whole is stressed. The effects of trifluralin incorporated pre-sowing and fluometuron applied at cotton thinning are described in detail.

INTRODUCTION

During 1967 seven cotton herbicide experiments at sites in northern Nigeria were used to evaluate the feasibility of herbicide use by peasant cotton growers. Apart from work at Samaru by Dransfield (1961) on the effects of dalapon in cotton, there appears to have been no previous publication on cotton herbicide experiments in the area. Previous work by the author, Ogborn (1964) and Low (1964) in East Africa is partially applicable.

These trials are part of a larger programme whose general background is described by Ogborn (1969). Detailed investigations by Norman (1967) at three northern Nigerian villages have confirmed that there is a period during which the demand for labour to control weeds by hand hoeing represents the main limiting factor to the area of crops which can be grown during the remainder of the season. The available evidence indicates that the peak demand for labour occurs in June and July.

The object of this paper therefore is to measure the extent to which the demand for handweeding could be reduced or dealyed by herbicide applications in this experiment.

METHOD AND MATERIALS

Object To measure the effects of low rates of herbicides on the amount of weed growth, the timing of supplementary hand cultivations and the yield of the cotton crop.

Sites Five of the experiments were situated at farms or stations run by the former Northern Regional Government of Nigeria. The other two were situated at the Samaru and Mokwa stations of the Institute for Agricultural Research (I.A.R.), Ahmadu Bello University.

Design 2^3 factorial with 2 additional nil plots per block. 10 plots per block replicated four times.

Plot size Gross : 6 x 12 yd
Net : 4 x 10 yd = 1/121 acres.

Crop spacing 3' x 1' on ridges.

Treatments The eight factorial combinations of three herbicides (presence v. absence).

Material		Symbol
Trifluralin	0.5 lb/ac incorporated pre-sowing	Tr
x		
Fluometuron	1.0 lb/ac semi-directed at time of thinning cotton	Fl
x		
Paraquat	0.25 lb/ac semi-directed at first appearance of cotton flowers	P*

*This treatment was omitted at Mokwa and Samaru.

Basal fertiliser 1 cwt per acre of 21 14 0 compound fertiliser.

Methods of application. The applications were all made with a Policlare knapsack sprayer fitted with a floodjet using a spray volume of 25 gallons p.a. The trifluralin was incorporated by hand hoeing.

Observations Each plot of the experiment was weeded and observed as a separate unit. Records of weekly growth scores, frequency of hand weeding, weight of weeds removed and yields of cotton were taken and analysed statistically.

The weeds were allowed to wilt on the plot of origin after hand-pulling, shaken free from soil, allowed to dry for six days under cover and then weighed.

The dominant weeds on each site were collected and identified. Records of observations were incomplete for some trials.

RESULTS

A part of the data collected in these experiments has been omitted in order to conform to the length of paper prescribed for this conference.

The effects of paraquat which was applied at the end of the normal hand weeding periods recorded here are therefore not presented. The weed control effects were spectacular but came too late in the season to reduce the amount of hand weeding. The effects on yield of seed cotton were small.

The experiments fall naturally into two groups. The first group (Table 1) where cotton yields were low and there was a serious weed problem can be compared with the second group where yields were over 1,000 lb/ac of seed cotton and there were fewer weeds (Table 2).

When the abbreviation "n.ap." occurs in a table it implies that the herbicide had not been applied before the hand weeding.

Because each plot was weeded individually, the first, second and third weedings did not occur during the same week in all plots of an experiment but a modal date has been chosen. For example in Table 1 at Dengi the second weeding on most plots occurred in the fifth week through in fact only some of the fluometuron treated plots and none of the 'trifluralin + fluometuron' ever needed a second weeding.

The rainfall reported for each site was the amount recorded during the period of recorded weed control and was only part of the total rainfall available to the crop.

Table 1

Weights of air-dry weeds removed during hand weeding and yields of seed cotton in lb/ac

Lower yielding group of experiments

Site Kafinsoli. Sowing date 22.7.67. Rainfall 21.8 in

Week after sowing	Weeds 4th	Weeds 10th	Seed cotton	Dominant weeds
Hand weeding only	3384	451	98	*Mitracarpus scabrus*
+ trifluralin	2912	413	86	*Amaranthus* sp.
+ fluometuron	n.ap.	374	54	*Borreria* sp.
+ trif. + fluom.	n.ap.	107	150	
			± 13.2	

Site Dengi. Sowing date 23.7.67. Rainfall 3.8 in

Week after sowing	Weeds 4th	Weeds 5th	Seed cotton	Dominant weeds
Hand weeding only	1096	4836	451	*Commelina* sp.
+ trifluralin	1986	5560	448	*Ipomea* sp.
+ fluometuron	n.ap.	794	490	*Borreria* sp.
+ trif. + fluom.	n.ap.	0	433	*Mitracarpus scabrus*
			± 44.5	*Senecio* sp.

Site Samaru. Sowing date 20.7.67 Rainfall 20.5 in

Week after sowing	Weeds (Early)*	Weeds 3rd	Weeds 5th	Weeds 10th	Seed cotton	Dominant weeds
Hand weeding only	(1587)	1735	1587	1555	520	*Dactylotenium aegyptium*
+ trifluralin	(546)	1372	546	1589	405	*Eleusine indica*
+ fluometuron	n.ap.	n.ap.	n.ap.	248	321	*Amaranthus* sp.
+ trif. + fluom.	n.ap.	n.ap.	n.ap.	534	366	*Cyperus* sp.
					± 47.4	*Digitaria chevalieri*

* Weeds removed before sowing

Site Mokwa. Sowing date 14.7.67. Rainfall 24.5 in

Week after sowing	Weeds 10th	Weeds 13th	Seed cotton	Dominant weeds
Hand weeding only	1252	901	638	None collected but
+ trifluralin	921	826	626	*Imperata cylindrica*
+ fluometuron	n.ap.*	0	601	known to have been
+ trif. + fluom.	n.ap.	0	523	present on the site
			± 46.7	

* Herbicide delayed in transit, applied six weeks after thinning.

Table 2

Weights of air-dry weeds removed during hand weeding
and yields of seed cotton in lb/ac

Higher yielding group of experiments

Site Konan kuka. Sowing date 1.7.67. Rainfall not recorded

Week after sowing	Weeds 4th	Weeds 12th	Seed cotton	Dominant weeds
Hand weeding only	404	1358	1240	Vetveria negritana
+ trifluralin	395	653	1289	Ipomea sp.
+ fluometuron	n.ap.	380	1358	
+ trif. + fluom.	n.ap.	0	1512	
			± 103.2	

Site Biu. Sowing date 20.7.67 Rainfall 14.1 in

Week after sowing	Weeds 4th	Weeds 8th	Seed cotton	Dominant weeds
Hand weeding only	243	257	1413	Senecio sp.
+ trifluralin	252	261	1261	Pennisetum pedicellatum
+ fluometuron	n.ap.	243	1646	
+ trif. + fluom.	n.ap.	180	1540	
			± 118.1	

Site Gusau. Sowing date 19.6.67 Rainfall 30.4 in

Week after sowing	Weeds 4th	Weeds 12th	Seed cotton	Dominant weeds
Hand weeding only	Not recorded	287	1618	Dactylotenium aegyptium
+ trifluralin	"	129	1416	Mitracarpus scabrus
+ fluometuron	"	168	1531	Cyperus sp.
+ trif. + fluom.	"	80	1567	
			± 140	

DISCUSSION

For a considerable period in northern Nigeria peasant farmers have been recommended to sow their cotton in June and to protect it with an insecticidal spray. Nevertheless the great majority sow their crop in July or later when insecticidal sprays are unlikely to give an economic return. Their persistence in this practice suggests that some factors in their overall farming system make it difficult for them to follow the recommendation. Cereals and other food crops planted in May usually require hand weeding and thinning in June and July. This work conflicts with the start of the cotton crop and causes a peak labour demand which is believed to set a limit to the area which can be cultivated by a peasant farmer and his family.

This area could potentially be increased if the labour of establishing the cotton crop could be reduced. The well proven soil incorporated herbicide trifluralin was chosen to be applied to selected cotton sites early in the season before the food crops are sown in May and early June. It was hoped that the amount of weeding required to prepare the site at cotton planting time would be reduced and that the trifluralin would still retain some useful activity after the soil disturbance caused by weeding and ridging up the site. Pre-emergence applications of herbicides at sowing were excluded because of the high risk of accidental over-dosage during peasant use, but an established cotton crop three to five weeks old was expected to tolerate a considerable over-application of herbicide to the soil at this stage.

Herbicide effects on hand weeding The results in Tables 1 and 2 were recorded as weights of air-dry material to avoid the necessity for relying upon visual scores by inexperienced and uncalibrated observers. There probably was some variation in moisture content in the air dry material during the season but the observations made at Samaru indicate that the recorded weights were a good objective measure of the amount of supplementary hand labour required to maintain weed control. The oven dry matter content of the air-dry material at Samaru varied between 70 and 80 per cent during the season.

The intention of applying trifluralin early in April had to be abandoned because of the late arrival of the herbicide and the difficulties in distribution. At Samaru the material was applied 'Early' on 18th June but at all the other sites it had to be applied during the actual site preparation at planting time. At Samaru the weed weight was reduced by two thirds. The effect on the first weedings after planting was much less. At Dengi and Biu there were actually greater weights of weeds recorded from the trifluralin plots than from the untreated controls. A possible explanation is that resistant broad leaved weeds at these sites benefited from the reduced competition from annual grasses which were well controlled by trifluralin. These two sites also had the lowest rainfall. Fluometuron applied after cotton thinning gave considerable reductions in weeds at all centres except Biu and controlled a different range of weeds from trifluralin. The combination of the two materials gave the best weed control except at Samaru.

Effects on yield Except at Kafinsoli where there was a crop failure caused by poorly distributed rainfall, both herbicides were associated with small general reductions in yield on the lower yielding group of sites. Trifluralin has been reported to cause stunting of cotton roots by Anderson et al.(1967). This would be more serious and prolonged on a site where cotton is growing slowly than where the crop is vigorous and the proportion of the root system growing below the treated layer is larger. Trifluralin also was associated with small proportional descreases in two out of the three higher yielding sites. The manufacturers of fluometuron state that damage to cotton may be observed under unfavourable circumstances. Particularly severe damage was observed at Samaru where an application was deliberately made 'over the top' to test the danger from careless spraying only eighteen days after sowing. The crop was subsequently badly infected with bacterial wilt and recovery from the attack was much slower on the plots which had received fluometuron. A statistically significant yield decrease was observed.

Evaluation of treatments Though the post-emergence application of fluometuron reduced the supplementary hand weeding more than trifluralin, the reduction occurred too late in the season to be of such value as the effects of the latter. It seems clear that trifluralin at a dosage of 0.5 lb/ac is insufficiently active against the vigorous broad leaved weeds occuring at sites like Dengi and Biu but where the main early weed growth is annual grasses the application does seem to have economic possibilities.

If it be assumed that at Samaru in 1967 the first two weedings occurred during the labour peak and that a reduction in yield was caused by trifluralin, a simple calculation shows that the area of cotton could be increased by 73% and the output of cotton by 35%. At current cotton prices the 'break-even' price of trifluralin would be £5.4.0d per lb a.i. In practice herbicides would also make it possible and probably more profitable to sow an unchanged area of cotton earlier. King (1967) showed that large yield increases could be obtained by planting earlier in July.

Possible methods of application The only method of application which is likely to be practicable for use by peasant farmers in the near future is the hand spreading of granular formulations. Until these are available for testing in Nigeria a truly realistic evaluation of cotton herbicides for peasant farming will not be possible.

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A COTTON/WEED COMPETITION EXPERIMENT

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Summary Competition between cotton plants and two vigorous annual weeds, *Amaranthus hybridus* and *Nicandra physaloides* were studied at Henderson Research Station (altitude 4,200 ft., rainfall 34.6 cm and irrigated with 14.0 cm water). Various weedy and weed-free periods (2, 4, 6, 8 weeks and full season) during the summer were observed for their effect on crop and weed cover, soil moisture status, nutrient removal and seed cotton yields.

This experiment was conducted in a season of below average rainfall (42.7 cm) which probably retarded emergence of late weeds and vegetative development of both crop and weeds. However, cotton yields were critically affected when the season's initial weeds were allowed to grow for longer than two weeks after crop emergence. Weeds which emerged after hand cultivation at four weeks did not seriously affect seed cotton yields. It is thought that this critical period of weed competition (from two to four weeks after crop emergence) may be of longer duration in a wetter season. Despite this reservation it is important that the period at which weed competition is critical is of relatively short duration.

Competition for light was probably the main factor which influenced crop yield, while competition for moisture and plant nutrients were probably of secondary importance.

INTRODUCTION

The effects of weeds on cotton yields are well known. However, only a limited number of workers have attempted to define the stages at which weed competition seriously affects cotton yields. This report deals with the effects of fast growing highly competitive weeds in cotton, a relatively slow developing row crop. In addition, competition for light, moisture and nutrients resulting from differential periods of weed competition was studied.

METHOD AND MATERIALS

Cotton was planted on October 31st 1967 in a randomised block experiment with four replicates. The variety, Albar 637, was grown at a standard spacing of 90 cm x 15 cm (36 in. x 6 in.). An overhead irrigation of 7.5 cm was applied on November 3rd and the crop emerged on the 9th November, 1967. Thereafter the crop was subjected to differential periods of weed competition.

The main weed species naturally present in the soil was *Amaranthus hybridus* and *Nicandra physaloides* both of which are tall, vigorous broad-leaved annual weeds. No herbicides were used in this experiment and all weeds removed manually according to treatment, were classified,

Table 1

Percentage cover of the crop and of weeds at fortnightly intervals after crop emergence

Treatment		Number of weeks after crop emergence 2	4	6	8	10	12	14	16	18
Clean full season	Crop	7	14	27	53	60	87	88	96	96
	Weed	0	0	0	0	0	0	0	0	0
Clean first 8 weeks only	Crop	6	13	27	55	66	86	93	95	93
	Weed	0	0	0	0	0	5	4	4	5
Clean first 6 weeks only	Crop	8	14	28	44	61	86	85	85	76
	Weed	0	0	0	8	2	3	10	14	21
Clean first 4 weeks only	Crop	6	13	26	52	65	75	76	75	62
	Weed	0	0	1	6	6	16	22	25	38
Clean first 2 weeks only	Crop	7	12	28	44	45	11	0	0	0
	Weed	0	19	19	35	46	89	100	100	100
Weedy full season	Crop	7	4	2	1	0	0	0	0	0
	Weed	16	82	92	96	100	100	100	100	100
Weedy first 8 weeks only	Crop	7	6	3	1	17	18	38	55	60
	Weed	27	85	95	99	0	0	0	0	0
Weedy first 6 weeks only	Crop	8	7	6	17	28	37	68	82	87
	Weed	15	83	86	0	0	0	0	0	0
Weedy first 4 weeks only	Crop	8	5	24	36	50	76	85	92	93
	Weed	21	83	0	0	0	0	0	0	0
Weedy first 2 weeks only	Crop	6	14	25	50	64	91	96	97	96
	Weed	19	0	0	0	0	0	0	0	0

counted, and records taken of dry matter yields and nutrient removals.

Two weeks after emergence of the crop, weekly measurements were made on the percentage soil covered by weeds or the crop by means of a quadrat frame (Cackett, 1964). Percentage cover was taken as an indication of the amount of overhead light which would reach the crop or weed. Crop rows were aligned from East to West and the sun passed virtually overhead at this latitude (18.5°S) during November to February.

Soil moisture status was recorded by means of daily electrical resistance readings from nylon blocks installed at a depth of 15 cm (6 in.) midway between two crop rows. Following long rainfree periods (at six and nine weeks after emergence) gravimetric samples were taken to soil depths of 0 to 15 cm, 16 to 30 cm, 31 to 60 cm, and 61 to 90cm.

Nutrient removal by the crop (N, P, K, Ca, Mg and Zn) was determined on a composite sample of 16 cotton plants per treatment taken at 19 weeks after emergence. Similar analyses were carried out on

A. hybridus, N. physaloides, other dicotyledons and grasses at weeding or at 19 weeks on unweeded plots.

Pickings of seed cotton were made of mature lint at 25 weeks and the remaining immature lint at 31 weeks after crop emergence.

RESULTS

Crop and Weed Cover

Cotton took at least 13 weeks to reach 95 to 100% cover while the weeds (mainly Amaranthus hybridus and Nicandra physaloides) had reached 95% cover at five weeks and 100% cover by nine weeks after crop emergence. These weeds generally emerged two or three days before the crop. Table 1 gives details of the percentage cover by crops and weeds for the first 18 weeks of the crop's life.

Weed competition during the first four to six weeks and after the first eight weeks did not seriously reduce the crop cover attained at 18 weeks. These results were, however, obtained in a season of low and erratic rainfall which resulted in slower vegetative growth of both the crop and the weeds than would normally be the case in a wetter season.

Moisture

The nylon block readings indicated that the moisture content of the soil was lower whenever weeds were present. For example "weedy full season" resulted in a low soil moisture condition throughout the season while "weedy first 8 weeks" had a low level of soil moisture early in the season and an adequate moisture condition later in the season. Furthermore "clean first 2 weeks" had a lower moisture status later than earlier in the season.

Gravimetric samples were taken on January 10th during a period of low soil moisture condition and the results obtained show that especially where weeds were present early in the season they removed more moisture, at all depths, than did the crop (Table 2). The crop extracted proportionately more moisture in the top 30 cm than from greater depths.

The experiment received a 7.5 cm (3.0 in.) irrigation on November 3rd 1967 and 6.5 cm (2.4 in.) on 19th January, 1968. Rainfall was 6.3 cm (2.5 in.) in November, 7.2 cm (2.9 in.) in December, 1967, 10.3 cm (4.1 in.) in January, 7.8 cm (3.1 in.) in February, and 3.0 cm (1.2 in.) in March, 1968.

Nutrients

Nutrient removal by the crop was determined at 19 weeks after emergence and by the main weeds present at weeding or at 19 weeks on unweeded plots (Table 3). Nutrient content of the crop was severely reduced either (a) when weeds competed throughout the season or (b) when a crop was weed-free for the first two weeks or (c) when the crop was weedy for the first eight weeks. In these instances weeds removed 3 to 4 times more nitrogen, potassium and magnesium than a weed-free crop, but similar quantities of phosphorous, calcium and zinc.

Table 2

Mean moisture percentage at various soil depths in plots planted with cotton on which differential periods of weed competition were imposed

Treatment	Sampling depth			
	0-15 cm	16-30 cm	31-60 cm	61-90 cm
Clean full season	11.0	14.1	18.5	17.1
Clean first 8 weeks only	10.7	13.6	18.7	18.0
Clean first 6 weeks only	10.1	12.3	17.1	19.5
Clean first 4 weeks only	10.3	13.1	18.0	18.8
Clean first 2 weeks only	8.7	10.9	17.6	17.2
Weedy full season	8.2	10.0	17.1	15.8
Weedy first 8 weeks only	7.8	11.2	16.9	17.0
Weedy first 6 weeks only	11.1	13.7	17.8	18.6
Weedy first 4 weeks only	10.1	12.0	15.3	16.0
Weedy first 2 weeks only	8.3	15.1	19.8	20.8
Field Capacity	26.6	28.1	29.6	30.7

FIGURE 1. Crop value (£ Rhodesian) as influenced by different periods of weediness:

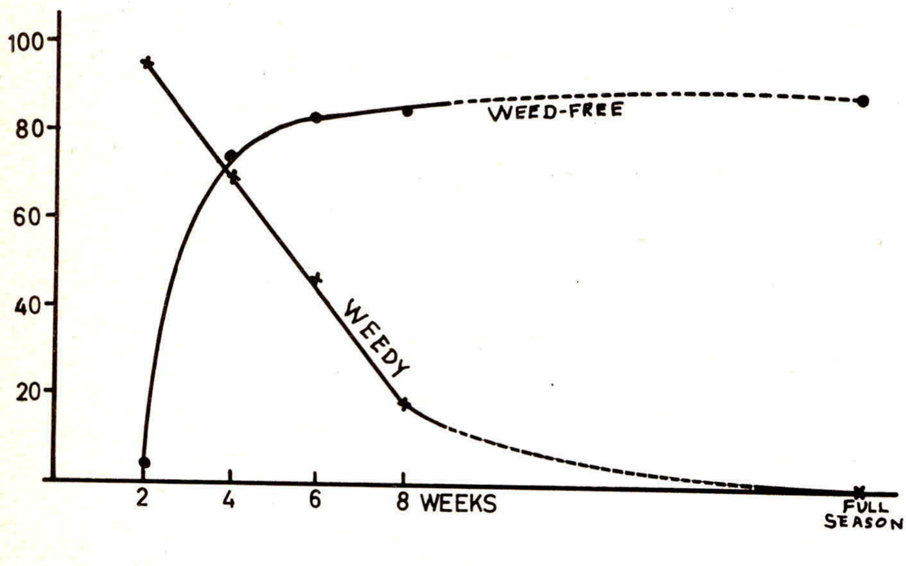

Table 3

Dry matter weight of nutrients removed by cotton and weeds (lb/acre).

Treatment		N	P	K	Ca	Mg	Zn
Clean full season	Crop	133	22	88	56	25	0.23
	Weed	-	-	-	-	-	-
Clean first 8 weeks only	Crop	146	25	88	56	28	0.31
	Weed	3	1	4	1	1	0.01
Clean first 6 weeks only	Crop	129	22	80	55	28	0.17
	Weed	19	3	27	6	6	0.03
Clean first 4 weeks only	Crop	161	28	115	58	29	0.28
	Weed	93	6	69	22	21	0.06
Clean first 2 weeks only	Crop	63	8	40	25	12	0.08
	Weed	256	14	114	36	43	0.19
Weedy full season	Crop	34	7	19	17	8	0.05
	Weed	401	27	367	80	95	0.28
Weedy first 8 weeks only	Crop	78	10	26	38	21	0.10
	Weed	153	15	224	87	53	0.16
Weedy first 6 weeks only	Crop	110	17	52	52	27	0.16
	Weed	86	7	137	48	26	0.11
Weedy first 4 weeks only	Crop	126	21	76	49	28	0.16
	Weed	34	5	53	26	13	0.08
Weedy first 2 weeks only	Crop	134	20	89	51	23	0.16
	Weed	4	1	4	3	2	0.01

Seed Cotton Yields

The various treatments had a marked effect on the total crop produced as well as on the amount of mature and immature seed cotton produced (Table 4).

Table 4

Mean seed cotton yields in pounds per acre and crop value as influenced by differential periods of weed competition

Treatment	Mature	Immature	Total	Value £ Rhodesian
Clean full season	2319	228	2547	88.3
Clean first 8 weeks only	2193	292	2485	85.6
Clean first 6 weeks only	1993	447	2440	82.7
Clean first 4 weeks only	1734	448	2182	73.5
Clean first 2 weeks only	Nil	Nil	Nil	Nil
Weedy full season	Nil	Nil	Nil	Nil
Weedy first 8 weeks only	204	404	608	18.1
Weedy first 6 weeks only	936	484	1420	46.3
Weedy first 4 weeks only	1776	137	1913	66.6
Weedy first 2 weeks only	2446	299	2745	94.7
LSD (5%)	449	300	532	-

Note: Value of crop produced based on a price of 8.5 pence per pound for mature and 6.5 pence per pound for immature seed cotton.

Where the original weed growth was allowed to remain in the crop for longer than two weeks crop yields were drastically reduced. If the second flush of weed growth started at four weeks or later crop yields were not seriously affected (Fig. 1). However, in a season of heavier rainfall, it is likely that later emerged weeds may have had more effect on the crop.

DISCUSSION AND CONCLUSIONS

Competition for light probably accounted for the main effect of weeds on final crop yields. Wherever weeds were present they generally covered the soil (and crop) more rapidly than the cotton did. However, in an established crop it took several weeks for weeds to become dominant.

Weeds removed moisture more rapidly and to a greater depth than cotton did. However in a season of below-average rainfall (34.6 cm or 13.8 in.) and light irrigation (14.0 cm or 5.4 in.) crop yields were not seriously reduced by weed competition in the first two weeks or beyond four weeks.

Although weeds removed large amounts of nutrients, provided they were not competing seriously with the crop at two to four weeks of age they did not appreciably reduce final crop yield. This applied where adequate soil fertility was provided but may not be true in soil of low fertility.

These observations need to be repeated in other seasons but the main finding of this preliminary study is that the initial weeds should not be allowed to compete for more than two weeks after cotton emergence. Although the second flush of weeds (after weeding at four weeks) did not seriously reduce yields it is anticipated that in a wetter season these would have established themselves sooner and may later have become vigorous competitors.

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