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Presentation by H.A. Roberts of the preceding eight papers.

At previous Conferences, we have been able to follow the story of the search for a residual pre-emergence treatment for weed control in sugar beet, culminating in the development of a mixture of endothal and propham which is now in commercial use. This mixture features in two of the reports before us at this session. In the first, Bagnall and Minter describe experiments on various soil types to determine the possible value of the potassium, ammonium and an amine salt of endothal for weed control in sugar beet. They found that although these salts gave excellent control of some species, several important weeds of sugar beet were not killed, and they conclude that in general, the endothal/propham mixture gave results superior to those obtained with the endothal salts by themselves.

In a second paper, Bagnall and Caldicott report experiments to determine whether the endothal/propham mixture can be used for the pre-emergence treatment of brassica crops, a situation in which there is an urgent need for an effective pre-emergence herbicide. Unfortunately, it was found that with the horticultural brassicas there was an insufficient degree of selectivity, and the crops were damaged by the rates of application necessary for adequate weed control. Some of the fodder brassicas, such as marrowstem kale, turnip, rape and field cabbage were not unduly checked by the endothal/propham mixture when used at the appropriate rate for sugar beet, but the fact that these crops are normally drilled at a time when the rainfall necessary for herbicidal action is most likely to be lacking, would seem to be a severe limitation on this method of weed control.

Another material discussed at a previous Conference is dichlobenil, and R.J. Stephens now reports a preliminary experiment to determine the possibility of applying it several months before sowing or planting a crop. The work emphasises the potency and persistence of this herbicide, and although transplanted cabbage grew well in plots which were still weed free, all the other crops examined were damaged when sown or planted 6 - 7 months after treatment of the soil with rates greater than 2 lb per acre. This damage was generally greater where the herbicide had been incorporated by rotary cultivation.

In two papers by R.G. Hughes, alternative herbicides are examined for two crops, maize and spring-sown field beans, in which pre-emergence treatment with simazine is now an established practice. In both, atrazine proved more effective than simazine, especially under dry conditions, but prometryne gave poorer weed control. It was found that there was no disadvantage in delaying the treatment of field beans with simazine until crop emergence, and it is suggested that the later spraying might be desirable where late-germinating weeds are expected.

The remaining three papers are concerned with the evaluation of various recently developed soil-acting herbicides for weed control in vegetables crops. King and Hancock present the results of eight trials with peas, and their work emphasises the importance of soil type in the selection of a suitable herbicide. Some herbicides, such as neburon, gave good results on light mineral soils, but on heavier or organic soils had little effect on the weeds. Conversely, others were liable to cause crop injury on mineral soils. Linuron, for example, appreciably damaged the crop when applied at 1 lb per acre on a sandy loam, but appears to be promising for use on heavier soils. Amiben gave better weed control than the other soil-acting herbicides on peaty soils, with no crop damage. On mineral soils, however, crop damage occurred, a finding in agreement with the results of Roberts and Wilson, who record yield reductions from 2 lb per acre on a sandy loam and conclude that there is insufficient selectivity for this herbicide to be safe for peas on light soils.

R.J. Stephens reports experiments with carrots in which several soil-acting herbicides gave promising results, among them prometryne and linuron. Amiben also performed well in this crop, and Roberts and Wilson conclude from their evaluation of this material in twelve crops that carrots, together with parsnips and parsley, were the only ones which show sufficient inherent tolerance for amiben to be safely used on light soils.

As King and Hancock point out, an effective soil-acting, pre-emergence herbicide would be valuable for use in peas even though selective post-emergence treatments are available. The same is true for other crops, and certain materials, such as the chlorpropham/diuron mixture included in their trials, are commercially used and have proved very effective on some soils. The situation at present seems to be that for both the large-seeded leguminous crops and for the umbelliferous crops, there are several experimental materials which show distinct promise, and these include linuron, neburon, prometryne and amiben. The selection of the most appropriate herbicide, however, depends to a large extent on the type of soil involved, and it is evident that to establish more fully the potential uses of these materials further experimental work will be necessary.

Research Summary

RESPONSE OF PLANTS TO LOCALISED APPLICATION OF HERBICIDES TO THE ROOTS

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Summary: Experiments were carried out on peas and barley grown in water culture. The effect of herbicides of widely different modes of action applied to the whole root system was compared to the effect when one third of the roots were exposed to correspondingly higher concentrations of toxicant dissolved in the nutrient solution.

INTRODUCTION

A herbicide applied to the soil cannot, economically, be incorporated into the whole root-zone depth. Different parts of the root will be in contact with different concentrations of herbicide at any one time. To improve reliability of performance of herbicides in the soil, more information on the relationship of plant response to spatial variation of herbicides is required. The effect of non-uniform application of herbicides, with respect to horizontal variation, to the roots of peas and barley in water culture is reported here.

METHODS AND MATERIALS

Peas and barley are grown in full nutrient solution under controlled growth room conditions. The plants were grown in separate half pint glass vessels. 2 oz specimen tubes were used inside the main vessels for the divided root experiments. The herbicides used were atraton, chlorpropham, propham and the sodium salts of MCPA, 2,3,6-TBA, DNOC and TCA. Concentrations chosen were those which produced obvious and characteristic symptoms or death of the plants within a week of application to the whole root system in nutrient solution (150 ml). Three times the appropriate concentration was applied to one third of the roots in 50 ml solution and the remaining two thirds of the roots were placed in uncontaminated nutrient solution (100 ml). Plants were offered the same amount of herbicide in both treatments.

RESULTS

MCPA applied to the whole root system killed the plant while the same amount to one third of the roots caused only local damage and had little effect on the plant as a whole. Atratone, chlorpropham and propham and 2,3,6-TBA killed the plants whether application was to one third or all the roots. Roots in direct contact with 2,3,6-TBA or the carbamates were deformed or killed, while those in uncontaminated solution remained healthy. The effect of atraton and high concentrations of chlorpropham to a portion of the roots was transmitted to the remainder not in the toxic solution. TCA and DNOC gave variable results with respect to the health of the whole plant but whereas TCA had no obvious effect on root growth, DNOC destroyed the root tissue with which it was in contact.

Barrons (1951) showed that a portion of roots of wheat seedlings growing into a solution of dinoseb were inhibited and discoloured while those in water grew normally. Top growth was not affected. 2,3,6-TBA, atraton and the carbamates reduced transpiration rates whether applied to part or whole root systems. MCPA and DNOC had little effect on transpiration when applied to one third of the roots. The effect of TCA on water uptake was variable.

DISCUSSION

Differences in plant response to whole or partial exposure of the root system to a dissolved toxicant varies greatly with the herbicide. At one extreme atraton produces the same response whether application is to all or one third of the roots. This would be expected where the herbicide is taken up passively by the roots and exerts lethal effect in the aerial parts of the plant. At the other extreme MCPA produces little general effect when applied to part of the root system, which suggests complete localisation of the herbicide in the root tissue. This could have been expected from the work of Blackman (1959), McCready (1961) and Crafts and Yamaguchi (1960) on uptake and accumulation of 2, 4-D by roots. Sufficient DNOC may be taken up by one third of the roots to kill the whole plant. In this respect DNOC applied to the roots behaves as a more freely translocated herbicide than MCPA in contrast to effects obtained when sprayed on foliage. 2,3,6-TBA, TCA and the carbamates are similar to atraton in that contact with part of the root system is adequate for transfer to the upper part of the plant where they are effective.

Since the conditions of these experiments were highly specialised a small trial plot experiment was carried out. Plaster pellets containing MCPA (acid) and atraton placed in 1 in., 2 in. and 4 in. grid formation, and uniform sprays were applied 2 in. below a random sowing of peas, beans, mustard and barley. The dose of herbicide to each plot was 10 lb/ac. Atraton killed all the plants whether the dose was in the form of discrete pellets or a uniform spray. When applied as a spray, MCPA prevented emergence completely of all species except of barley, which died soon after emergence. All species grew normally on the plot treated with pellets 2 in. or 4 in. apart.

That the action of atraton is not dependent on extreme uniformity of presentation to the roots may be part of the explanation for the triazine type of herbicides being less dependent on rainfall and soil conditions than many other compounds.

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Discussion of preceding eleven papers

DR. E. HOLMES (Chairman) We have heard nothing whatever about the machinery for the application of these products to the soil near the crop plants. Can the speakers tell us anything about the application machinery used for these soil herbicides?

DR. K. HOLLY There are a very large number of problems on the application side. One of the most obvious is that many of these soil acting herbicides are rather expensive as compared with phenoxyacetic compounds at a few shillings per acre. Here, one of the savings that can be made is by band spraying, and some band sprayers are being developed in this country. They require good nozzles, because unlike ordinary boom sprayers there is no overlap to help remedy uneven application by any one nozzle.

There is the problem of incorporation of soil-acting herbicides and whether one machine can be used to apply the herbicide and incorporate it in one operation. It is useful to have one machine doing the whole job because where volatilisation may occur one wants to get incorporation following after herbicide application as rapidly as possible. This procedure was discussed at the 1960 conference when there was a paper on the particular machine that we have been concerned with at Oxford for both spraying and incorporating herbicides. Other machines have been developed commercially to do a similar job. I think we are entitled to ask for more help from machinery manufacturers in pushing ahead with the design of machinery to provide practical solutions to some of the problems we are working on from the biological point of view. Finally there is room for a great deal of work to ascertain the performance of implements which might be used for incorporating herbicides under a variety of conditions.

MR. A.J. LAMBIE Bearing in mind the fact that the destruction of herbicides in the soil is brought about by bacteria that use them as substrates; does the possibility exist that bacteria may increase so that although a given pre-emergent herbicide may be effective in its first year of application, its persistence may be successively reduced so that after three years it is ineffective?

DR. K. HOLLY Theoretically this is a possibility, as is borne out by the work of Audus with some phenoxyacetic acids where there was a lag period before decomposition started. Decomposition of subsequent additions of the same herbicide started without occurrence of an initial lag period. This effect has not shown up with some other herbicides. Consecutive applications of amitrole, which appeared to be broken down microbiologically, did not lead to any increase in speed of disappearance of later additions. I think that applications of herbicide in the field seldom follow each other sufficiently rapidly for such an increase in breakdown rate to occur. The next application is not made until most of the first application has disappeared and the micro-organisms are present in their usual numbers existing on their natural substrates in the soil.

MR. P.J. BOYLE Dr. Holly: to what extent do soil-acting herbicides which are also volatile, such as EPTC, di-allate and tri-allate, move in the soil in the vapour phase and, if so, to what extent is this movement able to compensate for uneven incorporation?

DR. K. HOLLY Movement does occur in the vapour phase in the soil, but there has been very little work done to my knowledge to determine the relative magnitude of movement in the vapour and water phases. This is a difficult problem for the physical chemists to sort out.

DR. E. HOLMES Presumably they vary tremendously with the soil moisture content.

DR. K. HOLLY Yes, they do.

MR. E.R. BULLEN The paper presented by Messrs. King and Hancock indicates that amiben may be safe enough for use on peas on organic soils. Carrots and lettuce appear to be relatively tolerant of this herbicide from Roberts and Wilson's work. Could Mr. Roberts say whether this treatment has been tested or would be worth testing, for these crops on the black fen soils of the Eastern Counties?

MR. H.A. ROBERTS We have not worked on these soils ourselves, nor do I know whether any work with the two crops you mention has been carried out elsewhere. Our impression is that both crops, and especially carrots, possess a comparatively high degree of inherent tolerance to amiben, and in view of the good weed control reported by King and Hancock, I certainly agree that it would be well worth while to examine the possibilities of amiben for carrots and lettuce under these conditions.

MR. G.W. CUSSANS I would very much like to endorse the remark made by Dr. Holly when he said that there is a tremendous need for research and development work into the questions of nozzle design in general and band spray nozzles in particular. I would also confirm that, in my experience, there is great scope for educating farmers in the importance of nozzle design and in the "basic arithmetic" of band spraying. It may not be quite in order, but it is interesting to note that the two most recent developments in application machinery reported to this Conference in 1960 and again in 1962 have been stimulated by the Agricultural Chemicals Industry, not by the Agricultural Machinery Industry.

In connection with the activity of soil-acting herbicides I should just like to make one observation and enquire whether this has been observed or explained by other workers. I have made a large number of applications of the endothal/propham mixture and I have tried to include in all trials treatments of both chemicals individually as well as in mixture and treatments at a high dose level so that the activity of the chemicals can be measured by estimating damage to the crop, which is a constant factor, rather than by effect on weeds which vary in distribution from experiment to experiment. When the ratio of 4 : 3 for endothal/propham was chosen we assumed, from the evidence available at that time, that crop tolerance to these herbicides was roughly in this ratio. In my subsequent experiments, however, this has only been true in a minority of cases and in other cases endothal has been relatively more active than propham or vice-versa. I have as yet found no obvious correlation with environmental conditions and I would very much like to know if others have observed similar inconsistencies and if anyone has a theory to explain them. Would this be, for example, a soil type effect, a moisture effect or, a soil type/moisture interaction effect?

MR. B.H. BAGNALL In answer to Mr. Cussans, one of the things you have got to remember is the importance of rainfall and you are going to be very lucky if you get two similar sites with the optimum amount of rainfall. Because of the solubility of endothal it requires much less rainfall than propham and under these conditions you are going to be in difficulties to judge how these two chemicals effect sugar beet in a different area in different circumstances. One has to judge by looking at the results over a season and not on each site. In my own experience I should not like to judge more closely than that, in view of the variability of rainfall as well as the ever present variability of soil type.

MR. G.A. TOULSON We have met with considerable success in the control of weeds in kale using soil acting herbicides in trials carried out on moist organic soils of Wales. Amiben under these conditions appears to be more promising than EPTC or CDAA. Even with $1\frac{1}{2}$ lb per acre, amiben gave a considerable reduction of a wide range of weeds without injury to the crop. It seems that these wet conditions suit the use of soil-acting herbicides, but it is a pity that some of the products are so expensive for dealing with low-valued crops.

MR. B.H. BAGNALL There is one comment I would like to make in connection with the soil analysis we have heard about for residuals. In my experience the average farmer gets very confused between chemical analysis for NPK and mechanical soil analysis. If we have to take a soil sample for dose determination I always point out to the farmer that it is for a mechanical analysis for herbicides and should not be confused with a chemical analysis for fertilizer ingredients. Some of the members of the N.A.A.S. may like to comment on the point.

MR. W.T. COWAN Mr. Chairman, you opened this discussion by throwing out some questions on application of soil acting herbicides, and yesterday we touched on difficulties with other materials. One difficulty frequently causing trouble is overlap. All our recommendations are against this; but in practise it is not at all easy to match spray swathes exactly in the length of a field. Is there not a simple answer to this? Why not fit two jets at the extremities of the boom with half the output of those on the remainder of the boom? Surely this is not too much to ask of a farmer. Spray operators are used to overlapping. Then let them; but make sure they are not over-dosing.

SESSION 8

Chairman: Mr. P.H. Brown

WEED CONTROL IN PERENNIAL HORTICULTURAL CROPS

A REVIEW OF THE ROOTING BEHAVIOUR OF FRUIT PLANTS, IN RELATION TO THE USE OF SOIL-ACTING HERBICIDES.

R.I.C. Holloway

East Malling Research Station, Maidstone, Kent.

Soil-acting herbicides are of particular value in fruit plantations because complete and permanent weed control, at least around each tree or bush, is often desired. By the use of herbicides that act only through the soil the risk of damage to foliage and fruit by accidental spraying or drift is eliminated, but there must still be selectivity between weed and crop. This may be by simple physical avoidance, whereby the herbicide does not reach the crop roots, or by true physiological selectivity. The innate tolerance to simazine of young grafted apple trees has been shown (Casely, 1960), although this material was found to damage apple seedlings (Dermine, 1960). In order to achieve the safe use of soil-acting herbicides in fruit plantations an understanding of the rooting behaviour of the fruit plants is essential and must be used in conjunction with information on the movement of herbicides through the soil.

The particular aspects of rooting that are of importance in relation to the use of herbicides are as follows:-

1. The distribution of roots in depth.
2. Their distribution horizontally from the plant.
3. Their seasonal activity.
4. Variations in these factors due to soil type and management.
5. Variations between species and varieties.

The rooting habit of the apple, on which the most detailed studies have been carried out, will be discussed first, followed by shorter notes on the other fruit plants. All are vegetatively reproduced, so that there is no tap root.

APPLE

Excavation of a series of 10-year-old trees on a range of rootstocks on 3 widely different soil types showed that the general root conformation was the same in all cases (Rogers and Vyvyan, 1934). There was a main scaffold of horizontal or undulating roots, between 25 and 50 cm deep, with many 'sinkers' striking vertically downwards. The dwarfing rootstocks did not have a shallower root system than the more vigorous ones, the depth of rooting being limited by the underlying rock, commonly at 4-5 ft under the loam soil, or, under the clay, by a rising winter water table. Where there was an accumulation layer (B horizon) above the rock the roots ramified freely in it. This indicates that it is important to consider this accumulation layer, and not just the top soil, in herbicide residue studies, especially as the life of a fruit tree may be 50 years or more. In all cases the root spread was very much greater than that of the branches. Some trees had a very one-sided root system, with over 40 per cent of the total root weight in one quadrant. Thus application of a herbicide only in alternate alleys could not be expected to affect all trees equally. The nearest measure we have of the distribution of the absorbing roots is the distribution of the fibre (diameter less than 1 mm) on which they are borne. The fibre was fairly evenly distributed in depth and in spread, about 50 per cent occurring below 50 cm. The percentage of total fibre in the square metre block of soil surrounding the trunk will of course depend on age and size of tree; in these 10-year-old trees it was usually between 6 and 12 per cent. The rootstock M.I. has a particularly high concentration in this area, about twice as much as M.II. Thus herbicides applied close to the trunk might affect about 10 per cent of the fine roots, if they penetrated the whole root depth.

Although the general conformation was the same, there were considerable differences on the 3 soil types. On the clay there was a more compact root system, with a smaller spread than on the loam, and the main scaffold roots were deeper. On the sand, where the trees were much smaller, the roots spread nearly 3 times as far as the branches and the main roots were shallower than on the other soils. The stem/root ratio averaged 0.84 on the sand and 2.2 on the loam, so that on the poor sand nearly 3 times as much root was required to support a given amount of shoot as on the loam. Studies by Coker on 5 soil types largely confirm these findings (Coker, 1958b). He found that shallow soils, or those with poor drainage, which are effectively shallow, produced a root system with the fibre concentrated nearer the surface, and that a sandy soil favoured shallower fibrous roots than clay. Thus, although part of the greater sensitivity of plants to herbicides on light soils may be due to free movement of the herbicide the shallower fibrous roots and greater root/shoot ratio would also be expected to make them more susceptible to damage.

The trees so far described were grown in cultivated orchards, but it is now common for mature apple trees to have a closely-mown sward beneath them. Apples on M.IX were found to have similar scaffold roots under the two systems (Coker, 1959). Although the trees had been in grass for 9 years, the main root system was probably formed in the 7 years before grassing-down. Trees in both systems equally exploited the deeper soil layers, but many roots grew up into the turf where they extended and branched: under cultivation, roots extending towards the surface were continually cut off. Close to the trunk in grass, where the grass was only infrequently cut, there were few roots near the surface, but in cultivation, where this area was hand-hoed, there was a collar of fibre. Thus fine roots developed freely where there was no competition from grass and they were not cut off by deep cultivations. In cultivation the main roots ran just below the normal cultivation depth, and some quite large roots had been cut by a deeper-than-usual cultivation. This work confirms the findings of Rogers and Vyvyan that there is a greater concentration of fibre around the collar than further away. The great increase in collar fibre that occurred where cultivation and competition were reduced by hoeing might also be expected to result from local herbicide applications. Overall herbicide applications could be expected to produce a uniform distribution of roots, as under a sward, rather than the patchy distribution occurring under cultivation. It is therefore important to remember that the root system is dynamic, and that the use of herbicides can be expected to alter the root conformation. Roots near the soil surface enable the tree to make use of light summer rains that would otherwise evaporate and to benefit from the readily available nutrients that are present there. Ploughing the sward to 15 cm beneath the trees excavated by Coker would have destroyed 25-50 per cent of the fibrous roots. The cutting of main roots and elimination of a high proportion of the fine roots by infrequent cultivations, as might be carried out in conjunction with herbicide usage, would give the trees a severe check.

So far we have considered the extent of the root system as shown by excavations. Studies in root observation trenches have given much information on the development of roots (Rogers, 1939). The young roots were white and succulent, with short root hairs. After 1 to 4 weeks they began to suberize, the root hairs shrivelling and the cortex turning brown and eventually shrivelling and disappearing. The central cylinder then either thickened and became a permanent part of the root system or else rotted away. Thus the root grows into a piece of soil, absorbs water and other materials (including possibly herbicides) from it and then the absorbing organs die away. The tip may pass on to other regions, and new roots come again through the same soil. Thus the roots comb through the soil, wave after wave. A root exudate, which may have an absorbing function, has been observed in apple but not in other fruit plants.

The greatest root growth occurred in early summer, up to 9 mm per day for a week. There is sometimes a smaller peak following autumn rains. Active root growth began 1 or 2 months before active shoot growth and finished after it. There was a close correlation with soil temperature, root growth beginning at 45°F. and following the temperature even before there were any leaves on the tree: the later decline was probably partly due to moisture tension.

PEAR

Excavation of a pear on Quince A (Rogers, 1933) showed that the root system was similar to that of the Malling apple stocks, with main horizontal roots and fine descending roots.

Pear on seedling pear, as still used in many parts of the world, had very vigorous vertical roots, but no true tap root.

PLUM

Like the apple and quince, plums produce a system of shallow scaffold roots with vertical sinkers (Peren, 1921; Rogers, 1952). In California, it was found that the main growth of Myrobalan plum occurred in autumn and spring (Kinman, 1933). Plums are grown on a range of stocks of different species, and as they appear to be rather more sensitive than apples to some soil-acting herbicides it is unfortunate that there is not more information on their rooting habit.

CHERRY

Cherry roots, growing in association with vines, have been excavated in Italy (Breviglieri, 1952). The trees were grafted on seedling Prunus avium. Deep ploughing of the alleys had restricted shallow roots to the tree rows. There were few deep roots, the maximum depth being 197 cm, with most roots between 30 and 50 cm.

BLACK CURRANT

Excavation of eight-year old black currants growing on a very sandy soil showed that the root systems filled the soil to a depth of 100 to 150 cm, the deepest roots penetrating to 214 cm (Rogers, 1933).

Eight-year-old black currants grown under straw (for $2\frac{1}{2}$ years) and cultivation have also been studied (Coker, 1958a). In cultivation, a mass of fibrous roots extended outwards just below the surface in the area near the bush which was not deeply cultivated, but farther out roots above 15 cm had been cut off by cultivation. Under straw, roots grew up into this previously cultivated area, but there were fewer deep roots. Part of this effect may be due to non-cultivation. In uncultivated black currants, maintained weed-free by herbicides, an increase was found in root growth in the top 2 inches (Robinson, 1961).

Currants are particularly forward in starting root growth in the spring, long before the shoot growth (Goff, 1898). Because of this early start, and their tendency to produce a mat of fibrous roots in the surface some currant roots are almost sure to be in physical contact with applied herbicides, although many roots also explore the deeper layers of the soil.

GOOSEBERRY

Eight-year-old gooseberry bushes growing on a very sandy soil were excavated (Rogers, 1933). The roots had a tendency to grow in 2 whorls, one arising from the base of the cutting and one from near the soil surface. Each had horizontal scaffold roots and fine descending roots, down to a maximum depth of 247 cm.

RASPBERRY

The roots of five-year-old raspberries growing on a medium sandy loam at East Malling have been excavated (Christensen, 1947). Most roots were gently undulating, with others descending vertically to a maximum depth of 175 cm. The rows were 6 ft apart and roots spread through the whole of this area. Small rootlets were most numerous near the crown and at the tips of roots. Sucker shoots arose at all depths down to 90 cm and soon developed their own root system although they remained connected to the parent.

STRAWBERRY

Studies of strawberry plants at East Malling showed that the roots penetrated to 30 cm in the first year and 60 cm in the second year (Rogers, 1952), although at Long Ashton few roots were found below 13 inches, with 90 per cent in the upper 6 inches (Ball and Mann, 1927). The fibre and main roots were not measured separately. It was also found that few roots spread beyond the leaves. A recent excavation at Efford showed that the roots penetrated to depths of $2\frac{1}{2}$ ft and had a spread of 30 inches, (Hughes, 1961). In Colorado strawberry roots spread up to 6 ft and were found as deep as 40 inches, varying with variety (Hanson, 1931).

There is detailed information on the seasonal development of strawberry roots (Mann and Ball, 1926, 1927). It was found that growth of primary roots was preceded by shoot growth, most occurring in late summer and autumn, with little in spring. After planting in September new laterals formed on the runner roots, and new primary roots arose from the crown above the old roots: development of these roots continued into November. In March there was some shoot growth and a few new primary roots developed, followed by the production of numerous fine laterals in April. In July new primaries formed from the base of the new crowns and in August very many laterals were produced. Many new roots were formed in September, comprising up to one-third of the total system. Development was similar during the second year, with the production of much fibre in the spring and the formation of new primaries above the old roots in late summer.

The greater susceptibility of strawberries to applications of simazine in spring than at other seasons has been attributed to the development of fibrous roots that occurs then (van Staalduine, 1960). The variable results obtained with other herbicides in the winter (Holloway, 1958) may depend on the persistence of the herbicide into the period when these roots ramify.

The development of roots on newly formed strawberry plants in the runner bed is of special interest because the plants will root through soil treated with simazine without damage (van Staalduine, 1960; Holloway, 1962). Studies in the United States showed that the runner plants become independent of the mother only when a large proportion of the roots have branched, and that the newly formed root system is conical (Rom, 1958). The developing roots may grow for 5 to 10 cm before branching occurs, so that the fine absorbing roots of the new plant are several centimetres below the soil surface and may not be reached by some herbicides.

CONCLUSION

The work reviewed shows that all fruit plants have extensive root systems, spreading far beyond the branches and to great depths on suitable soils. The root system, and particularly the distribution of fine absorbing roots, is greatly affected by soil and by cultural methods. The dynamic nature of the root systems has been shown. A striking feature is the ability to explore and utilize the surface layers extensively if the cultural method allows this. The use of herbicides, resulting in the absence both of weeds and of deep cultivations, may lead to a change in root distribution and a more efficient use of the richer surface layers of soil, provided that the herbicide itself does not affect the fruit plant roots in these layers.

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Research Summary

THE USE OF BIPYRIDYL HERBICIDES IN SOFT FRUIT CROPS

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The use of herbicides to eliminate cultivation in soft fruits is a promising new cultural practice (Robinson 1962a). Experiments at Loughgall indicate that paraquat and, to a lesser extent, diquat are useful for the control of established weeds in the winter prior to treatment with a persistent soil-applied herbicide in the spring. Work with bipyridyl herbicides included field trials to determine the susceptibility of common weeds and to assess the tolerance of soft fruits to an incorporated pre-planting treatment and to overhead and directed applications in the growing and dormant seasons.

The properties and mode of action of diquat and paraquat have been discussed by Cronshey (1961). Field trials showed that the most common winter weeds of soft fruit plantations at Loughgall, namely, *Poa annua*, *Stellaria media*, *Senecio vulgaris* and *Ranunculus repens* (Robinson 1961) were susceptible to application of paraquat at 0.25 to 0.5 lb/ac in the winter. A dose of 0.5 to 1 lb/ac killed *Holcus lanatus* and *Agrostis stolonifera* and temporarily suppressed the top growth of *Agropyron repens*. Diquat was effective against the above-mentioned broad-leaved species but not against *Agropyron repens*; *Poa annua*, *Holcus lanatus* and *Agrostis stolonifera* were occasionally killed by a dose of 1 lb/ac in December but were usually only scorched. The toxicity of both herbicides to *Ranunculus repens* is particularly advantageous as this species, already prevalent, is increasing because of its tolerance to simazine.

Diquat and paraquat are absorbed on soil by ion exchange (Crossley 1961, Anon 1961). The absence of any residual effect in the soil was supported by the results of an experiment in which young plants of blackcurrant, gooseberry, raspberry and strawberry were uninjured when planted in soil immediately after paraquat at 4 lb/ac had been incorporated to a depth of 6 in. Directed sprays of diquat and paraquat at 1 and 2 lb/ac applied annually for two or three years also had no harmful effect on these crops. Overhead application of diquat at 1 lb and paraquat at 0.8 lb in 100 gal/ac during the growing season caused severe injury to the aerial parts of gooseberries and raspberries and more extensive injury to blackcurrants and strawberries.

Differences were also apparent in the susceptibility of these crops to overhead applications in the winter. After leaf fall, gooseberries showed marked tolerance; in tests on four varieties there was no evidence of any reduction in bush vigour, crop yield or fruit size following overhead doses of either diquat or paraquat applied at 4 lb/ac in December 1960 and repeated on the same bushes in December 1961. Blackcurrants appeared to be susceptible to spray wetting by either herbicide where doses above 0.3 lb/ac were used. Applications of 0.3 to 0.6 lb/ac in October, December or February caused slight damage to two varieties and higher doses resulted in more severe injury. Raspberries were intermediate in sensitivity between gooseberries and blackcurrants; in December application at 1 lb/ac had no harmful effect but a dose of 4 lb/ac caused temporary chlorosis of foliage at bud burst which persisted for about a month. Winter applications varying from 0.25 to 0.75 lb/ac scorched the foliage of established Cambridge

Vigour and Talisman strawberries but growth in the spring was normal and berry size and yield were not reduced. In contrast, doses as low as 0.2 lb/ac caused severe damage when applied in the growing season. Under conditions where injury occurred, paraquat was usually slightly more phytotoxic than diquat on all four crops. The addition of wetter (0.1 per cent Agral 90) often enhanced the effect of both herbicides on weeds but had no obvious effect on their phytotoxicity on soft fruits in the winter.

These results suggest that application of either herbicide at 0.5 to 1 lb/ac with a wetter would be safe in gooseberry and raspberry plantations when the plants are dormant. In blackcurrants these doses may only be applied with safety as a directed spray. Doses less than 0.75 lb/ac appear promising for use on dormant, established strawberries but more work is needed under a wide range of conditions and on other varieties to determine the safety of this treatment.

In strawberry plantations, the practice of non-cultivation is complicated by the need to suppress runners. Directed applications of paraquat and diquat at 0.5 to 1.0 lb/ac in the summer and autumn have been used successfully for this purpose (Robinson 1962b). Occasionally slight chlorosis occurred on the foliage of parent plants, apparently as a result of translocation from treated runners. This injury was temporary and there was no obvious reduction in plant vigour or crop yield.

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Research Report

OBSERVATIONS ON THE USE OF 2,4-DES, CHLORPROPHAM AND DINOSEB ON TALISMAN STRAWBERRY

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Summary: A comparison was made of autumn applications of chlorpropham and dinoseb, with summer applications of 2,4-DES, and combined summer and autumn applications. Unsprayed treatments using normal cultivation methods were also included. All herbicide treatments depressed yield in the maiden year, but there was no marked reduction of yield during the second and third years. Chlorpropham at 2 lb/ac applied in November plus two applications of 2,4-DES at 4 lb/ac during the summer gave efficient weed control over a three year cropping period at a cost comparable with normal commercial cultivations.

INTRODUCTION

Following the work carried out by Roach (1957) and Holloway (1958) a three year trial was laid down to compare 2,4-DES applied during the spring and summer with chlorpropham and dinoseb applied in the late autumn. The same materials were also used in combination as summer and autumn treatments, and all chemical treatments were compared with traditional methods of cultivation with a view to finding a practical and economic method of weed control in strawberries.

METHODS AND MATERIALS

The following treatments were compared on the variety Talisman, the first application being made in November 1959, 7 weeks after planting. The total number of applications over the period November 1959 to May 1962 is given in brackets.

Autumn treatments

- 1A Chlorpropham 1 lb/ac after hoeing in November (3 applications)
- 1B Chlorpropham 2 lb/ac after hoeing in November (3 applications)
- 1C Dinoseb (amine) 1 lb/ac in November without hoeing (3 applications)
- 1D Dinoseb (amine) 2 lb/ac in November without hoeing (3 applications)

Summer Treatments

- 2A 2,4-DES 4 lb/ac annually before fruiting, except in the maiden year (2 applications)
- 2B 2,4-DES 4 lb/ac annually before fruiting (3 applications)
- 2C 2,4-DES 4 lb/ac before and after fruiting each year, commencing after fruiting in the maiden year (4 applications)
- 2D 2,4-DES 4 lb/ac before and after fruiting each year (5 applications)

2E 2,4-DES 4 lb/ac twice before and once after fruiting each year, commencing after fruiting in the maiden year (6 applications)

2F 2,4-DES 4 lb/ac twice before and once after fruiting each year (8 applications)

3A Chlorpropham 2 lb/ac after hoeing in November (3 applications) plus 2,4-DES 4 lb/ac before and after fruiting each year (5 applications)

3B Dinoseb (amine) 2 lb/ac in November without hoeing (3 applications) plus 2,4-DES 4 lb/ac before and after fruiting each year (5 applications).

Unsprayed treatments

4A Normal commercial practice (hand hoeing and cleaning with two-wheeled rotavator when considered necessary).

4B Clean cultivation (plots kept continually clean throughout the life of the crop by hoeing and rotavating).

Chlorpropham and dinoseb (amine) were applied in 100 gal/ac of water and 2,4-DES in 200 gal/ac, all materials being applied overall by means of an Oxford Precision Sprayer. The plots consisted of 20 plants in two rows, at a spacing of 3 ft x 1 ft 3 in, and were arranged in a randomized block design with four replications. In accordance with local commercial practice the plants were not strawed before picking.

The plots weeded by commercial methods were cultivated four times in the first year, and five times in each of the two subsequent years; on the clean cultivated plots eleven cultivations were given in the first year, fifteen in the second year and eleven in the third year. Each of these cultivations consisted of hand hoeing the plants and rotavating lightly between the rows.

RESULTS

Effects of treatments on the crop

The effects of the various herbicide treatments on crop yield over the three year period of the trial are shown in Table I. In the first year, owing to adverse weather conditions, the plants were planted late and did not establish well during the winter, with the result that the maiden yields were low.

All treatments affected growth and development to some extent in the first year, the plants treated with 2,4-DES in March being the worst affected. This treatment also reduced the yield of fruit considerably in the maiden year. The other treatments depressed yields slightly but not significantly compared with normal cultivation.

In the second year there were no marked differences between the yields, but the stunting effect noted in the first year on the plants treated with 2,4-DES in March was still present after fruiting in 1961. In the third year plant growth and development were normal for all treatments, and differences in yield were small. The plants treated in autumn gave slightly lower yields in general, but the differences were not significant. Differences between the figures for total yields over the three years of the trial were also not significant.

TABLE I - EFFECT OF HERBICIDES ON YIELD OF STRAWBERRIES

OVER A THREE YEAR PERIOD

Treatment	Yield in cwt/ac					
	Maiden year		Second year		Third year	
	Dessert fruit	Total of all grades	Dessert fruit	Total of all grades	Dessert fruit	Total of all grades
1A	2.2	5.8	54.9	131.6	41.6	136.0
1B	1.8	5.8	52.8	133.1	47.5	156.7
1C	2.0	4.9	57.5	133.6	41.8	139.0
1D	2.2	4.9	63.7	134.7	39.9	149.4
2A	2.3	8.6	61.1	154.4	51.2	154.6
2B	2.0	6.6	51.8	124.3	40.8	133.6
2C	3.1	8.9	66.3	151.3	43.8	136.1
2D	3.2	7.7	62.2	157.5	42.6	135.5
2E	3.7	10.3	54.9	122.2	52.3	156.3
2F	0.5	3.4	67.3	144.0	61.4	185.3
3A	2.3	6.0	62.2	129.5	58.0	155.7
3B	2.5	5.7	51.8	126.9	44.2	146.8
4A	3.1	10.5	67.9	158.5	51.3	160.9
4B	2.7	6.7	67.9	160.6	53.0	156.8
SIG DIFF (P = 0.05)	1.98	2.83	16.86	26.99	15.79	22.63

Effects of treatments on weeds

Chlorpropham and dinoseb both gave a considerable degree of weed control through the winter until the early spring, after which the treatments became less effective as the season progressed. Chlorpropham effectively controlled all weeds present except *Senecio vulgaris* (groundsel) whilst dinoseb was effective against all weeds except *Poa annua* (annual meadow grass). 2,4-DES at all times of application reduced the population of broad-leaved weeds, but *Poa annua* was not completely controlled and with treatments applied early in the season there was a high rate of increase in the autumn. The combined chlorpropham and 2,4-DES treatment gave a good control of all weeds; dinoseb plus 2,4-DES was less effective due to lack of control of *Poa annua*. Both treatments compared favourably with the clean cultivated plots.

On the unsprayed plots, 14 cultivations were required in the three years to obtain a good commercial standard of weed control by hand hoeing and rotavation, whilst the plots kept continuously clean by similar methods required 37 cultivations.

Details of all cultivations are given in Table II, together with the actual cost of materials and estimates of labour costs per acre. Labour costs for herbicide application are based on a standard cost for knapsack sprayers.

TABLE II - ESTIMATED COST OF TREATMENTS PER ACRE

Treatment	Number of cultivations 1959-62	Cost of chemical treatments		Cost of cultivations	Total cost
		Materials	Total including labour		
		£	£	£	£
1A	11	3	11	86	97
1B	11	6	14	86	100
1C	11	4	12	86	98
1D	11	8	16	86	102
2A	14	8	18	131	149
2B	14	12	27	127	154
2C	14	16	36	127	163
2D	14	20	45	121	166
2E	12	24	54	113	167
2F	11	32	72	103	175
3A	11	26	59	71	130
3B	11	28	61	76	137
4A	14	-	-	137	137
4B	37	-	-	251	251

DISCUSSION

The first years results show that all of the materials used depressed the vigour and yield of strawberries when fruited as maiden plants. The effect of the March applications of 2,4-DES in the first year also reduced the vigour in the second year, but yields were comparable with other treatments. In the second and third year there was no marked depression of yield by any of the herbicide treatments compared with normal cultivations, the combined summer and autumn treatments giving the most efficient weed control. The cost of the combined chlorpropham and 2,4-DES sprays could be reduced by limiting the applications of 2,4-DES to one spray applied in May with only a slight increase in the number of cultivations required. Herbicide treatments reduced the amount of cultivation required, but in some cases increased the total cost of weed control. Where labour is a limiting factor, however, this can be justified. With all herbicide treatments the expenditure on cultivation was less than the cost of weed control by cultivation alone. Taking into account the cost of materials plus the cost of application, the summer herbicide treatments appear to be more expensive than mechanical cultivation up to a good commercial standard but the autumn sprays were cheaper. The combined sprays cost slightly less than normal mechanical cultivation over the whole year and gave a more efficient weed control.

Acknowledgements

The authors are indebted to D.J. Fuller, who initiated this work, and was responsible for the experiment during 1960.

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Research Report

THE USE OF SIMAZINE IN STRAWBERRY PROPAGATION BEDS

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Summary: Simazine at 0.5 and 1 lb/ac was applied in June to a propagation bed of 3 varieties of strawberry. Simazine did not reduce the number of well-rooted runners produced: its use increased the number of late-formed runners of 2 varieties. Treated plants cropped normally the following year.

INTRODUCTION

The removal of weeds from strawberry propagation beds (runner beds) by hoeing and hand pulling is perhaps more laborious than any other weed control practice in fruit growing. In removing weeds from the mat of stolons that forms, disturbance of rooting plants is inevitable and may delay or reduce the production of well-rooted plants. The tolerance of simazine by young strawberry plants was observed in 1958 (Van Staalduine, 1960).

METHODS AND MATERIALS

The first fully replicated trial of herbicide in runner beds was carried out at East Malling in 1961 to determine whether or not the use of simazine has any effect on the number or quality of runners produced. Eighteen single mother plants of each of the varieties Cambridge Favourite, Redgauntlet and Royal Sovereign, planted out at 9 x 12 ft to give isolated blocks, were used for each treatment. The treatments were simazine at 0.5 and 1 lb/ac, sprayed over the whole plot area, and unsprayed control plots given normal management. At the beginning of June when runner formation started, the ground was hoed and the simazine applied as a 50 per cent wettable powder in 100 gall/ac of water. After this the control plots were weeded three times. The runners were 'laid on' to encourage rooting and to keep the progeny of each mother plant separate.

RESULTS

No simazine damage appeared on any leaves. The rooted runners were counted in situ in mid-August: in the varieties Redgauntlet and Royal Sovereign there were no differences between treatments but simazine treated Cambridge Favourite had 50 per cent more rooted runners than the controls at this stage.

At the end of October the runners were lifted, graded and recorded. There were no important differences in the results obtained with the two rates of simazine and so these can be considered together. Cambridge Favourite gave 15 per cent more runners with a well-developed fibrous root system from the simazine treatments than from the controls. For the other two varieties there were only small differences. There were also many later-formed runners with unbranched or no roots. With both Cambridge Favourite and Royal Sovereign the simazine treatments gave an increase of nearly 40 per cent in this category, although with Redgauntlet there was again no difference from the control.

At lifting time weeds covered 70 per cent of the available ground on the control plots, up to 5 per cent on the 0.5 lb/ac simazine plots, and well under 5 per cent on the 1 lb/ac simazine plots.

Plants from each treatment were planted out in October, to fruit in 1962. There were no differences in yield between the treatments.

DISCUSSION

The use of simazine at 0.5 lb/ac in this strawberry runner bed had resulted in excellent weed control throughout the runnering period, whilst double this rate has not reduced runner production. The large increase in the number of late runners of Cambridge Favourite and Royal Sovereign formed on the simazine treated plots can be attributed to the fact that runner density on the control plots had reached such a level that removal of weeds had become impossible. These later runners are useless in autumn, but many might be usable if the runner bed were kept until the spring. In Cambridge Favourite, however, the large increase in the number of early rooted runners still showed in the autumn as an increase in the number of plantable runners. The runner bed trial has been repeated in 1962.

REFERENCE

VAN STAALDUINE, D. (1960) The use of simazine in strawberries. Proc 5th British Weed Control Conf 341-350.

Research Report

RECENT RESULTS FROM STRAWBERRY HERBICIDE TRIALS

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Summary: In a series of trials on Cambridge Favourite strawberries, simazine caused more crop injury when applied in spring than after harvest or in autumn. There was more injury when the period following spring application was wet than when it was dry. A previous application in autumn also increased the effect of spring treatment. A combination of winter and post-harvest simazine treatments caused no crop injury and compared favourably with application of chlorpropham in winter and 2,4-DES in spring and summer. For spring treatment, amiben granules, N-4-(4 chlorophenoxy) phenyl N'N' dimethylurea and N,N-dimethyl-a,a-diphenylacetamide (diphenamid*) appeared worthy of further trial. The relative resistance of certain newly planted strawberry varieties to simazine in autumn was found to be different from that in spring. A tentative classification of degree of resistance is given.

INTRODUCTION

In the last few years there has been increasing interest in the possibility of employing simazine as a selective herbicide in strawberries. Both in Britain (Sutherland 1960, Robinson 1962) and Holland (van Staalduine 1960) simazine has given promising results applied as an overall spray, but the safety of the treatment appears to depend to a considerable extent on time of application, climatic conditions, variety and soil-type (Ivens 1962). The series of experiments described was started in 1960 to obtain information on the first three of these factors, and to compare the effects of simazine with those of possible alternatives, such as 2,4-DES, chlorpropham and some newer experimental compounds. Of the latter, amiben and 2,5-dichloro-3-nitrobenzoic acid were reported as promising in strawberries by Amchem (1959) and N-4-(4-chlorophenoxy)-phenyl-N'N'-dimethylurea (CIBA 1983) by CIBA (1961). N,N-dimethyl-a,a-diphenylacetamide (diphenamid*) was shown to have selective properties in this crop in 1962 (Anon 1962).

METHODS AND MATERIALS

The trials were conducted on the Weed Research Organisation farm at Begbroke, north of Oxford, on a slightly acid, light sandy-loam soil with an initial organic matter content of 7.6 per cent overlying a calcareous gravel at 2 ft. The field had been ploughed out of grass in the summer before planting. In the main series of trials, Cambridge Favourite strawberries were planted either in October 1960 or March 1961. With the earlier planting, yields were recorded in 1961 and 1962. With the spring 1961 planting, plants were deblossomed in the first year and yields recorded in 1962. The variety trial was planted in September 1961. The plant spacing was 3 ft x 18 in. and yields were recorded

* Common name accepted by Weed Society of America but not by B.S.I.

from 24 plant plots (3 rows of 8 plants). The treatments were applied with an Oxford Prevision Sprayer at a volume rate of 50 gal/ac and were replicated 4 times. Where necessary, the plots were hoed before spraying so that the treatments could be applied to clean ground. The following formulations of chemicals were used:- simazine 50 per cent wettable powder, 2,4-DES 93 per cent sodium salt, fenuron 25 per cent wettable powder, chlorpropham 40 per cent emulsifiable concentrate, chlorpropham/fenuron mixture 16/4 per cent, amiben 24 per cent solution triethylamine salt (ammonium salt in later sprays) and 10 per cent ammonium salt granules, 2,5-dichloro-3-nitrobenzoic acid 24 per cent solution ("Dinoben") and 10 per cent granules, diphenamid 80 per cent wettable powder, N-4-(4-chlorophenoxy)-phonyl N'N' dimethylurea 50 per cent wettable powder (CIBA 1983), 2,6-dichlorobenzonitrile 50 per cent wettable powder, linuron 50 per cent wettable powder, dimethyl-2,3,5,6-tetrachloroterephthalate 50 per cent wettable powder ("Dacthal").

RESULTS

On the area planted in October 1960, two trials were conducted, one to compare the effects of simazine at different times of year, the other to compare the effects of simazine treatment with those of chlorpropham and 2,4-DES, alone or mixed with a small amount of fenuron.

<u>Simazine date of spraying trial</u> (H/8/61)

Simazine was applied at doses of 1 and 2 lb/ac in spring (10 April, 1961), after harvest (17 July) and in autumn (3 October). The spring treatment was the only one causing any obvious effect on the plants. With 1 lb/ac, the older leaves of a number of plants developed necrotic patches and there appeared to be a slight check to growth, but the yield (total of marketable and unmarketable) was not affected (see Table I). With the higher rate, all plants were affected to a varying degree, up to 15 per cent being killed and double this number severely stunted. The average yield reduction with this treatment was 22 per cent but, later in the season, the stunted plants appeared to recover to a large extent. There were no differences in ratio of marketable to unmarketable fruit.

In early autumn the dead plants were replaced by well-grown runners and in April 1962 a further dose of 1 lb/ac was applied to the plots treated with 1 or 2 lb/ac the previous spring, as shown in Table I. This had no obvious effect on the foliage and there was no significant yield reduction in 1962, even where the plants had been injured by the higher dose in spring 1961. A dose of 2 lb/ac was also tested in April 1962, and was applied to the plots which received 1 lb/ac the previous July. The effects on the plants were much less severe than those of the single dose of 2 lb/ac applied in the spring of 1961. There were slight leaf symptoms on a few plants but growth was not obviously reduced and there was no effect on yield. The difference in crop reaction in the two years is most likely to be associated with the rainfall. The table includes rainfall data for various periods before and after the spring applications and it will be seen that the greater injury in 1961 was associated with much higher rainfall in the period immediately after spraying.

TABLE I - THE EFFECTS OF SIMAZINE APPLIED AT DIFFERENT TIMES OF YEAR ON YIELD OF CAMBRIDGE FAVOURITE STRAWBERRIES

1961		1962	
Treatment	Yield tons/ac	Treatment	Yield tons/ac
SPRING (10 April)		SPRING (11 April)	
1. Simazine 1 lb/ac	0.62	Simazine 1 lb/ac	7.9
2. Simazine 2 lb/ac	0.51	Simazine 1 lb/ac	7.1
POST-HARVEST (17 July)		SPRING (11 April)	
3. Simazine 1 lb/ac	0.64	Simazine 2 lb/ac	7.4
4. Simazine 2 lb/ac	0.68	Untreated	7.0
AUTUMN (3 October)		SPRING (11 April)	
5. Simazine 1 lb/ac	0.65	Simazine 1 lb/ac	7.3
6. Simazine 2 lb/ac	0.67	Untreated	7.9
7. Control, handweeded	0.66	Control, handweeded	7.2
Sig. diff.(P = 0.05)	0.11	Sig. diff.(P = 0.05)	N.S.
Rainfall (in.) before and after spring treatment			
Week before spraying	1.05		0.83
Day before spraying	0		0.04
Day after spraying	0.43		0
Week after spraying	0.89		0.06
Month after spraying	2.58		1.22

Comparison of simazine with 2,4-DES, chlorpropham and fenuron (H/22/60)

In the trial comparing simazine with chemicals already used in strawberries, the winter treatments were simazine 1 lb/ac, chlorpropham 1 lb/ac and a chlorpropham/fenuron mixture at doses of 1 and 0.25 lb/ac. Combined with these treatments were either, spring applications respectively of simazine 1 lb/ac, 2,4-DES 4 lb/ac and a 2,4-DES/fenuron mixture at 4 and 0.25 lb/ac, repeated as necessary through the summer or, a post-harvest treatment with simazine. Details of the treatments applied in the periods prior to harvesting are shown in Table II, together with the mean yields.

TABLE II - THE EFFECTS OF VARIOUS WINTER (W) AND SPRING-SUMMER (S) TREATMENTS ON YIELD OF CAMBRIDGE FAVOURITE STRAWBERRIES. (THE DATES OF APPLICATION REFER TO THE 12 MONTH PERIODS PRIOR TO HARVESTING).

Treatment Dose/ac active material	1960/61			1961/62		
	Dates applied		Yield tons/ac	Dates applied		Yield tons/ac
	1960	1961	1961	1961	1962	1962
1. W Simazine 1 lb	Nov	-		-	Jan	
S " 1 lb, as needed	-	Apr	0.34	July	Apr	6.2
2. W Simazine 1 lb	Nov	-		-	Jan	
S " 1 lb, post-harvest	-	-	0.64	July	-	8.0
3. W Chlorpropham 1 lb	Nov	-		-	Jan	
S 2,4-DES 4 lb, as needed	-	Apr May	0.53	July Aug Oct	Apr	7.3
4. W Chlorpropham 1 lb	Nov	-		-	Jan	
S Simazine 1 lb, post-harvest	-	-	0.63	July	-	6.8
5. W Chlorpropham/fenuron 1 / $\frac{1}{4}$ lb	Nov	-		-	Jan	
S 2,4-DES/fenuron 4 / $\frac{1}{4}$ lb as needed	-	Apr May	0.56	July Aug Oct	Apr	6.6
6. W Chlorpropham/fenuron 1 / $\frac{1}{4}$ lb	Nov	-		-	Jan	
S Simazine 1 lb, post harvest	-	-	0.57	July	-	8.4
7. Control, handweeded	-	-	0.59	-	-	7.2
Sig diff (P = 0.05)			0.16			1.3

The rainfall figures for the periods before and after the April treatments are the same as those given in Table I

None of the initial winter treatments had any obvious effect on the plants, but, when the first spring treatments were applied, simazine caused injury resulting in the death of about 20 per cent of the plants and a considerable growth reduction in another 20 per cent. In this trial 1 lb/ac of simazine in the spring of 1961 caused much more damage than in the date of spraying trial described earlier. It is thus apparent that, although the winter simazine treatment had no obvious injurious effect, its persistence was sufficient to increase the degree of injury caused by the subsequent spring treatment. Of the other spring treatments, 2,4-DES applied in April caused slight formative effects, and the mixture with fenuron caused marginal chlorosis of the leaves whenever it was applied, but the growth of the crop did not appear to be affected and none of the combinations of winter and spring treatments had any effect on yield in the first year.

In the autumn of 1961, the dead plants were replaced. The second application of winter treatments was made in January and, again, no chemical had any evident effects, except for slight marginal chlorosis with the chlorpropham/fenuron mixture. As in the date of spraying trial, the spring treatment with simazine had less effect in 1962 than in 1961, again, presumably because of the rainfall difference. The yield with this treatment was significantly lower than with some of the others, and, although it was not significantly lower than the control, the latter may have been slightly depressed by weed competition resulting from a delayed hand-weeding in the late summer. Nevertheless, the percentage reduction is small compared with that of the previous year and the results suggest that not only have the plants badly checked in 1961 made a large degree of recovery, but also that the filled-in plants have grown well despite the two applications of simazine that they received.

The principal weeds appearing in the control plots during the 1960/61 winter were Poa annua, Cerastium spp., and Ranunculus bulbosus, while Matricaria spp., Capsella bursa-pastoris and Stellaria media occurred in smaller numbers. None of the treatments was effective against Ranunculus but all were effective against the two principal annuals and the general level of weed control was high. Simazine was more effective against Matricaria and Capsella than chlorpropham, and the mixture with fenuron gave better control of Matricaria than chlorpropham alone. On Poa annua, however, and to a lesser extent on Cerastium, chlorpropham gave control for a longer period than simazine so that, in April, it was proving more effective. During the spring and summer, simazine was markedly superior to either 2,4-DES or the 2,4-DES fenuron mixture, but where there was no treatment between winter and the post-harvest period, more hand-weeding was required on the simazine plots, especially in the first year. Neither of the two 2,4-DES treatments was effective against grasses and, although dicotyledons predominated in the summer, a single treatment only provided control for 4 to 6 weeks. A total of 5 applications was required to control weeds throughout the season and, even with these treatments a certain amount of hand-weeding was required.

During the second summer of the trial, far less weed has germinated on the treated plots than in the first season and fewer treatments have been required to keep the plots clean. On the control plots, however, although weeds have been prevented from seeding as far as possible, the weed population appears to be as high as ever and there has been no reduction in the amount of hand-weeding required.

Possible alternatives to simazine (H/15/61)

In the summer of 1961, a trial was started with amiben and the related compound 2,5-dichloro-3-nitrobenzoic acid. The chemicals were used both as aqueous sprays and as granules, dichloronitrobenzoic acid at doses of 3 and 6 lb/ac, amiben at 6 lb/ac only. The treatments were applied on 3 July and again on 12 October with the results shown in Table III.

TABLE III - THE EFFECTS OF A RANGE OF SOIL-ACTING CHEMICALS ON CAMBRIDGE FAVOURITE STRAWBERRIES AND A MIXED STAND OF WEEDS.

Treatment (Applied 3 July and 12 October, 1961)		1961				1962
		Mean score for crop damage Scale 0 - 3*		Per cent weed kill		Yield tons/ac
				Count	Estimate	
		14 July	17 Sep	14 Aug	15 Nov	
Sprays						
1. 2,5 dichloro-3-	3 lb/ac	0.5	0	46	40	-
2. nitrobenzoic acid	6 lb/ac	0.5	0	37	70	7.6
3. Amiben	6 lb/ac	2.0	1.5	64	80	6.5
Granules						
4. 2,5 dichloro-3-	3 lb/ac	0	0	38	45	-
5. nitrobenzoic acid	6 lb/ac	0	0	65	60	-
6. Amiben	6 lb/ac	0	0	65	90	7.5
repeated 17 Apr 1962	5 lb/ac					
7. Control, handweeded		0	0	0	0	8.5
Sig diff (P = 0.05)		-	-	-	-	0.93

*0-3 = slight, moderate and severe stunting

Treatment (Applied 17 Apr and 29 Aug 1962)		Estimated per cent weed kill		1962 Yield tons/ac
		14 May	3 Oct	
Sprays				
1. 2,4-DES	5 lb/ac	65	5	8.5
2. Simazine	½ lb/ac	95	90	7.9
3. CIBA 1983	5 lb/ac	85	85	7.7
4. Diphenamid	5 lb/ac	75	90	8.3
7. Control, handweeded		0	0	8.5
Sig Diff (P = 0.05)				N.S.

The liquid formulation of amiben affected the crop in a few days. As the young leaves expanded the leaflets were narrower than usual and a characteristic discolouration developed, a narrow dark green band appearing round the leaf margin, while the rest of the leaf was pale in colour. Runner production was also affected. At the same rate dichloronitrobenzoic acid caused slight colour effects, but these were only temporary and there was no obvious reduction in growth. The granules caused much less injury than the sprays and with the summer application neither chemical had any obvious effect.

When the treatments were repeated in autumn the amiben granules had no obvious, immediate effect. When the plants resumed growth in the spring, however, some distortion was noted although, again, the effect was less marked than with the spray. The difference between the two formulations is also indicated in the yield figures. Two applications of the liquid formulation caused a significant reduction in crop of nearly 25 per cent, while three applications of granules caused a smaller reduction which was on the borderline of significance.

As regards weed control, amiben was somewhat more effective than the nitro-compound, there was little difference between the liquid and granular formulations and the autumn application was generally more effective than that made in summer. In July no treatment gave more than moderate control of weeds and Poa annua was especially resistant.

Although dichloronitrobenzoic acid was evidently more selective in strawberries than amiben, it seemed unlikely ever to become available commercially and was, therefore, omitted from the trial in 1962. In its place as spring treatments were substituted CIBA 1983 and diphenamid together with 2,4-DES and a low rate of simazine. These treatments were applied on 17 April. They caused no visible injury and, as shown in the table, were all without effect on the following crop. 2,4-DES 5 lb/ac gave the least effective control of weeds, CIBA 1983 5 lb/ac was approximately equivalent to simazine 0.5 lb/ac, while diphenamid was somewhat less effective and appeared roughly similar to amiben.

A small observation trial with several other chemicals was sprayed in July 1961. When raked lightly into the soil, 2,6-dichlorobenzonitrile caused slight injury at 2 lb/ac and severe injury at 5 lb/ac. When the surface was left unraked there was only slight injury with 5 lb/ac but 2 lb/ac failed to control weeds. Linuron caused injury at 1 and 2.5 lb/ac while dimethyl-2,3,5,6-tetrachloroterephthalate at 4 and 10 lb/ac had no obvious effect on either crop or weeds.

Varietal differences in response to simazine (H/23/61 and H/2/62)

In a trial conducted to obtain preliminary information on varietal differences in susceptibility, simazine was applied on 12 October, 1961 at doses of 0.5, 1 and 2 lb/ac to 13 varieties of strawberry planted about 3 weeks earlier. The effects were compared with similar treatments applied on 25 April, 1962. In all, 12 plants of each variety were treated and each plant was scored for injury at intervals. With 1 lb/ac and 0.5 lb/ac there was generally much less injury than with 2 lb/ac and the effects were less consistent. To obtain the classification shown in Table 4, the average has been taken from scores of the 2 lb/ac plots at two dates and the range of values has been subdivided equally into four. The terms resistant, moderately resistant, moderately susceptible and susceptible have been tentatively assigned to these categories but it is emphasised that the classification is of comparative value only and that it refers to a relatively high dose applied at a relatively susceptible time.

TABLE IV - THE RELATIVE RESISTANCE OF STRAWBERRY VARIETIES TO APPLICATION OF SIMAZINE AT 2 LB/AC IN AUTUMN AND SPRING BASED ON VISUAL SCORING ON A SCALE 0-5

Autumn application (3 weeks after planting)

Resistant	Moderately Resistant	Moderately Susceptible	Susceptible
Redgauntlet (1.2)	Huxley (1.9)	Senga Sengana (2.5)	Cambridge Prizewinner (3.2)
Talisman (1.4)	Merton Princess (2.0)	Cambridge Rival (2.6)	Early Cambridge (3.2)
Cambridge Favourite (1.5)		Regina (2.8)	Royal Sovereign (3.6)
Cambridge Rearguard (1.7)		Cambridge Vigour (2.9)	

Spring application (Maiden plants)

Resistant	Moderately Resistant	Moderately Susceptible	Susceptible
Cambridge Prizewinner (0.6)	Talisman (1.4)	Cambridge Rearguard (2.1)	Regina (3.0)
Huxley (0.8)	Cambridge Favourite (1.5)		Senga Sengana (3.2)
Redgauntlet (1.2)	Cambridge Vigour (1.5)		
	Royal Sovereign (1.5)		
	Early Cambridge (1.6)		
	Merton Princess (1.7)		
	Cambridge Rival (1.9)		

Basis of scoring $\frac{1}{2}$ = slight scorch on a few leaves
1 = moderate scorch, growth reduced
2 = growth reduced to about 50 per cent
3 = severe reduction in growth, plant appears to be recovering
4 = severe reduction in growth, plant appears to be dying
5 = dead.

It is evident that strawberry varieties differ considerably in their response to simazine and the results suggest that time of year (or possibly speed of establishment) influences the relative susceptibility. With the autumn application, for example, Royal Sovereign was the most susceptible species, most plants being killed by 2 lb/ac, whereas in spring it suffered relatively little injury. Cambridge Prizewinner also was one of the more susceptible in autumn yet appeared to be the most resistant when treated in spring. Redgauntlet, Talisman, Huxley and Cambridge Favourite were among the most resistant at both dates.

DISCUSSION

The results of the present series of trials agree with work in Holland (Van Staalduine 1960) and N. Ireland (Robinson 1962) in showing that simazine is less safe when applied in spring than after harvest or in autumn. Possible reasons for this have been discussed by Ivens (1962). The injury to the plants is greater in some years than others and the difference is probably associated with differences in climatic conditions. A single application of simazine of 1 lb/ac was not sufficient to reduce yield in either year, but in the wetter spring it caused visual symptoms of injury on the foliage and more severe damage when it followed a similar treatment in autumn. The safety margin with a dose of 1 lb/ac is evidently not large enough for spring treatment to be recommended under our conditions. Lower rates are often sufficient to give reasonable weed control, however, and further work with a dose of 0.5 lb/ac appears to be justified.

On newly planted strawberries 1 lb/ac of simazine applied in autumn has caused little injury in the present trials. In the variety trial, however, although this dose had little effect on most varieties, 2 lb/ac was more generally damaging, so that, again there is an insufficient margin of safety with 1 lb/ac and further investigation of a lower rate is required.

Varietal differences in susceptibility to simazine were considerable, but, with some varieties, appeared to vary according to the time of application. With these, the differences probably depend at least to some extent, on differences in rooting behaviour. With those whose reaction was much the same at different times of year, the degree of resistance noted is probably more closely related to the inherent resistance of the variety. The classification of Talisman as one of the most resistant varieties agrees with van Staalduine (1960), though under his conditions, Senga Sengana was more resistant than indicated by the present observations. Cambridge Favourite, which Caseley (1961) suggested as being exceptionally resistant to simazine, reacted in much the same way as Talisman in our trials. Differences in susceptibility are only likely to be of practical importance if simazine is applied at susceptible stages of growth or at dangerously high doses.

Of the chemicals tested, simazine was generally more effective as a herbicide than any other, both in the range of species killed and in the duration of control. Under certain conditions, however, particularly in a mild winter in areas where Poa annua and Cerastium spp. or Stellaria media are the principal weeds, and where there are few composites, chlorpropham can give equally good results and may be a useful alternative. Of the newer compounds, tested particularly as alternatives to simazine for use in spring or soon after planting, the most promising appear to be amiben in granular form, CIBA 1983 and diphenamid, though it may yet be found possible to obtain adequate control of weeds at those times without injuring the crop by using lower doses of simazine.

Acknowledgements

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Research Report

A COMPARISON OF CHEMICAL AND CULTURAL METHODS OF WEED CONTROL IN STRAWBERRIES

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Summary: An experiment in progress for over three years showed that a system of weed control based entirely on herbicides with no soil disturbance was a promising alternative to cultivation in strawberries. Crop yield was similar under both treatments except in the first year when yield reduction, attributed to chlorpropham injury, occurred on herbicide-treated plots. The soil crust which formed on these plots had no obvious adverse effect on plant performance but resulted in increased run-off and soil erosion. Mulching with straw and farmyard manure prevented erosion but had no significant effect on the crop. Weed control was more effective and less expensive on herbicide-treated plots especially in the last year.

INTRODUCTION

In spite of the widespread belief among practical growers in the need for cultivation to maintain satisfactory conditions for plant growth, interest is increasing in the possibility of using herbicides to eliminate the need for cultivation in many crops (Elliott et al. 1962). Promising preliminary results were obtained at Loughgall in 1957 and 1958 with a system of non-cultivation in blackcurrants and gooseberries and an experiment was started in 1959 to compare the control of weeds in strawberries by traditional cultivation and by the use of a herbicide programme without any soil disturbance.

METHODS AND MATERIALS

The strawberries, variety Cambridge Vigour, were planted in October 1958 and were clean cultivated until July 1959 when the different weed control treatments were started. The soil, which was a bright brown clay loam developed from local carboniferous limestone drift, contained in the 0 - 4 in. layer approximately 25 per cent coarse sand, 40 per cent fine sand, 10 per cent silt and 20 per cent clay.

The trial was laid out in four randomised blocks (each 4 yd x 48 yd) which sloped uniformly to the west with a gradient of 1 in 7. The main plots were 2 yd x 48 yd and contained a single recorded row with a guard row on each side. During 1960 slight run-off and soil erosion occurred from non-cultivated plots and it was considered that some means of inhibiting erosion was necessary. Consequently, in 1961, main plots were divided into four sub-plots (each 2 yd x 12 yd) and mulching treatments were superimposed on two of these. These treatments were applied between the plant rows and consisted of well rotted farmyard manure at 10 tons/ac and wheat straw at 2 tons/ac. The manure was applied in April 1961 and application was repeated on the same plots in April 1962. In both years the straw was applied post-flowering in early June to avoid increasing the risk of frost damage. On cultivated plots, the manure and straw were subsequently worked into the ground, but both mulches persisted on non-cultivated plots throughout the year. No additional mulch was used to protect the fruit from soil splashing.

Weed and runner control

In July 1959, the main weeds present in the experimental area were *Poa annua*, *Stellaria media* and *Senecio vulgaris*; these were controlled as follows:-

Herbicide-treated plots

The herbicide programme was not planned in detail beforehand but the most suitable treatments were used according to which weed species were present or expected. In the first year, it was not possible to obtain complete weed control with herbicides of known safety, but where it was necessary to include a herbicide believed to be lacking in the required selectivity, application was made either as a spot-treatment or as a carefully directed spray. For example, application of dalapon was necessary in April 1960 because of the occurrence of well established plants of *Poa annua*. As strawberries are known to be susceptible to overall application of dalapon (Robinson, 1958), the spray was directed carefully on to the grass and little wetting of the strawberry foliage occurred. Strawberry runners were controlled by a directed application of diquat or paraquat.

Herbicide treatments were usually applied at 50 gal/ac by means of a pressure-retaining knapsack sprayer; where directed sprays were necessary these were applied in calm weather. In 1962, the nozzle was sometimes replaced by a dribble bar (using the principle of the Plant Protection Ltd. inter-row weeder (Plant Protection Ltd., 1962) to enable spot treatment to be carried out irrespective of wind conditions.

The herbicide programme used to give complete control of weeds and runners between July 1959 and October 1962 is shown in Table I.

Clean-cultivated plots

Usually five cultivations and hoeings were needed each year to maintain cultivated plots in a reasonably clean condition. Between July 1959 and October 1962, the plant rows were hand-hoed and the alleys rotary-hoed on the following dates:-

1959 - 28 July, 28 August, 13 October, 5 November.
1960 - 5 April, 9 June, 1 August, 14 September, 26 October.
1961 - 24 February, 27 March, 10 May, 27 July, 7 September.
1962 - 11 April, 13 June, 20 August, 21 September, 10 October.

Measurements of plant and fruit size, and leaf nutrients

On two picking dates during the harvest period in 1960 and also in 1961 and 1962 all saleable fruit was divided into the three grades listed below and the weight of fruit in each grade was recorded.

Grade I. Fruits more than 3 cm in diameter.
Grade II. Fruits between 2 and 3 cm in diameter.
Grade III. Fruits less than 2 cm in diameter.

The heights and spreads (across the row) of plants were measured periodically with calipers made for the purpose.

In 1961 and 1962, leaf samples for nutrient analysis were taken immediately after the crop had been picked. On each occasion, about fifty young fully expanded leaves were taken from each sub-plot and the samples were analysed for nitrogen, phosphorus, potassium, calcium, magnesium and sodium.

TABLE I - HERBICIDE PROGRAMME USED TO SUPPRESS WEEDS AND RUNNERS (JULY 1959 - OCTOBER 1962)

Date of application	Main 'weeds' present	Herbicide lb/ac	Method of application*	Cost of herbicide per acre of crop
29.7.59	None; ground hoed on 28.7.59	2,4-DES 6	Overall	£6. 0. 0.
28.8.59	Seedlings of _Senecio vulgaris_, _Stellaria media_ and _Poa annua_	Simazine 1	Overall	£3.10. 0.
1.12.59	None	Chlorpropham 2	Overall	£2. 0. 0.
27.4.60	_Poa annua_) _Senecio vulgaris_)	Dalapon 3.7 Diquat 1	Spot treatment Spot treatment	£1.12. 0. £2. 0. 0.
3.5.60	As on 27.4.60 but weeds dying	2,4-DES 6	Overall	£6. 0. 0.
4.8.60	_Stellaria media_, _Senecio vulgaris_ and strawberry runners	Diquat 0.5	Carefully directed spray	£1. 0. 0.
31.8.60	_Poa annua_ and strawberry runners	Paraquat 0.5	Carefully directed spray	£-.17. 0.
7.11.60	_Stellaria media_	Simazine 1.5	Overall	£5. 5. 0.
18.5.61	None	2,4-DES 6	Overall	£6. 0. 0.
10.8.61	_Poa annua_	Simazine 2	Spot treatment	£3.10. 0.
18.9.61	Strawberry runners	Paraquat 0.5	Carefully directed spray	£-.17. 0.
27.10.61	Strawberry runners	Paraquat 1	Carefully directed spray	£1.14. 0.
21.11.61	None	Simazine 1.5	Overall	£5. 5. 0.
13.8.62	Strawberry runners	Paraquat 0.5	Carefully directed spray	£-.17. 0.
21.9.62	Strawberry runners	Paraquat 1	Carefully Directed spray	£1.14. 0.

*Spot-treatments were applied to the weeds only; carefully directed sprays were applied to the entire soil surface not occupied by crop, avoiding the strawberry foliage as much as possible.

TABLE II - EFFECT OF METHOD OF WEED CONTROL AND MULCHING TREATMENT ON PLANT HEIGHT

Method of weed control	Mulching treatment	Height; in.					
		28.4.60	8.6.61	28.8.61	25.10.61	31.5.62	27.9.62
Herbicides only	None	8.2	12.2	8.8	8.0	10.5	10.9
	Straw			9.1	8.4	10.5	11.4
	Manure			9.1	8.1	10.5	11.1
	Mean	8.2	12.2	9.0	8.2	10.5	11.1
Cultivation	None	9.3	12.7	8.1	7.8	10.8	10.6
	Straw			8.0	7.8	10.6	11.1
	Manure			8.3	8.1	10.7	11.5
	Mean	9.3	12.7	8.1	7.9	10.7	11.1
Significant difference (P = 0.05) Between method of weed control means		0.5	NS	NS	NS	NS	NS

TABLE III - EFFECT OF METHOD OF WEED CONTROL AND MULCHING TREATMENT ON PLANT SPREAD

Method of weed control	Mulching treatment	Spread; in.					
		28.4.60	8.6.61	28.8.61	25.10.61	31.5.62	27.9.62
Herbicides only	None	11.3	18.0	18.8	17.4	17.9	21.9
	Straw			18.7	17.1	17.9	22.4
	Manure			18.3	17.0	17.8	22.2
	Mean	11.3	18.0	18.6	17.2	17.9	22.2
Cultivation	None	13.3	18.0	16.3	15.0	17.6	18.7
	Straw			16.5	14.1	16.7	19.5
	Manure			16.6	14.8	17.1	19.3
	Mean	13.3	18.0	16.5	14.6	17.1	19.2
Significant difference (P = 0.05) Between method of weed control means		NS	NS	1.3	0.9	NS	0.6

RESULTS

Effect on plant size

Growth was normal on all plots until March 1960 when crop foliage on herbicide-treated plants appeared chlorotic with marginal necrosis. Measurements of plant height and spread in April 1960 showed that the size of these plants was reduced, the decrease in height being significant (P = 0.05) (Table II). Similar symptoms occurred in other trials where chlorpropham was applied during the mild winter of 1959/60 and the injury in the present experiment was attributed to the chlorpropham applied on 1 December 1959. Damaged plants made fairly good recovery during May and June 1960 but were still obviously reduced in size at fruiting time. After harvest, recovery appeared to be complete. Measurements made during 1961 and 1962 showed that there was no significant difference in plant height between treatments, but plant spread was significantly greater (P = 0.05) on herbicide-treated plots in the autumn of both years (Table III). This difference seemed largely to be due to the removal of some of the outside leaves on cultivated plots during mechanical cultivation. Throughout the course of the experiment, differences between mulching treatments were not significant.

Effect on crop yield and fruit quality

Crop yield was reduced on herbicide-treated plots in 1960, but in 1961 and 1962 the differences in yield were not significant (P = 0.05) (Table IV).

TABLE IV - EFFECT OF METHOD OF WEED CONTROL AND MULCHING TREATMENT ON CROP YIELD

Method of weed control	Mulching treatment	Yield cwt/ac		
		1960	1961	1962
Herbicides only	None	95.4	141.0	94.7
	Straw	-	123.4	91.8
	Manure	-	136.0	94.3
	Mean yield	95.4	133.5	93.6
Cultivation	None	113.0	126.7	94.8
	Straw	-	120.2	91.8
	Manure	-	138.9	95.0
	Mean yield	113.0	128.6	93.9

Significant difference (P = 0.05)

Grading the berries revealed no significant difference in fruit size between treatments in any year.

Effect on leaf nutrients

In 1962, the nitrogen status of the leaves was slightly higher on herbicide-treated plots, both mulched and unmulched, than on corresponding cultivated plots; mulching with manure also resulted in an increase in leaf nitrogen. Differences between treatments in the other nutrient elements were not significant.

Effect on weed control

The herbicide programme gave very effective control of weeds and on no occasion did weed growth cover more than 20 per cent of the soil surface. Control was particularly good in 1961 and 1962 when the ground remained in an almost weed-free condition; *Senecio vulgaris* and *Stellaria media* were completely absent and the main weeds were occasional plants of *Poa annua* and strawberry seedlings.

Diquat and paraquat gave good control of strawberry runners. Some scorching occurred on the outside leaves of parent plants and, occasionally, the young leaves showed slight chlorosis, apparently as a result of translocation from treated runners. The damage seemed to be negligible, however, and subsequent growth was not affected.

Weed control was less satisfactory on cultivated plots. Hoeing five times each year prevented the occurrence of any serious weed infestation but the area of ground covered with weeds immediately before each hoeing ranged from 25 to 70 per cent. *Senecio vulgaris* and *Stellaria media* were still the most prevalent weeds on cultivated plots in 1962 and *Poa annua* was also plentiful.

Effect on soil conditions

Within two months of the cessation of cultivation, a hard crust had formed on the surface of herbicide-treated plots. On unmulched plots the surface continued in this condition for the remainder of the experimental period, but soil cracking during dry weather and earthworm burrows prevented the surface from becoming completely sealed. During the first ten months of 1962, when treatment with simazine was unnecessary, about 50 per cent of the exposed surface became covered with moss (*Funaria hygrometrica*). On cultivated plots a crust occurred intermittently but was broken up by periodic hoeing.

The partial sealing of the surface of unmulched, herbicide-treated plots resulted in erosion, as indicated by the presence of quantities of washed soil at the lower end of these plots after heavy rain storms. Both mulching treatments appeared to prevent erosion and no soil loss was evident from mulched plots from spring 1961 onwards. On cultivated plots, the crust was usually sufficiently broken to allow rain to infiltrate, but soil loss occurred on some occasions, particularly in the winter.

Cost of treatment with herbicides

Detailed costings on weed control operations were not kept, but using the prices prevailing at the time (Column 5, Table 1) and assuming that spot-treatment and directed sprays were applied to half the area treated overall, the cost on an acreage basis of the herbicides used between 1958 and 1962 was as follows:- 1959 (6 months only) £11.10. 0., 1960 - £16.14. 0., 1961 - £17. 6. 0., 1962 (10