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SESSION 7

Chairman: Dr. E. Holmes

HERBICIDES ACTING THROUGH THE SOIL - A REVIEW

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INTRODUCTION

An ever-increasing number of herbicides are effective when applied to the soil. In the new edition of the Weed Control Handbook which will appear early in 1963, 76 organic herbicides are mentioned. They may be classified according to their route of entry into plants, as follows:

30 enter only from the soil

19 enter through the leaves and from the soil

25 are dependent on foliar entry in practical usage, though 13 of these can nevertheless be active via the soil

2 are aquatic herbicides which enter from water

Thus there are only 12 out of 74 herbicides in respect of which uptake from soil is insignifcant in considering their herbicidal effects.

The alkylphenoxy acids which are used mainly as foliar applications are still two decades after their discovery, the most extensively used of all herbicides but herbicides acting through the soil are becoming used increasingly for a wide diversity of purposes.

Annual plants are most susceptible to herbicides at the time of germination and generally increase in resistance thereafter. Soil-acting herbicides have the great advantage that they can kill the germinating weed sooner than a herbicide which relies on post-emergence foliar entry. Their primary use is to control weeds prior to emergence, thus giving the tremendous benefit of very early removal of weeds competition. Studies to measure the competitive effects of weeds in annual crops invariably show that competition during the very early stages of crop growth is responsible for a greater part of the yield depression. Thought is now being given to the pre-emergence control of broad-leaved weeds in cereals (e.g. Parker, 1962a; Holroyd, 1962) and it will be interesting to see whether the increases in yield that result from such treatments are greater than from the conventional post-emergence control methods.

Soil-acting herbicides are used for the control of germinating weeds in a wide variety of situations. These may be categorised as follows:

1) Annual crops

(a) grown from seed and germinating at about the same time as the weeds.

(b) vegetatively propagated and planted under conditions favourable for weed germination, e.g. potato.

(c) after establishment e.g. the control of spring germinating weeds in an autumn sown crop.

(d) after transplanting of established seedlings, when soil conditions favour weed germination.

2) Perennial crops

(a) herbaceous

(b) woody crops, such as most temperate fruits, and ornamental shrubs

(c) plantation crops, mostly tropical.

3) Total weed control, to maintain an area free of germinating weeds.

Soil-acting herbicides are also used for the control of weeds at later stages of growth. Examples are the application of fenuron and of the chemical combinations of substituted ureas with TCA for the control of established woody weeds, TCA for the control of rhizomes of *Agropyron repens*, and EPTC for the prevention of the successful sprouting of tubers of *Cyperus rotundus* (nutgrass, a tropical and sub-tropical sedge).

A great diversity of chemicals are effective as herbicides in the soil. There is no restriction to particular groups. A fair cross-section is represented in the Research Reports presented later in this Session.

In the early days of the introduction of selective soil-acting herbicides there were grave misgivings regarding the feasibility of the widespread adoption of their use in farming practice. They were thought to be too variable in performance and too greatly influenced by factors which could not be controlled. As the years have passed much has been learnt about these factors which govern their performance and as such knowledge accumulates it can be utilised to define the methods of use so as to give the best and most reliable results. The present paper is a brief and general review of background knowledge of the behaviour of soil-acting herbicides and the implications for practical usage.

In the complex situation of the herbicide in the soil many problems are physicochemical in nature. For detailed treatment of such matters there are reviews by Freed *et al* (1962) and Hartley (1960). The equally important topic of microorganisms in soil and their importance in the breakdown of herbicides is covered in the review by Audus (1960).

In the present paper the subject is best covered by considering in sequence the events which follow the application of a soil-acting herbicide to the surface of the soil.

LOSSES FROM SOIL SURFACE

In the first place if the soil surface is dry the herbicide will remain there until the advent of sufficient moisture for it to diffuse or leach into the soil. During such a period on the surface of the soil the herbicide is particularly liable to loss by photochemical decomposition and by volatilisation into the atmosphere. Degradation by ultraviolet light is particularly well substantiated with monuron and diuron; Weldon & Timmons (1961a) found that artificial UV illumination of these herbicides for 28 hours resulted in a 75 per cent decrease in biological activity. Even more striking is the report by Sheets (1962) that exposure of a solution of amiben to sunlight for 6 hours led to breakdown of 50 per cent of the chemical. Sheets also cites an experiment in which monuron and diuron disappeared more rapidly from soil exposed to sun than from shaded soil. He points out however that the higher soil temperatures in sun make it impossible to separate losses from decomposition and losses by volatilisation.

It is now known that volatilisation can be an important source of loss of herbicides from the soil surface even of chemicals which are not ordinarily thought of as being volatile. Vapour movement and loss has been studied particularly with the thiolcarbamates, notably EPTC. Volatilisation of this herbicide from moist soil is much greater than from dry soil (Fang _et al_, 1961). This appears to be due to co-distillation whereby organic compounds having a low water solubility but a measurable vapour pressure will distil with water (Freed _et al_, 1962). The latter workers also cite data for vapour loss of chlorpropham from a sandy loam soil at 24°C. In 16 hours 2 per cent was lost if the soil was dry and the air still. If instead the soil was moist the loss increased to 10 per cent. If the soil was moist and there was a wind this loss increased still further to 26 per cent. Losses of this magnitude occur only at high soil temperatures but in sunny weather soil surface temperatures may be considerably higher than air temperatures. Hill _et al_ (1955) considered that even with monuron volatilisation could be a significant factor when the chemical remained on the soil surface during a period of hot dry weather.

What can be done to avoid loss by decomposition or volatilisation if application is made during a dry sunny spell? Granular formulations have some advantage in these circumstances by protecting from light if they are of the type whereby the herbicide is incorporated in the substance of the granule, rather than being merely surface coated. The carrier used in the preparation of granular formulations can also influence the loss from volatilisation as has been shown for chlorpropham by Danielson (1959). Even the formulation of the spray liquid can influence vapour loss - thus addition of a relatively non-volatile solvent such as oil reduced the loss of EPTC during 24 hours in dry soil from 18 per cent to 6 per cent (Freed _et al_, 1962).

If application has been to a dry surface most herbicides will not start to control the weeds until the herbicide has moved into the body of the soil. This is generally brought about by natural rainfall, which is unreliable. Therefore preventive measures which also accomplish this will be more valuable. If irrigation equipment is available a heavy application of water may be helpful by moving the herbicide into the soil, protecting it from loss and enablying it to start functioning. A light application of water which merely moistens the surface layers must be guarded against because this will accentuate loss of a slightly volatile herbicide. The most reliable and widely applicable measure is to incorporate the chemical into the soil by mechanical means as soon as possible after application.

INCORPORATION INTO SOIL

Different implements and different soil conditions result in varying degrees of efficiency of incorporation. The depth of incorporation required will be governed more by the crop and the weed problem to be tackled than by considerations of preventing loss of herbicide, for maximum selectivity often depends on the positioning of the herbicide in the soil profile.

Most herbicides acting through the soil are thought to be taken up by the root system of the germinating weed rather than by the shoot as it pushes its way through to the surface. Therefore the herbicide must reach a position just below the germinating seed to be effective. This may be accomplished by diffusion or leaching of the herbicide, but mechanical incorporation can achieve this more precisely. Unfortunately singularly little is known about the depths from which normal weed populations arise. Some clues are provided by experiments in which seed has been sown at different depths and the emergence recorded, as has been done for Avena fatua and A. ludoviciana by Thurston (1951) and for certain small-seeded grass weeds by Dawson & Bruns (1962). The only direct information however is provided by investigation of naturally occurring weed populations and counting the proportions germinating at different depths. Some work of this type has been done by Roberts (unpublished information) at the National Vegetable Research Station. As one example from his data, in a spring germination on a sandy loam 32 per cent and 42 per cent of Viola arvensis seedlings appeared to have germinated in the first and second cm of soil respectively. In contrast only 5 per cent of Fumaria officinalis originated in the top cm and 26 per cent in the second cm. 69 per cent had originated from below 2 cm deep. F.officinalis would thus have been more favourably situated for resisting control by a herbicide applied only to the soil surface and not readily leached. Naturally there will be variation according to soil type, aeration, moisture and so on. The situation is also complicated by the fact that some weeds such as Stellaria media very rapidly develop roots from the below-ground portion of the hypocotyl. These contribute to the sensitivity of this weed to triazines and ureas by enabling it to pick up herbicide from the surface layers of soil. Nevertheless, once there is a bulk of information on normal germination depths of weeds incorporation can be planned to bring the herbicide into contact with the majority of the weeds, but without distributing the chemicals to an excessive depth in the soil. The latter can lead to reduction in herbicidal efficiency purely by a dilution effect, as has been indicated with EPTC, CDEC and CDAA by Ashton & Dunster (1961).

Another aspect of incorporation that has to be considered is that if the crop is deep-sown and the herbicide is not readily leached part of any selectivity that is obtained may be due to depth protection of the crop. In such circumstances incorporation must be very shallow to avoid removing this protection. Particular care must also be taken to ensure that the machinery used for planting is working as required; for example, seed drills must run at an even depth and potato planters must place the tubers all at the same distance below the surface.

A further complication is that some soil-acting herbicides have now been found which do not enter solely through the roots. One example is 2,4-dichlorophenyl 4-nitrophenyl ether which must be left as an undisturbed layer on the soil surface and presumably enters the shoot as it emerges from the soil (Tyson & Wood, 1962). Another example is di-allate. This herbicide has to be incorporated to avoid loss by volatility, but it appears that entry into both *Avena fatua* and wheat occurs primarily via the coleoptile rather than via the root system. Detailed work has shown that the positioning of this herbicide in the soil in relation to the position of the growing point of *A. fatua* and the crop can influence its selectivity (Friesen *et al*, 1962; Parker, 1962b). Similar work on other herbicide-crop-weed situations might well be fruitful in showing how selectivity of other soil-acting herbicides can be improved.

Finding where to place the herbicide in the soil in order to achieve maximum selectivity is only half the problem. The other half concerns how to put it there in practice. The agricultural implements available for incorporating herbicides into the soil do not give uniformity of distribution through the cultivated depth. Their efficiency for this purpose must therefore be studied under a range of conditions. Some work has been done on this subject by using fluorescent compounds as tracers and it has been found that even rotary cultivation gives far from uniform distribution. As an example one rotavation to a 6 in. depth left 79 per cent of the tracer in the top 3 in. of soil and only 21 per cent in the 3 - 6 in. layer (Staniland, 1961). An alternative is to develop special equipment for placing herbicides where they are required in the soil, as for example the device for underground application of herbicides in cotton fields described by Wooten & McWhorter (1961). There are, however, economic limitations on the use of special single-purpose machinery, and the more practical solution probably lies in finding out how best to use existing implements.

ADSORPTION

On entry into the soil the full amount of herbicide applied does not usually remain available for uptake by weeds. This is due to adsorption, by which the herbicide is bound on to the surfaces of organic matter and clay colloids. When adsorbed the herbicide is not in general freely available to plants, though there may be some exceptions to this. Hannah (1954) for example claims that CDEA and CDAA are adsorbed by soil constituents but still remain available to plants and that this is why these herbicides are active even in soils high in organic matter. In the more usual instances the adsorbed herbicide is unavailable to the plant, although the actual adsorption process is reversible. The extent of adsorption is dependent on the physicochemical properties of the herbicide and the amount and type of adsorbing sites present in the soil. Adsorption is responsible for much of the variability in performance of soil-acting herbicides between one soil and another, and in extreme cases, on soils very high in organic matter content, can lead to almost complete inactivation. In the most extreme case of all, the complete inactivation of diquat and paraquat in almost all soils, it is suggested that this results from fixation of these cationic compounds by base-exchange in the soil.

The importance of adsorption phenomena is now well appreciated as a result of many investigations on the influence of soil type on the toxicity of herbicides acting through the soil. For example the toxicity of diuron to cotton and Italian ryegrass in twelve diverse soils was investigated by Upchurch (1958). There was little variation in selectivity between the two species in this range of soils but a tenfold variation between soils in the dose required to produce the same degree of effect. There was a high inverse correlation between toxicity and organic matter content, cation exchange capacity and total exchangeable bases. Later, this work was extended to cover ten other herbicides namely chlorpropham, 2,4-D, 2,4-DES, CDEC, CDAA, EPTC, naptalam, simazine, dalapon and dinoseb (Upchurch and Mason, 1962). A wider range of soil properties was investigated and again organic matter content, cation exchange capacity, exchangeable calcium, total exchangeable bases, moisture equivalent and free drainage value were all highly and positively correlated with the dose required to produce a given level of effect. This applied generally to all the herbicides. These soil properties are all highly correlated among themselves but these workers concluded that the variation in response obtained could be attributed to adsorption on the organic matter. In general it required 5 times as much herbicide to produce the same effect in a soil with 20 per cent organic matter as it did in a soil with 4 per cent organic matter, whichever herbicide it was.

The tremendous ability of organic matter to adsorb herbicides is further shown by some data of Massini (1961) with 2,6-dichlorobenzonitrile. He found the ratio of concentration in the adsorbent to concentration in the liquid phase to be as great as 400 - 1000 for lignin as compared with 6 for a sandy soil and 180 for a potting soil.

Nevertheless other soil constituents cannot be ignored and, in particular, clay colloids may adsorb and inactivate herbicides as is shown for a series of substituted ureas by Coggins and Crafts (1959). They found that the least soluble ureas were inactivated most by the clay. In general there is a rough negative correlation between solubility of a herbicide in water and the extent to which it is adsorbed, though there are also differences according to chemical structure (Freed et al, 1962). In a list of eleven herbicides giving the fraction which is adsorbed these workers put dimethyl 2,3,5,6-tetrachloroterephthalate ('Dacthal') at one extreme with 0.9 adsorbed and amitrole at the other extreme with 0.1 adsorbed. Leopold et al (1960), measuring adsorption on to activated carbon, similarly found a strong inverse correlation between adsorption and solubility, with 98 per cent of the monuron and chlorpropham and 13 per cent of the TCA adsorbed at the respective extremes.

Clays lend themselves more to adsorption studies than does organic matter. The adsorption capabilities of various clay minerals have been studied by Frissel (1961) and Freed et al (1962). They agree in finding Kaolin to adsorb less than montmorillonite and illite. Illite adsorbed 77.5 ug/g whereas Kaolin only removed 30 ug/g. Frissel, as a result of his detailed studies, was able to draw up a table which gives the predicted percentage of herbicide which would be adsorbed and the predicted concentration in the soil solution for 10 herbicides in soils containing 3 clays and at 4 pH levels.

The foundation is thus being laid for the forecasting of the doses of soil-acting herbicides required to give a certain degree of response in particular soils. A pioneer attempt on these lines has been made for an endothal/propham mixture (Caldicott, 1962; Hunnam & Hey, 1962). If soils with a high organic matter content are avoided these workers are able to suggest a suitable selective dose on the basis of the percentages of clay and coarse sand in the soil. The necessary analysis of the soil is done by the commercial firm concerned prior to supplying the herbicide. This has worked successfully and seems likely to be the forerunner of many such schemes, doubtless differing in detail, whereby the agricultural chemical firms and the N.A.A.S. conduct soil analyses on a large scale in order to predict the dose of a soil-acting herbicide which should be applied in each field. This would parallel tomorrow the system whereby fertiliser requirements are forecast today.

MOVEMENT IN SOIL

Once the herbicide has been applied to the soil and possibly incorporated it must be remembered that the situation is not static but dynamic. Roots grow and exploit new layers of the soil and the herbicide moves by diffusion in the liquid and vapour phases and by leaching. In the first place such movement is closely connected with the adsorption phenomena already discussed. The more a herbicide is adsorbed the less likely it is to move. Thus Day et al (1961) comparing the leaching of amitrole in a wide variety of soils found it to be related to the adsorptive capacity of the soil. Many and varied studies of leaching behaviour have been made with a variety of herbicides, generally in columns in the laboratory and with much accelerated rates of water application. This can give a very different type of water movement to that which obtains in the field and the application of these results to agricultural conditions is open to doubt. In any case the prime factor governing the movement within the soil is the rainfall regime which is uncontrollable. The nature and intensity of this rainfall also influences the extent of leaching as has been shown for monuron by Upchurch & Pierce (1957). Thus our present knowledge of movement of herbicides only enables us to say why something happened and not to forecast its happening. However it is now possible to indicate those herbicides which are generally immobile, usually those of very low water solubility, such as neburon which are unlikely to reach deep-rooting crops. At the other extreme are the herbicides which are known to be easily leached such as TCA, amiben and 2,3,6-TBA and which may reach roots deep in the soil in toxic amounts.

PERSISTENCE IN SOIL

The final topic to consider is the length of time for which a soil-acting herbicide will remain capable of inhibiting the growth of plants. Disappearance may be due to a variety of causes - vapour loss upwards into the atmosphere, loss into the deeper soil layers by leaching, chemical reaction by oxidation or hydrolysis, and microbiological decomposition. Often it is difficult to separate out the relative importance of these factors. An example of this occurs with EPTC. In moist soil there is a very considerable disappearance of this herbicide which has been attributed to vapour loss assisted by co-distillation (Fang et al, 1961). In dry soil these workers found EPTC to be extremely persistent as also did Ashton & Sheets (1959). They suggest that this is due to the high ability of dry soil particles to adsorb EPTC and prevent vapour loss. On the other hand Sheets (1959) showed that autoclaving of the soil greatly retarded inactivation of EPTC thus indicating the importance of microbial breakdown. Dry soil conditions markedly reduce the activity of microorganisms and therefore this could also be responsible for an unknown proportion of the persistence in dry soil.

The dominant part played by microorganisms in disposing of herbicide residues in the soil has been demonstrated many times and with a wide range of herbicides. Their efficiency, though, varies tremendously according to soil conditions and the herbicide concerned so that in some instances the period of persistence is only a week or so and in others it is more than a year. Microorganisms can be very specific in the compounds they attack; this is true for example within the alkylphenoxy compounds where 4-CPA, MCPA, 2,4-D and 2,4-DB are readily disposed of whereas 2,4,5-T, 2,4,5-TB fenoprop and dichlorprop are much more resistant to microbial breakdown (Audus, 1960 ; Whiteside & Alexander, 1960).

Nevertheless in suitable environmental conditions almost any herbicide applied to the soil will be attacked by some representative of the soil microflora. As pointed out by Bollen (1962) the same morphological and physiological types of microorganisms occur in all soils, so that there should be few instances where the necessary organism is not present at all. However their activity varies greatly with many factors of the environment such as temperature, moisture, pH, aeration, amount of normal substrate such as organic matter, and so on. It is not surprising therefore that many workers report large variations in the persistence of a herbicide in different types of soil. A typical example is provided by the detailed work of Day et al (1961) and of Riepma (1962) on the breakdown of amitrole in soils. Day and his group found more than thirtyfold difference between soils in the rate of depletion under standard conditions. Riepma found evidence of an initial lag period before rapid disappearance occurs as has also been found for some other herbicides (e.g. phenoxyacetic acids by Audus, 1960; CDAA & CDEC by Gantz and Slife, 1960). This would be explicable in terms of the microorganisms having to become adjusted to the altered conditions consequent upon addition of the herbicide. On the other hand Burschel & Freed (1959) indicate that decomposition of some herbicides behaves as a first order reaction, probably because the microorganisms are in such abundance and other environmental factors so favourable that the rate-limiting component is the amount of herbicide present. It seems that different herbicides and different environments may give varying patterns of disappearance and it is not yet possible to forecast the detailed sequence of decomposition. However enough is now known to be able to say in a general way whether soil and other conditions during the season have been such as to favour or retard disappearance of a soil-acting herbicide applied earlier.

The immediate problem is whether the persistence of herbicides in soil can be controlled. To some extent it can. In the first place the users must be particularly careful where successive applications of the same herbicide are made, as in a perennial crop. As Sheets (1962) points out, if 80 per cent of an annual application of 2 lb/ac is inactivated each year and this application is repeated indefinitely, the amount still present in the soil when the time for the next application arrived would eventually approach 0.5 lb/ac. If the annual decomposition rate is 50 per cent the amount in the soil just before the annual application would eventually approach the amount added each year.

Sometimes soil environmental conditions can be altered to favour disappearance. Thus if the soil is dry, heavy irrigation can be helpful as has been shown by Weldon & Timmons (1961b) with diuron. It is conceivable that cultivations to facilitate aeration may also be useful and in addition cultivations may be used to dilute the herbicide through a considerable bulk of soil. This could form the basis of methods to enable replanting of a field after failure of a crop which has been treated with a soil-acting herbicide. Such a system has been worked out by Holstun & McWhorter (1962) for cotton treated with diuron.

A completely different way of controlling persistence is by changing the formulation of the herbicide, as shown by some detailed work of Danielson et al (1961). They found that with EPTC there was a considerable effect of carrier, with a kerosene formulation disappearing quickest, and of surface-active agent, with non-ionic and cationic, but not anionic, compounds increasing persistence. They found the total period of persistence of EPTC to be a complex function of its dose, solvent, specific surface-active agent, and the concentration of the latter.

Finally, Castelfranco & Deutsch (1962) have recently demonstrated that the addition of polysulphide ions to the soil accelerates the break-down of simazine in the soil, perhaps by catalysing hydrolysis of the herbicide. This opens up the possibility of using chemicals for the removal of unwanted herbicide residues in soils.

In conclusion, it would appear that substantial progress has been made in recent years in our understanding of the behaviour of herbicides in soils. Work in this field is being intensified in many countries and in addition to the agronomist who is directly concerned, the physical chemist, the soil scientist and the microbiologist are beginning to realise that there are many problems of interest to them in connection with herbicides acting through the soil.

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Research Summary

THE FATE OF THE HERBICIDE N-4(P-CHLOROPHENOXY)-PHENYL-N'N',-DIMETHYLUREA* IN SOILS AND PLANTS

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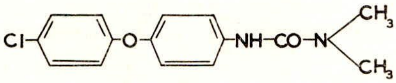
INTRODUCTION

N-4(p-chlorophenoxy)-phenyl-N'-,N'-dimethylurea (CIBA 1983) is a new selective herbicide which has been described previously at the EWRC Conference 1961 in Paris.



CIBA 1983 is formulated as a wettable powder containing 50 per cent of active ingredient. Depending on type of soil, the rate of application varies from 6 to 9 kg of the formulated product per hectare. It is recommended for use in strawberries, peas, carrots, celery, leek, fennel, currants, raspberries, gladioli, and fresias. Other possible uses are indicated in scorzonera, planted onions, iris, crocus, hyacinths, violets, and chrysanthemum before transplanting. Due to the level of tolerance towards CIBA 1983 of the first group of plants mentioned above, time of application depends mainly on the most susceptible stage of development of existing weeds. Experimental evidence indicates that this moment is reached at the appearance and unfolding of the cotyledons. Depending on weather conditions, season and preparation of the soil, this may be the case within 1 to 3 weeks after seeding, transplanting and/or preparation of the soil.

Except for the previously mentioned umbelliferous crops, for which CIBA 1983 exhibits a distinct selectivity, the use in several other crops is probably based upon the physical-chemical properties of the compound and upon a relative tolerance. To this group belong some varieties of strawberries which might exhibit chlorotic symptoms after application. Replicated yield trials were carried out in several climatically different zones and in one case on plants in poor conditions. However, no significant differences were found between treated and hand weeded plots. Our experience from these yield trials as well as the existence of weeds resistant to CIBA 1983 led us to an investigation of some problems connected with the fate of this compound in the soil and in plants.

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* This herbicide has the trade name "TENORAN".

RESULTS

Leaching of CIBA 1983

Leaching of CIBA 1983 as compared to N-(2,4-dichlorophenyl)-N'-butyl-N'-methylurea was studied in three different soils (sandy loam, clay loam and humus soil) and at two different soil-moisture levels (wilting capacity, field capacity). When 200 mm of simulated rainfall during a 45 hour period was applied, the bulk of CIBA 1983 remained in the top 1 cm layer of all three soils and at both moisture levels. Leaching was somewhat more pronounced in sandy loam. Only traces of CIBA 1983 were recovered from depths below 10 cm and in water percolating from soil columns.

The reference compound leached more easily, especially in sandy loam in which a great proportion (at wilting capacity) had moved below the top 5 cm layer. Leaching of both herbicides was more pronounced at the low than at the high moisture level.

It is suggested that leaching is no major factor in the removal of CIBA 1983 from soil layers. However, it appears that its very strong adsorption on soil particles might be a limiting factor in its availability in soils, and thus in its residual activity.

Uptake and Translocation of CIBA 1983-C^{14}

CIBA 1983-C^{14} was rapidly taken up from nutrient solution by the roots, and translocated into stems and leaves of the sensitive Galinsoga parviflora and the resistant Polygonum convolvulus plant. Uptake by the roots was much more pronounced in the former, whereas translocation into stems and leaves was more efficient in the latter. In both species there was a differential translocation into leaves in different positions on the main axis.

Translocation of CIBA 1983-C^{14} into stems and leaves of both species was depressed by increased external humidity, lowered temperature or change from light to complete darkness.

Only traces of radioactivity were translocated to neighbouring (lower, upper and opposite) leaves after application of CIBA 1983-C^{14} to leaf-sections (basal and apical) or to whole leaf surfaces (upper and lower). Some CIBA 1983 was translocated into the apical part of leaves treated at their base.

Acetone (and methylene chloride) extracts of dried powders of plants exposed to CIBA 1983-C^{14} for 48 hours contained approx. 80 per cent (60 per cent) of the total radioactivity (combustion) of the dried root;, stem- and leaf-tissues. In roots and stems the radioactivity extracted by acetone was demonstrated to represent unchanged herbicide only. With leaf extracts, results were less definite, but it appears that extracts from P. convolvulus leaves contained only unchanged CIBA 1983.

The results on uptake and translocation of CIBA 1983-C^{14} were compared with those on other herbicides, especially on 2-chloro-4,6-bis(ethylamino)-1,3,5-triazine.

Research Report

EXPERIMENTS WITH AMIBEN FOR WEED CONTROL IN VEGETABLE CROPS

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Summary: Field experiments were carried out with 3-amino-2,5-dichlorobenzoic acid (amiben) during 1959-61 to determine the value of this herbicide as a pre-emergence treatment for weed control in vegetable crops. The results indicated that on a light soil appreciable downward movement could occur under the influence of rainfall, and of twelve crops examined, only carrot, parsnip and parsley showed an adequate degree of inherent tolerance; the remainder were sometimes injured by doses necessary for weed control. Most annual weeds except *Fumaria officinalis* proved susceptible to doses of 2-4 lb/ac, but there was considerable variation in the degree of control obtained on different occasions. Experiments in which granular amiben was applied after transplanting brassica crops suggested that this method would not be sufficiently safe on light land.

INTRODUCTION

The selective herbicidal properties of 3-nitro-2,5-dichlorobenzoic acid ("Dinoben") were discovered by Amchem Products, Inc. in 1956, and at a later date, 3-amino-2,5-dichlorobenzoic acid (amiben) was found to have similar properties. Field testing in the U.S.A. in 1958 (Sutherland & McLane, 1958; Tafuro, 1959) showed amiben to be a promising pre-emergence treatment for soybeans and also revealed possibilities in the use of granular formulations for weed control in transplanted crops.

In order to determine the potentialities of these materials under British conditions, preliminary tests were conducted in 1959 and were continued in the following two years. The results are summarised in the present report.

METHODS AND MATERIALS

The experiments were all at Wellesbourne, on a sandy loam of the Newport series which was relatively low in organic matter. Except for two preliminary tests which were not replicated, the experiments were of randomised block design with three or four replicates and a plot size of 6 - 12 sq yd. The spray treatments (as triethylamine salt) were applied at 100 gal/ac; the granules (10 per cent acid wt/wt) were diluted with sand and broadcast by hand. Rates are given as lb/ac ae, and except where stated, the treatments were applied immediately after drilling. Weed kill was assessed by counting survivors in a number of random quadrats on each plot, and all plots were then weeded by hand so that effects on crop yield could be determined without complication from weed competition.

RESULTS

Two preliminary tests were conducted in 1959 in which amiben was applied at 1,2,4 and 8 lb/ac to single rows of twelve crops drilled at the normal depths. The first was begun during a dry period and received approximately 0.5 in. irrigation 10, 20 and 25 days after spraying. The second received 0.15 in. rain after spraying, but dry weather followed and 0.5 in. irrigation was given 10 days after spraying. From the records of stand, growth and fresh weight which were taken, the effect of treatment on the crops has been summarised by assigning a rating on a 0 - 10 scale, and the results are shown in Table I. It is evident that radish, cabbage, spinach, beet and onion were the most susceptible. Carrot, parsley and parsnip, however, appeared to show an appreciable degree of tolerance, while lettuce and the large-seeded legumes were also comparatively tolerant. Further experiments were therefore carried out with these crops.

Carrot, parsnip and parsley

An experiment begun late in the 1959 season showed that at rates up to 4 lb/ac amiben was without effect on stand or yield of these three crops. Amiben was subsequently included in several experiments with carrots and the results from two of these are shown in Table II. In 1960, there was some stunting of growth with 4 and 6 lb/ac but effects on final yield were slight while in 1961 there was no adverse effect from 4 lb/ac. In experiments with parsnip (Table III), amiben at 6 lb/ac caused slight retardation of growth in 1960 but in neither year was there any adverse effect on the yield of the thinned crops. Similar results were also obtained with parsley.

TABLE I. COMPARATIVE RESPONSE OF VEGETABLE CROPS TO PRE-EMERGENCE APPLICATION OF AMIBEN

Injury rating (1-3 = delay in emergence ; 4-6 = reduction in fresh wt. ; 7-10 = partial to complete kill)	First test				Second test			
amiben, lb/ac	1	2	4	8	1	2	4	8
Radish	7	9	10	10	0	1	7	8
Cabbage	10	9	10	10	0	9	10	10
Lettuce	0	3	7	7	0	1	6	6
Spinach	8	9	10	10	0	1	9	10
Beet (globe)	8	9	10	10	1	1	10	10
Onion	4	9	10	10	0	0	9	10
Carrot	0	0	4	7	0	0	0	6
Parsley	0	0	0	0	0	0	0	0
Parsnip	0	0	0	2	0	0	0	3
Pea	0	0	5	7	0	0	4	4
Broad bean	0	2	5	7	0	0	2	3
Dwarf French bean	0	0	3	7	0	0	1	2

TABLE II. EFFECT OF PRE-EMERGENCE TREATMENT WITH AMIBEN ON THE YIELD OF CARROTS

	1960		1961	
	weeds per cent kill	roots kg/plot	weeds per cent kill	roots kg/plot
amiben 2 lb/ac	52	32.6	40	20.5
" 4 "	84	27.3	66	24.8
" 6 "	89	29.4	-	-
Control, weeded	-	31.3	-	21.0
S.E. diff. between one treatment and control	(16 df)	± 1.36	(43 df)	±1.60

TABLE III. EFFECT OF PRE-EMERGENCE TREATMENT WITH AMIBEN ON THE YIELD OF PARSNIPS

	1960			1961		
	weeds per cent kill	roots no./plot	roots kg/plot	weeds per cent kill	roots no./plot	roots kg/plot
amiben 2 lb/ac	85	78	34.9	42	91	31.8
" 4 "	96	75	35.9	70	100	32.4
" 6 "	98	78	35.8	-	-	-
Control, weeded	-	80	37.1	-	94	31.8
S.E. diff. between one treatment and control	(61 df)	±3.2	±1.84	(44 df)	±5.0	± 1.22

Pea

Amiben was included in three trials with peas, and the results from two of them are presented in Table IV. Although in 1960 there was only light rainfall during the early stages of the experiment and no irrigation was given until three weeks after spraying, plants in all treated plots were stunted and the foliage had a glaucous appearance. Marketable yield was reduced by amiben at 6 lb/ac and both 4 and 6 lb/ac significantly reduced haulm weight. In 1961, when there was higher rainfall after spraying, plants in the plots treated with amiben were markedly retarded, and all amiben treatments significantly reduced pod and haulm weights

TABLE IV. EFFECT OF PRE-EMERGENCE TREATMENT WITH AMIBEN ON THE YIELD OF PEAS

	1960			1961		
	weeds per cent kill	mktble pods kg/plot	haulm kg/plot	weeds per cent kill	mktble pods kg/plot	haulm kg/plot
amiben 2 lb/ac	43	5.5	5.0	80	4.2	4.1
" 4 "	50	5.2	4.5	84	3.5	3.2
" 6 "	60	4.7	3.9	95	2.1	1.7
Control, weeded	-	5.4	5.4	-	5.4	5.8
S.E. diff. between one treatment and control	(45 df)	± 0.23	± 0.33	(35 df)	± 0.41	± 0.53

Lettuce

Amiben at 2,4 and 6 lb/ac was applied as a pre-emergence spray to drilled summer cabbage lettuce in 1960, and the results are shown in Table V.

TABLE V. EFFECT OF PRE-EMERGENCE TREATMENT WITH AMIBEN ON DRILLED SUMMER CABBAGE LETTUCE, 1960

	Weeds, per cent kill				Plants/ ft before thinning	Mktble heads/plot		Days delay in 50 per cent cut
	Fumaria offic	Chenop. album	Urtica urens	others		no.	kg	
amiben 2 lb/ac	0	84	77	67	11.3	38	10.9	1.4
" 4 "	19	95	80	87	11.0	28	7.3	4.6
" 6 "	51	99	93	93	7.6	20	5.2	8.5
Control, weeded	-	-	-	-	14.3	40	11.6	0.0
S.E.diff.between one treatment and control	(22 df)				-	± 2.1	± 0.86	-

Amiben caused revere retardation of early growth and also reduced plant stand, though not to such an extent that the desired population could not be obtained at thinning. The crop recovered to a considerable extent, but except at 2 lb/ac, the number and weight of marketable heads was significantly reduced, and all rates caused delay in maturity. In a second experiment in 1960, both liquid and granular formulations of amiben were applied to transplanted summer cabbage lettuce a week after planting. The results are shown in Table VI.

TABLE VI. EFFECTS OF LIQUID AND GRANULAR AMIBEN ON TRANSPLANTED SUMMER CABBAGE LETTUCE

		Weeds per cent kill	Mktble heads/plot no.	kg	Days delay in 50 per cent cut
amiben liquid, 2 lb/ac		68	26	6.6	2.6
" " 4 "		93	23	6.1	4.9
" granular 2 lb/ac		95	26	6.8	4.3
" " 4 "		99	21	5.5	5.3
Control, weeded		-	26	6.6	0.0
S.E. diff. between one treatment and control	(34 df)	-	$\pm$ 2.5	$\pm$ 0.59	-

None of the treatments caused significant reductions in number and weight of marketable heads, but all delayed crop maturity, especially the granular treatments.

In 1961, liquid and granular formulations of amiben and 3-nitro-2,5-dichlorobenzoic acid* were compared as pre-emergence treatments for drilled summer cabbage lettuce, and the sults are summarised in Table VII.

TABLE VII. EFFECT OF PRE-EMERGENCE TREATMENT WITH AMIBEN AND DINOBEN ON DRILLED SUMMER CABBAGE LETTUCE, 1961

		Weeds per cent kill	Mktble heads/plot no.	kg	Days delay in 50 per cent cut
amiben liquid, 2 lb/ac		64	32	8.2	2.2
" granular 2 "		49	21	8.1	1.8
3-nitro-) liquid	2 lb/ac	56	34	9.1	2.2
2,5-dichloro-) granular	2 lb/ac	51	37	9.6	1.0
benzoic acid)					
Control, weeded		-	37	9.6	0.0
S.E. diff. between one treatment and control	(22 df)		$\pm$ 2.5	$\pm$0.69	-

Initial injury to the crop was severe with all treatments, and there was some reduction in stand. Later on, however, there was almost complete recovery and the final yields were only slightly affected, although there was some delay in maturity

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* "Dinoben"

Transplanted brassicas

The possible use of granular amiben as a post-planting treatment for brassica crops was investigated in several experiments, and the results from three of them are shown in Table VIII.

TABLE VIII. RESPONSE OF BRASSICA CROPS TO POST-PLANTING APPLICATIONS OF GRANULAR AMIBEN

	Marketable heads per plot					
	Summer cabbage 1960		Summer cabbage 1961		Summer cauliflower 1961	
	no.	kg	no.	kg	no.	kg
amiben 1 lb/ac	26	35.2	28	23.8	26	33.1
" 2 "	21	31.0	24	20.1	26	31.1
" 4 "	12	16.1	16	12.0	27	28.0
Control, weeded	28	36.4	28	22.3	27	36.8
S.E. diff. between one treatment and control	± 1.0 (6 df)	± 2.65	± 4.8 (9 df)	± 4.08	± 0.9 (9 df)	± 1.96

In each experiment amiben caused some check to crop growth and there was a trend towards reduction of marketable yield with increasing dose rate, with delay in maturity. At 4 lb/ac, amiben gave significant yield reductions in all three experiments.

Effect on weeds

In the experiments, mixed weed populations were present in which *Poa annua*, *Fumaria officinalis*, *Polygonum aviculare*, *Chenopodium album*, *Thlaspi arvense*, *Capsella bursa-pastoris*, *Urtica urens* and *Veronica persica* were usually the principal species. Altogether, amiben at one or more doses was included in 27 experiments with various crops, and the relationship between dose and weed kill is shown in Fig. 1.

It is evident from Fig. 1 and from Tables II - VII that there was appreciable variation in the weed kill produced by a single dose on different occasions. This was apparently due mainly to differences in weather following application, but there were also some differences in response of weed species. All the species mentioned above were susceptible to amiben under favourable conditions with the exception of *Fumaria officinalis*. Even when excellent control of other species was obtained, control of *F. officinalis* was poor (Table V). Inspection of Fig. 1 suggests that on the whole the granular formulation gave better weed control than the liquid; where the two were directly compared, however, there were no consistent differences in weed kill (Table VI, VII).

DISCUSSION

The tests conducted in 1959 (Table I) showed that radish, cabbage, spinach, beet and onion were susceptible to pre-emergence applications of amiben, and these results are in agreement with those previously reported (Amchem Products, Inc., 1960). Comparison of the results of the two 1959 tests shows that there was striking variation in the degree of damage caused to the susceptible crops by the lower doses. This variation did not occur with various triazines under the same conditions (Roberts & Wilson, 1960) and it is supposed that some relatively slight difference in the conditions of the two tests markedly affected the degree to which amiben penetrated the soil.

The most tolerant of the crops examined were carrot, parsnip and parsley, and subsequent experiments (Table II, III) confirmed this result. Verlaat (1961) has also concluded that amiben shows promise for use in umbelliferous crops. In both 1959 tests, pea, broad bean and dwarf French bean were injured to some extent by amiben at 4 lb/ac. Later experiments with peas (Table IV) showed that even 2 lb/ac could cause stunting, and in 1961 the yield was significantly reduced by this dose. Reynolds & Armsby (1960) also reported delayed emergence and stunting with 4 lb/ac, and it would seem that on light soils there is insufficient selectivity for amiben to be useful in this crop. Amiben was included in four experiments with broad beans of which the results have already been reported (Roberts & Wilson, 1961). In 1960, when there was little rainfall after application, 6 lb/ac caused only slight stunting, but in 1961, even doses of 2 - 3 lb/ac resulted in delayed emergence, severe stunting and reduction in yield. These results suggest that on light soil amiben can readily move downwards under the influence of rain, and that the factor of 'depth protection' cannot be relied upon to protect the crop from damage. Only limited tests have been carried out with French and runner beans, but in one of these amiben at 2 lb/ac caused slight stunting and at 4 lb/ac the yield was reduced.

The comparative tolerance of lettuce observed in 1959 was borne out in later experiments. When applied to drilled lettuce, the initial effects of both amiben and 3-nitro-2,5-dichlorobenzoic were severe, but the crop recovered to a considerable extent. In 1960, however, with 4 lb/ac marketable yield was reduced and even with 2 lb/ac there was some delay in maturity. Similar delay in maturity was observed in transplanted lettuce in 1960 and in drilled lettuce with both compounds in 1961. It thus seems doubtful whether the degree of selectivity would be sufficient to permit either material to be used safely on lettuce.

The experiments in which granular amiben was applied after transplanting brassica crops gave variable results, apparently related to the amount of rainfall following application. In most experiments 4 lb/ac resulted in significant yield reductions and delay in maturity (Table VIII) while in some instances lower rates also reduced marketable yield. It therefore seems that on light soils granular amiben could not be safely employed for weed control in transplanted brassicas.

With the exception of <u>Fumaria officinalis</u> (Table V), most of the weed species encountered were susceptible to amiben, and on some occasions excellent results were obtained with 2 lb/ac. It is evident from Fig. I., however, that there was considerable variation in effectiveness. Some of the poor results could be attributed to dry conditions following application, but there was also evidence that heavy rainfall shortly after application could result in poor control (Roberts & Wilson, 1961).

The results as a whole indicate that, of the crops examined, only carrot, parsnip and parsley exhibited a sufficiently high degree of inherent tolerance to permit amiben to be used safely on light soils, and that in these crops the variation in degree of weed control might prove to be the limiting factor.

Acknowledgment

We are grateful to Amchem Products, Inc. for providing the herbicides used in this work.

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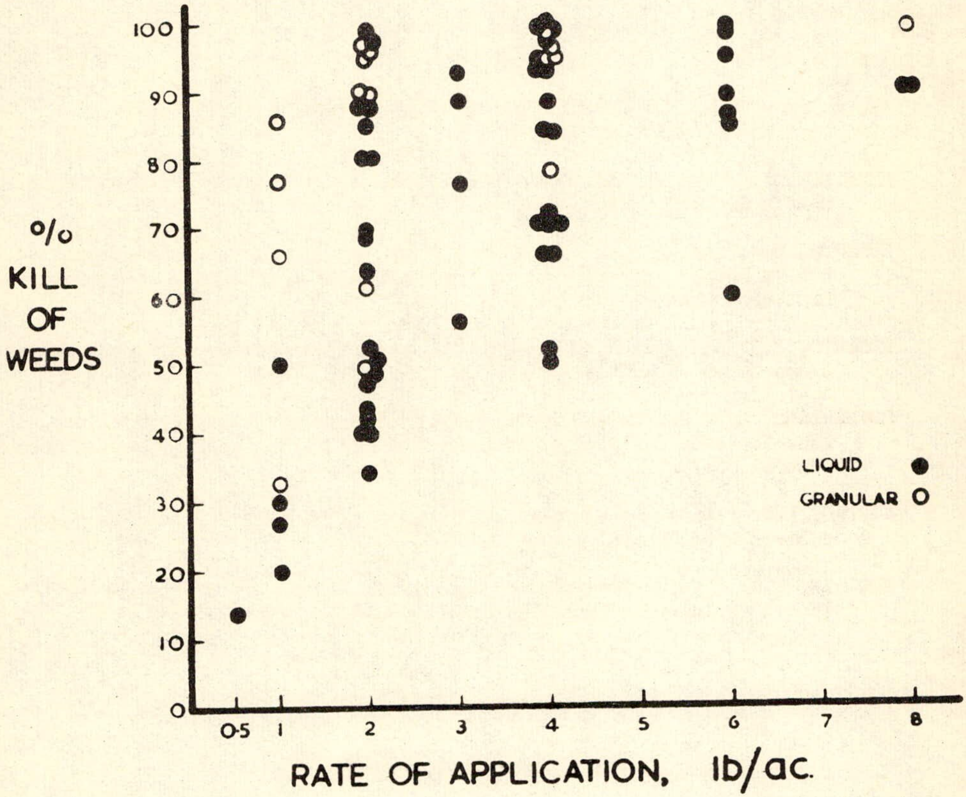
FIGURE 1. EXPERIMENTS WITH AMIDEN



Research Report

EXPERIMENTS ON THE CONTROL OF BROAD-LEAVED WEEDS IN PEAS - A PROGRESS REPORT 1961-62

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Summary: The following paper contains the results of eight trials with herbicides in peas, carried out by the P.G.R.O. in 1961 and 1962, on a wide range of soil types. During this period fourteen herbicides were examined.

None of the residual pre-emergence herbicides so far tested has been found to be satisfactory for general use on all soil types. Neburon has consistently given excellent weed control on light soils without causing crop damage. Amiben, although unpredictable on mineral soils, performed satisfactorily where the organic content was high. The chlorpropham mixtures containing diuron or fenuron have been used with reasonable safety on a limited range of mineral soils. However, control effected by these materials was not usually as good as that obtained by the post-emergence treatment of dinoseb-amine which in both years performed exceedingly well.

INTRODUCTION

The development in recent years of residual herbicides for use in peas suggests an attractive means of controlling weeds in this crop. Generally pea and weeds germinate and emerge at the same time and this limits the use of contact herbicides applied before crop emergence. Post-emergence applications of contact herbicides whilst giving satisfactory control can cause crop losses due to damage from tractor wheels, and can in some cases check the crop particularly the more tender varieties. Materials which can be either worked into the seedbed or sprayed after sowing, but before crop emergence, are therefore an extremely useful addition to the range of herbicides available for use in peas.

The P.G.R.O. commenced work on residual herbicides in 1958 with small indicator trials testing a limited number of chemicals (Anon, 1958). This early work demonstrated that the number of occasions, when a pre-sowing contact herbicide could be applied to weeds which had germinated before the crop was very few. During the 1959 and 1960 seasons twenty three pre-sowing and pre-emergence chemicals were tested on a range of soil types against both broad-leaved weeds and wild oats. (Reynolds and Armsby 1960). As a result of this work it was possible to separate the chemicals as those being more suitable against (a) broad-leaved weeds and (b) Avena spp (wild oats). Thus in 1961 and 1962 the two subjects were treated separately.

This paper will deal exclusively with results of trials carried out in 1961 and 1962 for the control of broad-leaved weeds in peas. The results of trials with wild oat herbicides are reported elsewhere at this conference (Armsby and Gane 1962).

METHODS AND MATERIALS

In both years applications were made with an Oxford Precision Sprayer using Allman '0' jets and the treatments were applied in water at the rate of 50 gal/ac. Plot size was 1/200th acre and at all sites in 1961 a randomised block layout with two-fold replication (including untreated control plots) was employed, while in 1962 four or five replications were used.

1961

The pre-emergence materials were applied approximately one week after the peas had been drilled. This interval could not in all cases be rigidly adhered to due to weather conditions. The early post-emergence applications, were made as soon as sufficient weeds were showing and before the peas became too large. It was only possible to apply the early post-emergence chemicals on the peas in the unfolded leaf stage at one site. The post-emergence applications of dinoseb-amine were made at a stage when it was considered that optimum conditions of weed growth and crop development had been reached at each site.

Treatments were assessed visually for weed control and effect on crop vigour.

1962

Weed control work in 1962 was divided into two sections:-

(a) Screening Trials, where the herbicides used in 1961 and certain new materials were applied by logarithmic sprayer (not reported here).

(b) Main Trials, replicated for yield purposes, and containing linuron, a promising new material, together with herbicides selected from the 1961 trials.

All treatments were applied pre-emergence except dinoseb-amine which was applied post-emergence.

In 1961 pre-emergence applications were generally made one week after the peas were drilled, but as the chitting of the peas was found to be a more reliable guide to the commencement of weed growth, the applications in 1962 were made when the peas were chitted but before the plumule had appeared. The post-emergence application of dinoseb-amine was again made when the conditions of weed growth and crop were considered to be satisfactory.

Visual assessments were made for weed control and crop vigour in 1962 and the trials were taken to the yield stage. At one site the weed pattern made it possible for detailed weed counts to be recorded and in addition pea counts were made at two sites.

Chemicals used in the two seasons were as follows:-

(PR = pre-emergence; PO = normal post-emergence; EPO = early post-emergence.

Herbicide	Formulation	1961	1962
neburon	50 per cent wettable powder	PR	PR
chlorpropham plus fenuron	20 " wt/vol) combined emulsifiable 5 " ") concentrate	PR	PR
chlorpropham plus diuron	20 " ") combined emulsifiable 4 " ") concentrate	PR	-
chlorpropham plus diuron	20 " ") combined emulsifiable 8 " ") concentrate	-	PR
chlorpropham	40 " " emulsifiable concentrate	PR/	PR
simazine	50 " wettable powder	PR/	-
BiPC plus OMU	11.5 per wt/vol) combined emulsifiable 16.5 " ") concentrate	PR	-
prometryne	50 per wettable powder	PR	-
N-3-methylphenyl-N'-dimethylthiourea (1)	50 per cent wettable powder 20 " wt/vol suspension	PR(site B) PR(sites C,D)	- -
linuron	50 per cent wettable powder	-	PR
amiben	24 " wt/vol as triethylamine salt	PR & EPO*	PR
dinoseb (amine)	18.5 per wt/vol as alkanolamine salt	PO & EPO*	PO
3-nitro-2,5-dichloro benzoic acid (2)	24 per wt/vol as triethylamine salt	EPO	-

(1) = "Thiuron" (2) = "Dinoben" / also in a mixture together

* in mixture together

Weed species present at the sites - 1961 and 1962

Name of weed	Site 1961 A	B	C	D	Site 1962 E	F	G	H
Urtica urens (Annual nettle)						X		
Polygonum convolvulus (Black bindweed)	X	X	X	X	X	X		
Brassica nigra (Black mustard)					X			
Sinapis arvensis (Charlock)	X	X	X					X
Stellaria media (Chickweed)	X	X		X	X	X	X	X
Galium aparine (Cleavers)				X	X			
Galeopsis tetrahit (Common hempnettle)	X			X				
Tussilago farfara (Coltsfoot)			X					
Mentha arvensis (Corn mint)				X				
Agropyron repens (Couch grass)								X
Cirsium arvense (Creeping thistle)			X					
Chenopodium album (Fat hen)	X	X	X	X	X	X	X	X
Fumaria officinalis (Fumitory)					X			
Senecio vulgaris (Groundsel)			X			X	X	X
Polygonum aviculare (Knotgrass)	X	X					X	X
Convolvulus arvensis (Field bindweed)								X
Sonchus arvensis (Perennial sowthistle)			X	X				
Polygonum persicaria (Redshank)	X							
Tripleurospermum maritimum ssp. inodorum (Scentless mayweed)	X	X				X		
Capsella bursa-pastoris (Shepherd's purse)		X					X	
Sonchus oleraceus (Annual sowthistle)							X	X
Veronica sp. (Speedwell)	X	X	X			X		X
Euphorbia helioscopia (Sun spurge)					X			
Melandrium album (White campion)		X						
Avena fatua (Wild oat)	X							X

TABLE I - 1961 SITE DETAILS

Site	A Stonea Isle of Ely	B Nordelph Norfolk	C Hemington Hunts.	D Crowland Lincs.
Soil type*	Peaty clay loam	Very fine sandy loam	Clay loam	Peaty loam
pH.	6.4	8.4	7.8	6.6
Organic matter (per cent)	17.5	2.4	2.8	20.3
Pea variety	Rondo	Big Ben	Big Ben	Harrison's Glory
Date: drilled	16 March	6 March	17 April	12 April
pre-emergence spraying	24 March	16 March/	25 April	20 April
seed-bed conditions	dry cloddy	dry cloddy	dry cloddy	level dry
pea emergence	8 April	20 March	6 May	27 April
early post-emergence spraying	22 April	7 April	15 May	5 May
later post-emergence spraying	15 May	5 May	2 June	19 May
Rain:- (in.) 14 days before,	0.08	0.08	0.87	Nil
14 days after, pre-emergence spraying	1.23	0.33	0.37	1.06

/ Prometryne was applied on 20 March.

TABLE II - 1962 SITE DETAILS

Site	E Nordelph Norfolk	F Horncastle Lincs.	G Sprowston Norfolk	H Yaxley Hunts.
Soil type*	Silty loam	Sandy clay loam	Sandy loam	Clay loam
pH.	8.4	8.4	7.7	7.7
Organic matter (per cent)	7.4	3.2	3.1	3.0
Pea variety	Big Ben	Kelv. Wonder	Diadem	Big Ben
Date: drilled	24 February	15 March	19 April	24 April
pre-emergence spraying	17 March	28 March	26 April	30 May
seed-bed conditions	dry level	moist level	dry level	dry level
pea emergence	9 April	9 April	6 May	8 May
post-emergence spraying	10 May	8 May	23 May	7 June
harvested	1st August (dry)	18th July (green)	31st July (green)	10th August (dry)
Rain:- (in.)				
14 days before,	0.25	0.21	0.65	Nil
14 days after, pre-emergence spraying	0.72	1.11	0.24	0.14

* Percentages of clay, silt and sand are within the ranges given by N.A.A.S. tables for soil texture.

RESULTS

1961

TABLE III - SCORINGS SHOWING WEED CONTROL AND VIGOUR OF PEAS
(mean of two replicates)

Scorings: Peas 0 = complete kill: 2.5 = very severe damage: 5 = severe damage: 7.5 = appreciable damage: 10 = no apparent damage.
Weeds 0 = no control: 2.5 = slight control: 5 = moderate control: 7.5 = very good control: 10 = almost complete control.
Type of damage c = chlorosis: s = scorch: d = stunting.

Site Date of assessment (NB see footnote) Material	lb a.i acre	A 30 May peas	 weeds	B 5 June peas	 weeds	C 16 June peas	 weeds	D 5 June peas	 weeds
neburon	2.0 4.0	10.0 10.0	1.5 3.5	10.0 10.0	9.5 9.0	10.0 10.0	4.5 3.0	10.0 10.0	3.5 5.5
chlorpropham plus diuron	1.0) +0.25)	10.0	5.0	10.0	9.0	10.0	4.5	10.0	6.0
	2.0) +0.5)	10.0	6.0	10.0	9.0	10.0	4.5	10.0	7.0
chlorpropham	1.0) +0.2)	10.0	2.5	10.0	8.5	10.0	3.5	10.0	6.0
	2.0) +0.4)	10.0	5.5	10.0	9.0	10.0	5.0	10.0	6.0
chlorpropham	2.0 4.0	10.0 10.0	3.0 6.5	10.0 10.0	8.5 9.5	10.0 10.0	4.5 5.0	10.0 10.0	7.0 5.5
chlorpropham plus simazine	1.0) +0.25)	10.0	4.5	10.0	9.0	10.0	4.0	10.0	6.0
	2.0) +0.5)	10.0	6.0	10.0	10.0	10.0	5.0	10.0	6.5
BIPC plus OMU	0.6) +0.9)	10.0	2.0	10.0	9.0	10.0	5.0	10.0	3.5
	1.2) +1.8)	10.0	3.5	8.5sd	9.5	10.0	4.0	10.0	5.5
simazine	1.0 2.0	10.0 10.0	3.5 6.0	10.0 9.0	9.0 9.0	10.0 10.0	5.0 4.0	10.0 10.0	5.0 4.5

TABLE III - (cont'd)

Site Date of assessment (NB see footnote) Material	lb a.i acre	A 30 May peas	weeds	B 5 June peas	weeds	C 16 June peas	weeds	D 5 June peas	weeds
prometryne	0.75 1.5	10.0 10.0	2.5 2.0	10.0 10.0	6.0 8.5	10.0 10.0	3.5 3.5	10.0 10.0	4.5 6.0
amiben	2.0 4.0	10.0 10.0	6.5 9.0	9.0d 8.0sd	8.5 9.0	10.0 9.8c	2.5 6.5	10.0 10.0	6.0 8.0
N-3-methylphenyl-N'-dimethylthio-urea (wettable powder)	3.0 6.0	n.u.		10.0 8.5	5.0 8.0	n.u.		n.u.	
N-3-methylphenyl-N'-dimethylthio-urea (suspension)	3.0 6.0	n.u.		n.u.		10.0 10.0	2.5 4.5	10.0 10.0	4.5 3.0
dinoseb-amine plus	1.0) +1.0)	10.0	9.0	10.0	7.5	10.0	7.5	10.0	8.0
3-nitro-2,5 dichloro benzoic acid	2.0)) +2.0)	10.0	9.0	10.0	9.5	9.8d	7.0	8.5sd	7.5
3-nitro-2, 5-dichloro benzoic acid	2.0 4.0	10.0 10.0	2.0 5.0	10.0 10.0	6.5 8.0	10.0 10.0	3.5 5.5	10.0 10.0	1.5 2.5
dinoseb-amine	2.5	10.0	8.8	10.0	7.5	9.5sd	8.0	10.0	9.0

NB. A series of assessments were made at each site but due to lack of space only the final assessment is shown.

<u>1962</u>

TABLE IV - SCORINGS SHOWING WEED CONTROL AND VIGOUR OF PEAS
(mean of four replicates except site H - five replicates)

Scorings: Peas 0 = complete kill: 2.5 = very severe damage: 5 = severe damage: 7.5 = appreciable damage: 10 = no apparent damage.
Weeds 0 = no control: 2.5 = slight control: 5 = moderate control: 7.5 = very good control: 10 = almost complete control.
Type of damage c = chlorosis: d = stunting: n.u. = not used.

Date of assessment (NB see footnote)		E 16 June		F 25 May		G 21 June		H 29 June	
Material	lb a.i acre	peas	weeds	peas	weeds	peas	weeds	peas	weeds
amiben	3.0	9.0d	9.0	n.u.	n.u.	n.u.	n.u.	n.u.	n.u.
chlorpropham plus diuron	1.0 +0.4	10.0	5.5	10.0	6.5	10.0	8.0	10.0	7.0
chlorpropham plus fenuron	1.0 +0.25	1o.0	6.0	9.5c	8.0	10.0	8.5	10.0	8.0
chlorpropham	2.0	9.5	8.0	10.0	6.0	9.5	7.5	10.0	6.5
linuron	1.0	-	-	10.0	9.0	7.5c	10.0	-	-
	1.5	9.8	9.0	-	-	-	-	10.0	8.5
neburon	4.0	n.u.	n.u.	10.0	8.5	10.0	9.5	n.u.	n.u.
dinoseb-amine	1.85	-	-	-	-	-	-	10.0	8.5
	2.25	10.0	9.5	10.0	5.0	10.0	9.5	-	-

N.B. A series of assessments were made at each site but due to lack of space only the final assessment is shown.

TABLE V - DETAILED WEED COUNTS AT SITE E. (10 MAY 1962)

(Figures are the total weeds from an area of 4 sq yd)

Treatment		Weed Species							
Material	lb a.i acre	Black mustard	Cleavers	Fat Hen	Fumi-tory	Chick-weed	Black Bind-weed	Sun Spurge	Total Weeds
amiben	3.0	4	1	1	7	0	0	0	13
chlorpropham plus diuron	1.0 +0.4	39	8	19	13	3	11	2	95
chlorpropham plus fenuron	1.0 +0.25	18	13	17	12	1	25	1	87
chlorpropham	2.0	17	7	10	32	0	10	5	81
linuron	1.5	6	16	1	17	0	18	3	61
Control (untreated)		64	21	48	35	9	24	4	205

NB dinoseb-amine had not been applied at the time the weed counts were made and these plots were used as additional controls. Later observations showed that dinoseb-amine had given almost complete control of all weed species (see Table IV).

TABLE VI - PEA COUNTS AT SITES E AND F - 1962

(Figures are numbers of plants per 24 ft of row and are the mean of four replicates)

n.u. = not used

Treatment Material	lb a.i/acre	Site E. 10 May	Site F. 8 May
amiben	3.0	88	n.u.
chlorpropham plus diuron	1.0 +0.4	90	62
chlorpropham plus fenuron	1.0 +0.25	84	58
chlorpropham	2.0	86	60
linuron	1.5	92	-
	1.0	-	58
neburon	4.0	n.u.	65
Control (untreated)		87	58

TABLE VII - PEA YIELDS IN CWT/ACRE (AT ALL SITES) - 1962

n.u. = not used

Treatment		E		F		G		H	
		Big Ben		K. Wonder		Diadem		Big Ben	
Material	lb a.i/ acre	Cwt/ acre	Control = 100	Cwt/ acre	Control = 100	Cwt/ acre	Control = 100	Cwt/ acre	Control = 100
amiben	3.0	28.4	197	n.u.		n.u.		n.u.	
chlorpropham plus diuron	1.0 +0.4	21.6	150	27.1	93	54.5	97	16.9	110
chlorpropham plus fenuron	1.0 +0.25	26.4	183	26.7	91	55.8	100	16.5	107
chlorpropham	2.0	25.1	174	25.8	88	54.1	97	14.5	94
linuron	1.0	-	-	29.2	100	42.9	77	-	-
	and 1.5	27.5	191	-	-	-	-	17.8	116
neburon	4.0	n.u.		32.6	112	57.3	103	n.u.	
dinoseb-amine	1.85	-	-	-	-	-	-	17.0	110
	2.25	31.2	217	32.2	110	56.3	101	-	-
Control (untreated)		14.4	100	29.2	100	55.9	100	15.4	100
Level of significance (per cent)		0.1		NS		5		NS	
Sig. diff. P=0.05		(±)5.0		-		(±)7.4		-	
Coefficient of Variation (per cent)		13.7		12.4		9.2		10.4	

Tenderometer readings were taken from the two sites in 1962 where the peas were harvested green. These figures are shown below.

TABLE VIII - TENDEROMETER READINGS FROM COMPOSITE TREATMENT SAMPLES
(Mean of four replicates)

Treatment		Site	
Material	lb a.i/acre	F	G
chlorpropham plus diuron	1.0 +0.4	104	122
chlorpropham plus fenuron	1.0 +0.25	105	125
chlorpropham	2.0	103	128
linuron	1.0	103	108
neburon	4.0	102	126
dinoseb-amine	2.25	105	124
Control (untreated)		105	127

1961 Results

Site A

At this site, on a peaty clay loam with high percentages of both clay and organic matter, the pre-emergence applications were made on a dry cloddy seed-bed which was far from ideal for residual herbicides. Rainfall prior to the application was low and there was no rain in the next six days; in the following eight days however, 1 in. of rain fell. Under these conditions only amiben gave satisfactory weed control and this was particularly good at the high dose, where wild oats were also controlled.

None of the other materials gave what could be considered to be a 'commercial' control and in practice they would have required a subsequent post-emergence treatment. Of the two early post-emergence treatments dinoseb-amine plus amiben gave useful control but it was not superior to dinoseb-amine applied alone at a later stage. Dinoben gave very poor control.

None of the pre-emergence treatments caused any visible crop damage.

Site B

The soil type at this site was a very fine sandy loam with low organic and clay percentages. The pre-emergence chemicals were applied to a dry seed-bed during a hot dry spell of weather and there was little rainfall either before or after applications had been made. All the treatments, both pre-emergence and early post-emergence, gave excellent weed control although BIPC plus OMU, simazine, amiben and N-3-methylphenyl-N'-dimethylthiourea caused varying degrees of crop damage. Possibly damage would have been more widespread and severe on this free draining soil if the rainfall had been higher. The residual activity of the materials persisted and weed control in most cases was excellent up to harvest time. Weed control at this site was so good that little difference could be seen between high and low doses of the chemicals.

Site C

Seed-bed conditions were rather cloddy and dry at this site in spite of light rain in the preceding fortnight. Rain fell on the day of application but there was little rain in the following fourteen days. Weed germination and growth on this heavy clay soil was limited and it was difficult to make accurate assessments of the degree of control given by the materials. Generally the pre-emergence chemicals gave poor control. The early post-emergence dinoseb-amine plus amiben treatment gave reasonable weed control but this was not comparable to the later post-emergence application of dinoseb-amine. The high dose of amiben caused some chlorosis and dinoseb-amine plus amiben stunted the crop to some extent. The post-emergence application of dinoseb-amine caused some scorch and slightly checked the crop but this was quickly outgrown.

Site D

The peaty loam soil at this site was similar to the soil at Site A but had a smaller clay percentage and was somewhat lighter in texture. The seed-bed for the pre-emergence applications was level and dry on the surface. There was no rainfall in the fourteen days prior to the applications but over 1 in. of rain fell in the following fourteen days. The materials performed better at this site than at Site A but while several materials gave good initial kills only the high dose of amiben and chlorpropham plus fenuron gave satisfactory kills which persisted. Of the early post-emergence applications dinoseb-amine plus amiben gave a reasonable kill but damaged the crop, while the control from 3-nitro-2,5-dichloro benzoic acid was negligible. Dinoseb-amine applied post-emergence gave markedly better results than any other treatment.

1962 Results

Site E

The soil at this site was a silty loam with a fairly high organic matter percentage. The pre-emergence herbicides were applied to a fine level seedbed which was dry on the surface but had moisture below the top 0.5 in. There was light rain prior to the applications but no rain fell in the following week. Weed growth was prolific and although amiben and to a lesser degree linuron caused a certain amount of crop damage, the good weed kills from these materials were sufficient for them to give significantly higher yields than the control. Chlorpropham plus diuron, chlorpropham plus fenuron and chlorpropham also significantly increased the yields over the untreated control. However, as is shown in Table V, they did not adequately control the black mustard, fat hen or funitory and consequently a post-emergence treatment would have been necessary in practice, particularly as the black mustard tended to become dominant at this site. Dinoseb-amine gave excellent weed control, the plots being virtually weed free and this treatment gave the highest pea yields, significantly outyielding chlorpropham plus diuron, chlorpropham and the control.

Site F

At this site the soil was a free draining sandy clay loam low in organic matter. Seed-bed conditions were good for the pre-emergence applications, the soil surface being level and moist. Rain fell after the materials had been applied and there was just over 1 in. in the following fourteen days. Considerable weed growth took place and much of the chickweed and groundsel, which tended to dominate the trial, was already established at the time when the pre-emergence applications were made. Neburon gave excellent control of all weeds, with the exception of the established groundsel, and there was no crop damage. This treatment gave the highest yield at this site. Linuron also gave excellent weed control, again with the exception of the established groundsel, but chlorosis of the lower pea leaves was seen in the early stages and these leaves eventually died. By the time that the second scoring was made, all trace of chlorosis had disappeared and eventually the yield obtained was equal to that of the untreated control. Chlorpropham and chlorpropham plus diuron did not control the weeds satisfactorily and the yields were below that of the control. Chlorpropham plus fenuron gave slightly better control but caused crop chlorosis which persisted for a considerable time. This undoubtedly accounted for the low yield from this material. Although control from dinoseb-amine was only moderate, it resulted in the second highest yield, giving an increase of 3 cwt/ac over the control. The poor kill was probably due to the cold and showery weather at the time of application.

Site G

This trial was on a soil similar to that of the previous site, being a free draining sandy loam of low organic matter but of lower clay content. The seed-bed was level and the soil surface for pre-emergence applications was dry. Very little rain fell either before or after the pre-emergence applications had been made.

Linuron caused appreciable crop damage under these conditions and in spite of almost complete weed control gave the lowest yield, being significantly lower than the control. Chlorpropham plus diuron, chlorpropham plus fenuron and chlorpropham adequately controlled the weeds but did not increase the yields over the untreated control; the yields from the two mixtures were in fact slightly lower. Excellent control was given by neburon on this soil and no damage was observed. This material and dinoseb-amine, which also performed well, did slightly increase yields over the untreated control.

Weed competition at this site did not appear to influence yields to any great extent. This explains the fact that although both neburon and dinoseb-amine gave excellent weed control, yield increases obtained by the use of these two materials were only slight.

Site H

This trial was drilled late in dry conditions and on the heavy clay loam soil little weed growth took place. This reduced the value of the trial and made assessments difficult. The best control from the pre-emergence chemicals was given by linuron and this also gave the highest yield. Adequate weed kills were given by chlorpropham plus diuron and chlorpropham plus fenuron but chlorpropham was only moderately successful in controlling weed growth and this material gave the lowest yield. Weed kill from dinoseb-amine was good and increased the yield over the control.

The effect of pre-emergence herbicides on plant populations and emergence

No effect on pea emergence or final plant stand could be seen on any treatment in either of the two years. Pea counts made at Sites E and F in 1962 confirmed that at these sites the materials had not affected the final plant stand.

The effect of herbicides on maturity at the vining stage

(Sites F and G - 1962)

As shown in Table VIII maturity was not influenced by any of the herbicides employed except in the case of linuron at Site G. On this light soil linuron caused appreciable damage and there was a two day delay in maturity as compared to the control.

DISCUSSION

The importance of soil type as a factor affecting the efficiency of residual herbicides is amply illustrated in the results from this series of trials. Thus neburon a very insoluble material with a high degree of absorption, performed particularly well on light, non-retentive, free draining soils giving good weed control without crop damage. On the other hand, on soils with a high clay or organic matter percentage neburon is so 'locked up' that weed kill is poor although again there is no crop damage.

Linuron, a more soluble chemical, while generally giving excellent weed control on all soil types except peats, causes crop damage on the lighter soils. Further work with this chemical on the heavier soils is indicated.

Crop damage from chlorpropham usually takes the form of delayed emergence, various degrees of stunting, or very occasionally reduction in plant emergence. The stunting may not always be readily seen. At three of the four sites in 1962, in spite of good weed kills, the yields from this material were less than that of the control. This suggests that chlorpropham at the dose used (2 lb a.i/ac) caused crop damage which was not visually apparent.

The chlorpropham plus diuron and chlorpropham plus fenuron mixtures very seldom gave any severe crop damage. Of the two, the fenuron mixture appeared to give very slightly more damage. This took the form of chlorosis of the lower leaves and was due to the fenuron rather than the chlorpropham. There was little to choose between the weed kills from these mixtures but in 1962 the fenuron mixture was the slightly more efficient. The increased percentage of diuron used in the 1962 formulation did not noticeable increase the weed control. Whilst these mixtures may perform well on certain soils with specific weed problems such as knotgrass, generally on the soil types tested the weed control was not good and in no way compared to the kill given by dinoseb-amine.

Amiben gives excellent control on highly organic peat soils although where the organic matter is lower, a check on the crop may be seen. On mineral soils excessive crop damage can occur and behaviour on these soils is unpredictable.

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Research Report

TRIALS OF SOIL-ACTING HERBICIDES IN CARROTS AND OTHER VEGETABLES

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Summary: Several promising new triazine and substituted urea herbicides were tested in carrots in comparison with an established mineral oil herbicide and also tested in peas, French beans and broad beans. These preliminary trials indicated that on various soils in Scotland some of these materials behaved as effective weedkillers, with satisfactory margins of crop safety.

INTRODUCTION

The use of persistent soil-acting herbicides such as simazine is now an accepted practice in fruit growing, and the results of using some of them in vegetables were reported by Roberts and Wilson (1961). The present paper describes trials of recently developed soil-acting herbicides in carrots in 1961 and in carrots, peas, French beans and broad beans in 1962, on light loam soils and a blowing sand in Scotland.

METHODS AND MATERIALS

Field trials with Carrots in 1961

Two experiments were conducted in 1961, one at Mylnefield on a light, freely draining loam, and the other near North Berwick on a blowing sand. The treatments, each of which was replicated five times in a latin square design, were propazine 0.5 lb/ac, amiben 4 lb/ac, OMU 0.55 lb/ac plus BiPC 0.38 lb/ac, selective mineral oil, 80 gal/ac, and clean-weeded control. Each unit plot consisted of a 15-foot section of a carrot bed formed of 7 drills six inches apart, sown with a hand-drawn precision seeder. The propazine, amiben and OMU + BiPC treatments were applied with an Oxford Precision Sprayer at a volume rate of 30 gal/ac, immediately after drilling, and the mineral oil was applied six weeks later at a volume rate of 80 gal/ac. A severe drought followed the drilling of the North Berwick experiment, and the germination and growth there were so poor that growth and yield records were not taken. The experiment at Mylnefield was lifted and weighed in September, 1961.

Glasshouse Experiment in 1962

Before testing some new and previously untried materials in the field, a small-scale glasshouse experiment was carried out with carrots, peas and ryegrass grown in standard seed trays containing ordinary field soil. The trays were filled and firmed to within about 1 in. of the top, using in each a standard volume of sieved, well-rotted turf loam. Carrots (var. Chantenay Red Cored), Italian Ryegrass (var. S.22) and peas (var. Kelvedon Wonder) were then sown together in each box so that each occupied rather less than a third of the space.

A measured volume of soil was added to each box and gently firmed, so that the seeds were covered to a depth of approximately half an inch. The boxes were then thoroughly watered from above and pre-emergence herbicides were applied individually to each with a "Kwikmist 200" hand sprayer, using a standard volume rate equivalent to 100 gal/ac. The treatments included one of simazine, two of amiben, three each of chlorpropham, propazine and a mixture of OMU plus BiPC, five each of prometryne and linuron, and two controls. The treatments were arranged on the bench in an unheated glasshouse in four randomized blocks. Each box was watered from above as required, through a fine rose. Records were made of the germination and growth of the three crops, and the carrot and ryegrass foliage was cut and weighed ten weeks after sowing.

Field Trials with Carrots in 1962

Two replicated field trials were conducted during 1962, one at Mylnefield on a light, well drained loam, and the other near North Berwick on a blowing sand. The plots, which were identical with those used for the 1961 trial, were arranged in six randomized blocks. The treatments were hand-weeded control, mineral oil at 80 gal/ac, chlorpropham 2 lb/ac + diuron 0.5 lb/ac, prometryne at 1 and 2 lb/ac, linuron at 1 and 2 lb/ac, N-(4-chlorophenyl)-N-methoxy-N-methyl urea (Hoe. 2747) at 1 and 2 lb/ac and OMU 0.55 lb/ac plus BiPC 0.38 lb/ac. All the chemical treatments except the mineral oil were applied at a volume rate of 30 gal/ac, immediately after drilling. The mineral oil was applied five weeks later at 80 gal/ac. The two trials were lifted and weighed in September, eighteen weeks after drilling.

Field trial with Carrots, Peas, broad beans and French beans in 1962

The treatments in this trial were a hand-weeded control and single applications of prometryne, 2,methylmercapto-4-isopropylamino-6-methylamino-1,3,5-triazine, (G34360), simetryne, N-(4-chlorophenyl)-N^1-methoxy-N^1-methyl-urea (Hoe. 2747) and linuron, each at rates of 1.0, 2.0 and 4.0 lb/ac. All the sprays were applied with an Oxford Precision Sprayer at a volume rate of 30 gal/ac. The plot size was 4.5 ft by 12 ft, with three short rows of carrots and two rows of each of the other crops running across this area. Six replicates of each treatment were arranged in randomized blocks. At the time when the chemical treatments were applied - 10 days after the final preparation of the land and shortly after drilling - a few annual weeds were beginning to emerge but the crop seeds had not germinated. After the initial effect of the herbicides on the weeds had been recorded, the plots were hand cleaned and subsequently kept clean to prevent further competition with the crops. The peas were harvested when the first-formed peas were hard and ripe, and the carrots will be lifted in October.

The chemicals used in the trials were as follows:-

propazine	- 50 per cent wettable powder
amiben	- 24 per cent wt/vol liquid formulation
OMU) BiPC)	- emulsifiable concentrate "HS/55"
mineral) oil)	- "Shell W" (proprietary selective mineral oil approved for use in carrots by A.C.A.S.)
simazine	- 50 per cent. wettable powder
N-(4-chlorophenyl)-N^1-methoxy-N-methylurea (Hoechst 2747)	- 80 per cent wettable powder