POTATOES FREE OF WEEDS

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During the past five years there has been a rapid development of chemical weedkillers for potatoes. The herbicides that are now commercially available are being offered to farmers as a substitute for traditional mechanical cultivations. It seems therefore that potato husbandry in the future may involve the choice of chemicals or cultivations or perhaps combinations of the two. Whatever the method, the individual steps necessary to produce a clean and vigorous crop will be dictated by a knowledge of the way in which the potato plant grows, and of the circumstances in which weeds compete with it. Only by an understanding of crop and weeds can a farmer prescribe the most appropriate remedy. It is the object of this paper to describe and clarify the nature of the weed problem in potatoes with particular reference to the types of herbicidal performance that are required.

Potato Growth.

The potato Solanum tuberosum L. is grown as an agricultural crop from tubers planted in the soil, allowing for considerable flexibility in the arrangement of the crop in the field, and in the individual pattern of plant development. In the Midlands of England main crop potatoes are planted at any time from mid-March until the end of April according to the season and the state of the soil. In the warm areas of the West and South-West they are planted earlier, while in the North of England and Scotland, planting may be later. A survey of potato growing carried out in England and Wales in 1948-50 (Boyd & Dyke 1950) together with experimental results obtained over these and subsequent years (Dyke 1956), (Harvey & Short 1959) confirms that maximum yields are not normally obtained from maincrops planted after the first two weeks in April. One of the aims of the widely accepted practice of chitting seed is to obtain early emergence, and a recent paper (Headford & Ingersent 1961) described the emergence of chitted King Edward seed $2\frac{3}{4}$ weeks after planting, this compared with an interval of $4\frac{1}{2}$ weeks for the unchitted seed. Another trial series (Baldwin 1963) demonstrated the earlier emergence of chitted seed in contrasting seasons when such factors as dry and cold weather and fertiliser scorch were involved. Depth of planting may also affect the time of emergence. Providing that the soil is warm, potatoes planted at a shallow depth are likely to emerge more quickly than those planted deeper. Experiments in Norfolk (Terrington E.H.F. 1963) showed a more rapid plant emergence when 2 - 4 in. of soil covered the potatoes in beds than where 6 in. covered the tubers in conventional rows. However, in another experiment on the same farm, which involved covers of 4 - 8 in. soil over the potatoes in rows, no differences in speed of emergence were observed.

The experience at Begbroke Hill over the past four years is shown in Table 1. The earliest planting occurred on the 28th March and the latest on the 26th April, the majority of plantings occurred during the first three weeks of April. Thereafter the potatoes took from 24 to 38 days to reach a stage at which herbicide application just prior to emergence occurred. The assessment of this stage was a subjective one based on examination of the young shoots growing towards the soil surface. The time intervals in

Table 1

Early growth potato crops at Begbroke Hill

Year	Variety	Chitted or unchitted.	Date of planting	Herbicide applied just prior to emergence	Interval in days.
1961	Farmcrop Majestic	unchitted	Mar.28-29	May 3	35-36
1961	Experiment Majestic	unchitted	Apr.13	May 11	28
1961	Experiment Majestic	unchitted	Apr.17	May 10	23
1962	Experiment Majestic	unchitted	Apr.12	May 20	38
1962	Experiment Majestic	unchitted	Apr.19	May 25	36
1962	Experiment Majestic	unchitted	Apr.26	June 1	35
1963	Exp. King Edward	chitted	Apr.4-8	May 4	26-30
1963	Exp. King Edward	chitted	Apr.8	May 4	26
1964	Exp. King Edward	chitted	Apr.1-3	May 1	28
1964	Exp. King Edward	chitted	Apr.6	May 5	29
1964*	Exp. K.Edward, Maj.	chitted	Apr.9-10	May 4	24-25
1964	Farmcrop K. Edward, Maj. Ulster Beacon	unchitted	Apr.10-14	May 12	28-32
1964	Farmcrop K. Edward	unchitted	Apr.18	May 12	24

*In this experiment the potatoes were planted 2 - 3 in. deep. All other potatoes were planted 3 - 4 in. below the soil surface.

Table 1 suggest that chitted seed tended to reach point of emergence rather earlier than did that which was unchitted, and also that early planted potatoes took rather longer to emerge than did late planted. These experiences suggest that there followed after planting a period of $3\frac{1}{2}$ to 5 weeks during which the crop provided no sort of competition with weeds, and during which weed control could easily be achieved by chemical or cultivation providing neither penetrated the soil to a depth sufficient to injure the young shoots and roots of the potato seed.

The duration of potato emergence is extremely variable; but comparatively unimportant so far as weed control is concerned because once an appreciable proportion of the crop is visible the circumstances change and the crop enters a new phase in its growth with more exacting requirements of weed control.

A study of farm and experimental records over the past four years at Begbroke Hill has shown that tractor cultivations with weed control as the object, were carried out during the four weeks after the beginning of potato emergence. This was the period during which weed suppression was necessary because of the absence of a full foliar canopy. It had been hoped to give guidance from the records as to the time taken to form a full canopy but this proved impossible because of the many inter-acting factors. Varieties differ markedly in the type of foliage that they produce. Potatoes planted in rows 28 or 30 in. apart take longer to fill the space between the rows than do those planted 24 or 26 in. apart. Adherence to a conventional pattern of planting in rows leads quickly to a cover within the row but slowly to a cover between the rows, while the planting of seed in a uniform pattern leads to an overall cover more quickly than does a conventional row arrangement. A high density of seed provides a canopy more quickly than low density. It seems that the achievement of a full canopy varies tremendously from field to field but that it could take from three to six weeks after the beginning of emergence. At Sutton Bonnington Majestic potatoes planted on the 13th April, emerged in mid-May, achieved 50% of their leaf area index by the third week in June and maximum leaf area index in about the third week in July. (Radley et al. 1960). During this difficult period between emergence and the formation of a full canopy, control by cultivation or chemical must be selective in the sense that it is achieved without damage to the aerial parts of the crop or to those contained in the soil.

Once the crop achieves a full canopy it is effective in suppressing weed growth. However, this phase of its life can be quite short. By mid-August, or earlier, if attacked by blight, the senescence of the leaves leads to an opening of the canopy and the crop is once again open to weed invasion. This latter period need not be serious if the crop enters it free of weeds because it occurs at a time of year when weed germination and growth is not vigorous.

The performance of weeds.

In considering how weeds may perform it is necessary to distinguish between potato crops that are cultivated for weed control and those that receive no soil disturbance and are subsequently sprayed with a herbicide. The reason for this lies in the effect that cultivations have on weed germination and emergence. A paper presented to this conference (Chancellor 1964) mentions a programme of three experiments, one of which is reported. The experience of these experiments is that the soil disturbance inherent in cultivation is a major factor bringing about the germination of annual weeds of arable land. This is in accordance with the experience encountered in preparing vegetable seedbeds (Roberts 1963). When farmers seek to control weeds in their potatoes by means of soil disturbance, they use a great variety of tractor mounted implements, and these they operate freely according to the needs of their particular crop and weed situation. It is therefore impossible to draw up any general principle of weed control except that of hitting the weeds as often and as effectively as is required.

When, however, the intention is to leave the potatoes and the soil undisturbed after planting so that the weeds may eventually be controlled by a herbicide, it can be expected that the weeds will emerge according to a pattern. The months of March, April and May are those during which rising soil temperature in association with the soil disturbance of seedbed preparation creates the conditions under which annual weeds will germinate. This they do in increasing numbers until a peak of emergence is reached and thereafter the number of fresh germinators falls off. These events vary from field to field according to the nature and quantity of weed seed present, and vary from year to year according to changes in climate, but the general pattern remains substantially the same.

An example of this may be seen on the control plots of a trial carried out at Begbroke Hill in 1964 (No. AA.21.64, see appendix for experimental details). No crop was planted, but the land was worked down as if for potato planting on the 31st March, 8th April and 17th April. The results in terms of total weed emergence are shown in Figure 1. As weeds usually vary in number from one plot to another, reliable comparisons can only be made of the different numbers in the same fixed quadrats assessed at different times, these are marked 'A' or 'B' in the figure. After working the land down to a seedbed on the 31st March, 39 weeds had emerged 25 days later, but during the next 10 days 72 more emerged to bring the total up to 111. After working down on the 8th April, 116 weeds had emerged 26 days later, and only 6 more emerged during the next 10 days. After working down on the 17th April, 89 weeds emerged after 26 days, and after an interval of a further 23 days the number recorded was virtually the same (88). The overall implication of these results on the plots marked 'A', which is confirmed by those marked 'B', is that during the first three weeks of April relatively few weeds emerged, during the last week of April and the first fortnight in May large numbers emerged, and thereafter in the second half of May and in early June, the numbers emerging were again small. It is also interesting to study the shaded parts of the histograms, which show the numbers of weeds that could be positively identified, the others being so newly emerged and small as to defy identification. 25 days after working down the numbers identifiable were, 31st March - none, 8th April - 31 out of 111, 17th April - 69 out of 89. As the date of working down advanced from March into April, so the proportion of identifiable weeds increased at the 25 or 26 day assessment, conversely, the number of newly emerged weeds that were too small to be identified declined to a very small part of the whole on the plots worked down on the 17th April. Thus can be seen a marked contrast in the pattern of weed emergence following the earliest and latest dates of working down a fortnight later. The former gave rise to a slow well spread emergence while that of the latter was fast and compact.

Some insight into the timing of this pattern of weed emergence may be gained by studying the meteorological records of the period (Table 2). With a total of 53.7 mm rainfall occurring on 7 days, the last half of March was damp. There should have been ample moisture in the soil for germination after working down on the 31st March. The average air temperature was low during the first week of April but it rose steadily as April progressed. The mean soil temperature at 2 in. depth remained low until the week beginning the 12th April and then rose quickly. Particularly significant is the minimum end of the soil temperature range, this rose from 1.0 to 8.3°C. from one week to the next after the 12th April. The second half of April was thus damp and warm, and these conditions were ideal for weed germination, and emergence after an appropriate time interval. May was warm but comparatively dry, there being only 22.9 mm rain occurring on 7 days of the month. The top inch or two of soil in which the majority of annual weeds germinate was thus damp and cool during the first half of April, damp and warm during the second half, and, in May the

Table 2.
Meteorological information at Begbroke Hill, 1964.

		MARCH				APRIL					MAY				JUNE			
	week	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4
	date inc.	1 7	8 14	15 21	22 28	29 4	5 11	12 18	19 25	26 2	3 9	10 16	17 23	24 30	31 6	7 13	14 20	21 27
TOTAL RAINFALL IN MM (>0.04 in. / >1.02 mm } wet day)		6.6	11.2	36.5	17.0	2.3	0	14.4	21.3	11.5	4.7	1.4	14.8	2.0	43.4	28.0	12.1	0
NUMBER OF WET DAYS		0	1	5	2	1	0	2	5	3	2	1	3	1	5	3	3	0
MEAN DRY BULB TEMP. in °C.		1.8	4.7	3.4	7.1	2.6	7.1	8.4	9.3	11.7	12.2	13.0	14.0	13.4	12.3	15.6	13.5	14.9
MEAN SOIL TEMP. AT 2 in at 9.20 am in °C		2.4	2.2	3.5	5.7	2.7	4.5	9.2	8.9	11.2	12.3	13.7	15.4	16.0	12.9	17.5	16.2	16.1
RANGE	MINIMUM °C.	0.4	0.1	0.7	2.7	2.1	1.0	8.3	8.0	9.7	10.7	12.2	12.9	14.0	9.2	14.8	13.0	11.4
RANGE	MAXIMUM °C.	6.1	6.6	7.4	7.8	3.6	8.4	11.0	9.7	13.1	13.8	15.0	19.0	19.5	16.4	20.1	20.0	21.6

soil was warm but tending to dry out on the surface.

Had this weather pattern been different, the emergence of weeds would not have occurred in the way that has been described. Since the germination and emergence of annual weeds occur as a result of particular soil conditions which are in turn brought about by climate, the pattern of weed emergence can to some extent be predicted by a study of the weather. An ability to understand the factors that are inter-acting to produce germination, together with an observation of the weeds as they emerge during the period after planting potatoes, can assist in the logical choice of a herbicide when the time for spraying arrives.

Annual Weed Control by Chemicals.

For purposes of controlling weeds in growing crops there are available a great variety of chemicals, and these can be grouped in accordance with their mode of action and therefore the way in which they should be used. Some aspects of their properties which are relevant to the potato are listed below.

a. Activity through the soil. This group of chemicals is taken up through the roots of plants so they need to be in the rooting zone of weeds shortly after they germinate. Application of the chemical to the soil after the weeds have emerged often leads to poor control. Some chemicals are sufficiently soluble to permit application to the soil surface without incorporation, but others require incorporation, as do some that are volatile. They vary in their persistence in the soil.

b. Active through both soil and foliage. To be of agronomic use, these chemicals must be capable of moving into the root system of weeds after application to the soil surface, because the presence of a crop usually precludes incorporation. Their foliar action is more effective on young weeds than on those that are well established. Chemicals of this type can be used to control emerged weeds and those yet to emerge, though in the latter case their effectiveness over a period of time depends on their persistence in the soil.

c. Active only through the foliage. If chemicals in this group are non-selective, they can only be used successfully when all the weeds are induced to emerge before the crop. If selective, they can be used after crop emergence, but experience suggests that they are often successful in this context only when the crop quickly provides a foliar canopy to suppress any further germination of weeds.

All these types of chemical action have been considered and indeed used experimentally for annual weed control in potatoes with the exception of the selective foliar spray, no suitable chemical for this purpose having been developed as yet. Purely soil acting chemicals applied at or shortly after planting have not found favour, possibly because of the long period of weeks during which they must suppress all weed growth before the potatoes form a canopy over the soil. It requires the presence of but one resistant weed species for an undesirable infestation to occur in these circumstances. All the chemicals which were available to farmers in 1964 were recommended for application just prior to the emergence of the potatoes, they consisted of three foliar/soil acting herbicides (linuron, a prometryne and simazine mixture, and dinoseb) and two non-selective foliar herbicides (diquat and paraquat). None of these chemicals are capable of controlling perennial weeds in potatoes.

When seeking to control weeds in his potatoes, a farmer has four broad alternatives. He may cultivate throughout the whole life of the crop. He may opt for chemical weed control up to potato emergence and rely on cultivation thereafter. He may cultivate before emergence and then apply a chemical to give weed control after emergence. Or he may rely on herbicides for control throughout the whole period from planting to the formation of the crop canopy. The first alternative is the traditional method and the one that is most commonly used, so little need be said about it here, apart from the observation that repeated cultivation for weed control is akin to "making a stick to beat ones own back" because of the effect of soil disturbance in stimulating germination.

The second alternative of using a herbicide to control weeds up to emergence and cultivating thereafter could have appeal in certain managerial circumstances where it is desired to save tractor work during a busy month of the year. It would also permit the land to be worked into ridges after potato emergence if this were desired. The herbicide in this context would require no residual action if it were put on just prior to potato emergence because weeds germinating afterwards would be controlled by cultivation. The cheapest and most comprehensive foliar spray would seem to be the correct one for these circumstances; cheap because the same operation might be done by harrowing, though this latter act would involve starting cultivation before rather than after potato emergence; and comprehensive because it would be required to control both mono- and di-cotyledonous species. Diquat and paraquat would appear well suited to this use apart from their cost.

The third alternative may occur where the potatoes have, of necessity, been planted in a sub-optimal seedbed and it is desired to work the land after planting. In this case the requirement is for a purely soil acting herbicide to be put on after the last cultivation to control all the weeds germinating thereafter. Bearing in mind that this application will usually occur in May, often a dry month, the chemical must be of sufficient solubility to be sure of working without rainfall, or be incorporated by cultivation into the soil, not an easy operation on the undulating surface that will usually be encountered. If the chemical is to be incorporated it must be without inherent toxicity to the potato because there can be no use of soil depth protection which may help in the selectivity of a surface applied chemical. The type of soil action produced by linuron and the methyl-mercapto triazines when applied to a clean surface, would appear appropriate to these circumstances, but these chemicals have admitted weaknesses in their spectra of weed control.

The fourth and certainly the most thought provoking alternative at the present time, is that of using chemicals as a substitute for cultivations throughout the whole period from planting to the closure of the crop canopy. The crux of the matter so far as the choice of chemical action is concerned, is the period of not less than seven and perhaps as many as twelve weeks during which the crop provides little competitive assistance to the herbicide, and this at a time of year when weed germination and growth is at its most active. As has already been said, purely soil acting herbicides put on at planting have not found favour, but this is mainly due to the shortcomings of such chemicals as are at present available. The properties required are a broad spectrum and reliable weed control, no toxicity to the potato and a soil persistence of 2 - 3 months; similar to the use of atrazine in maize. Such a chemical could provide a real challenge to those already in use.

Selective foliar sprays find ready acceptance by farmers because their use is well understood, but it is doubtful whether a single post-emergence application of this type of chemical could be used in potatoes. To be successful when used alone it would need to be applied seven weeks or more after planting and by this time the weeds might be so well grown as to be competing with the potatoes, furthermore the weed growth would be so substantial that it might be difficult to obtain full control by a single application. However, if the chemical were cheap enough, it might be used twice - before and after potato emergence. Such an approach may well be necessary on high humus soils, in which residual chemicals are usually inactive.

It is because of the sum of all these experiences that farmers now have available to them the compromise involving pre-emergence application of a foliar or foliar/soil acting herbicide. The purely foliar herbicide applied at this time is successful only if the weeds emerge before the potatoes. The differences in time interval between planting and emergence resulting from the use of chitted or unchitted potato seed and between deep or shallow planting are relevant to the action of this type of chemical. The easiest conditions for the purely foliar spray occur when unchitted potatoes are planted deep into a cool seedbed, and the weather then turns wet and warm; the annual weeds in the top inch or two should respond more quickly than the more deeply planted potatoes. An early compact emergence of weeds is essential to the success of the non-selective foliar spray when it is applied before potato emergence.

The use of a foliar/soil acting herbicide is an attractive one, but it could be difficult to operate when based on one chemical because the same dose must be appropriate for both foliar and soil action. Chemicals vary in activity in different soils, usually being more active in sandy soil than in clay and it may be difficult to vary the dose from soil to soil without affecting the foliar control. On technical grounds, the best foliar/soil acting herbicide is likely to be a mixture of a purely foliar chemical with a purely soil acting chemical. The two can be selected for their particular prowess, and their relative proportions can be varied from site to site according to the needs of the situation. If the weeds that have emerged are very small, only a light dose of the foliar component need be applied, a larger amount being necessary for a more mature crop of weeds; and in this connection it should be remembered that annual grasses, volunteer cereals and perennial weeds may have to be controlled as well as broad-leaved annuals. The dose of the soil acting component which will provide an adequate residual control on a light or sandy loam, may be less than is required on a heavy loam or clay. The soil acting component should be capable of suppressing perennial weeds because such species as _Agropyron repens_, _Cirsium arvense_ and _Convolvulus arvensis_ are often not fully emerged by the time that potatoes start to come through.

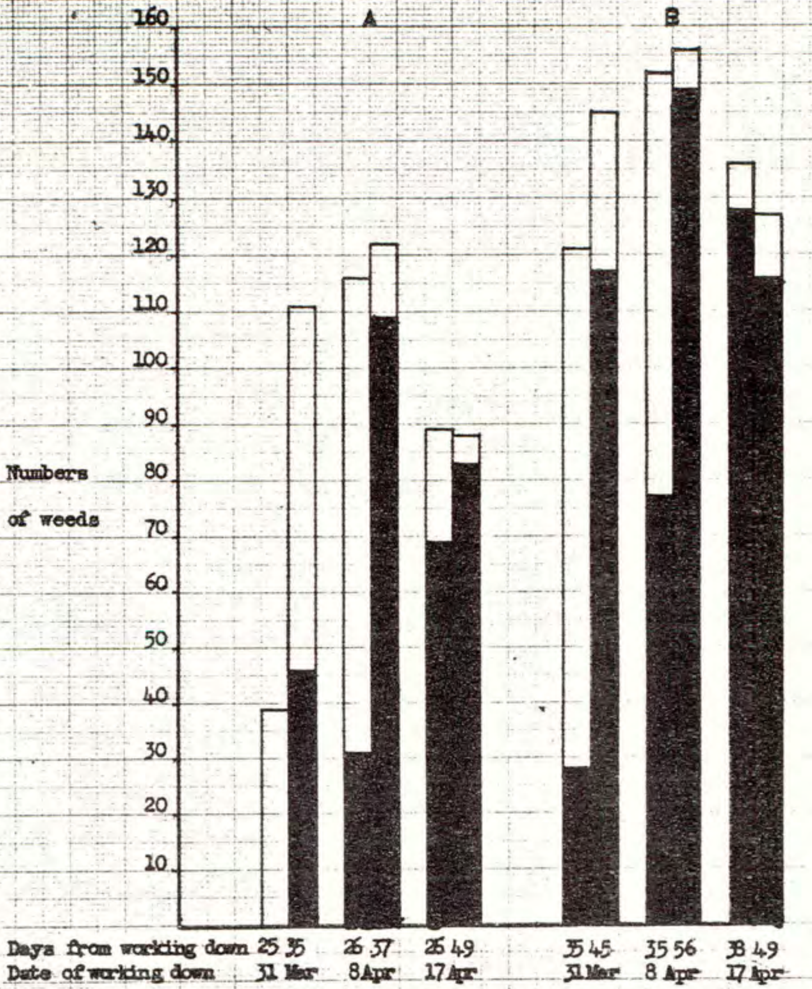

Figure 1

Experiment No. AA.21.64. Histogram showing total weeds visible in 210 fixed quadrats per control plot. Quadrat size 2¼ x 2¼ in.

A First assessment made 25 or 26 days after seedbed preparation.
B First assessment made 35 or 38 days after seedbed preparation.

Shaded areas indicate identifiable weed species.

APPENDIX

Details of Experiment No. AA.21.64 described in the text.

The object of the experiment was to study the pattern of weed emergence over the period normally covered by main crop potato plantings and to compare the efficiencies of the chief herbicides being used in the crop. The trial was carried out on the sandy loam soil of Begbroke Hill Farm.

Seedbeds were prepared on the ploughed and fertilised site on three occasions, the 31st March, 8th April and 17th April, with one pass of a rotary cultivator set at a working depth of 10 - 12 in. and followed by a light harrow. No crop was planted, but in order to cover the period of potato emergence appropriate herbicide applications were made 15 or 26 days and 35 or 38 days, after seedbed preparation.

A split plot design was used, with two replicates, the chemical treatment sub-plots measured 5 ft x 18 ft. The inclusion of unsprayed control treatments allowed weed emergence after spraying to be followed. The method of weed assessment was to peg the seedbed so that a wire screen sub-divided into 2¼ x 2¼ in. squares could be accurately placed, to give an area containing a grid of some 105 small fixed quadrats: this was repeated in each sub-plot. Emerged weeds in each grid square were counted immediately before spraying and again when the herbicide effects had developed. In all, some 25 weed species were identified, those occurring most frequently being Stellaria media, Papaver rhoes, Cirsium arvense, Plantago lanceolata, Polygonum aviculare, Trifolium pratense, Silene alba, Urtica dioica and various grass species. Those seedlings which were too small to identify, particularly in the two earlier seedbeds, were recorded as such.

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EXPERIMENTAL WORK ON THE USE OF TRIAZINES FOR WEED CONTROL IN POTATOES IN ENGLAND

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Summary 1. The paper summarises evidence from two years greenhouse and field investigations, with emphasis on the relative merits of different triazines for selective weed control in potatoes.

2. Among the 2-chloro substituted triazines, trietazine was found to be less toxic to both weeds and potatoes through the soil, but much superior to simazine in foliage action on young emerged weeds.

3. Certain 2-methyl-mercapto substituted triazines (ametryne, desmetryne and simetryne for example) were found to have useful activity on Galium aparine, a weed resistant to many other triazines including prometryne. All methyl-mercapto triazines tested showed a high degree of crop safety.

4. Evidence from sixteen replicated yield experiments showed frequent yield increases by chemical treatments over "farmer cultivated" controls. A case of yield depression by a simazine/prometryne combination on the variety King Edward grown on light sandy soil indicated the need for caution in the use of simazine for this variety/soil combination.

INTRODUCTION

The triazines represent a very promising group of herbicides for selective weed control in potatoes. The choice of the most selective triazine or combination of triazines is obviously a difficult task requiring several years work, considering the large number of active compounds in the triazine group.

Investigations on this subject started at Chesterford Park in 1961/62 and a preliminary research report on greenhouse studies (Milford and Pfeiffer) was presented at the Weed Control Conference in 1962. The research effort continued in the following years with increased intensity on two lines:

1. The development of a triazine combination based on triazines which were already commercially available.

2. The search for new triazines or triazine combinations of even greater selectivity or reliability.

Work on the first objective led to the introduction of a simazine/prometryne mixture in 1964. The experience in this first year of commercial usage has been if anything better than the previous research years would have indicated.

The investigations on the second objective have progressed to the point where alternative triazines with improved crop safety and weed control properties can be proposed for advanced field experimentation.

This research report presents a summary of the work so far carried out with some emphasis on the relative merits of different triazines rather than on the performance of one specific candidate herbicide.

Considerable information has already been produced by a number of countries, in particular by Geigy A G in Switzerland who first synthesised and supplied the triazines mentioned in this report. The results presented in this paper may help to clarify some questions on which evidence from different countries did not entirely agree.

Considerations on the broader agricultural aspects of the use of chemicals for controlling weeds in potatoes have to be excluded in this paper but it is hoped that the yield evidence obtained will form a contribution to the general problem of weed control by cultivation versus chemical techniques.

METHOD AND MATERIALS

Three types of techniques were used in the course of the investigations:

1. Greenhouse experiments
Potatoes were grown in 10" whalehide pots. This method gave useful indications of the effect of the triazines on potato yield. The standard errors in these trials were however fairly high.

2. Logarithmic yield experiments
These replicated trials were designed in such a way as to give weed control data at nine points (four halving distances along the log plots). These strips were sub-divided at harvest time into eight parts and yields taken of each.

3. Replicated yield experiments
These experiments were designed as randomised blocks with six replications for each treatment. The plot size was chosen in such a way that two complete rows of potatoes were treated for a length of 15-20 yards. The individual plots were separated by one guard row.

The "controls" consisted of two rows of potatoes adjoining the experiment on either side, as well as two rows in the middle of the experiment. On these "control" rows the potatoes received the normal farmer cultivation. In the 1963 experiments completely "unweeded" as well as "hand weeded" controls were also included, but this practice was not continued in 1964.

It was obviously impossible to randomise the "farmer cultivated" controls described above. The authors however felt that these controls were well enough distributed for a statistical analysis to give a useful indication of significance, although strictly speaking an analysis of variance might not have been applicable for the comparison of treatments with farmer controls.

The following triazine formulations were used:

	Chemical name	Formulation
simazine	2-chloro-4,6-bisethylamino-1,3,5-triazine	50% w.p.
trietazine	2-chloro-4-diethylamino-6-ethylamino-1,3,5-triazine	50% w.p.
simetryne	4,6-bisethylamino-2-methylthio-1,3,5-triazine	50% w.p.
ametryne	4-ethylamino-6-isopropylamino-2-methylthio-1,3,5-triazine	50% w.p.
prometryne	4,6-bisisopropylamino-2-methylthio-1,3,5-triazine	50% w.p.
desmetryne	4-isopropylamino-6-methylamino-2-methylthio-1,3,5-triazine	25% w.p.
G 36393	4-isopropylamino-6-(methoxypropylamino)-2-methylthio-1,3,5-triazine	25% w.p.

RESULTS

1. The relative value of 2-chloro substituted s-triazines

Certain chloro-triazines, when used alone, were found to be of practical value for potato weed control in some countries. In the authors' opinion they could also be useful partners in combination with methyl-mercapto triazines. The latter used alone were thought to be too rapidly decomposed in the soil to prevent a second germination of weeds in very wet seasons.

In our studies on the relative merits of different chloro triazines, our attention was concentrated on simazine and trietazine. (Milford and Pfeiffer 1962). In these first greenhouse experiments trietazine, applied to the soil, was about one third as active as simazine on both weeds and potatoes. There appeared therefore no grounds for preferring trietazine to simazine at that stage; if anything the opposite was indicated.

In subsequent logarithmic experiments comparing trietazine and simazine the lower crop toxicity of trietazine was confirmed, while under certain conditions trietazine gave better weed control than simazine.

The authors suspected that this surprising result could be due to a better foliage action of trietazine, which had a somewhat higher water solubility (20 p.p.m.) than simazine (5 p.p.m.). Greenhouse studies on this particular aspect confirmed the hypothesis as shown in Table 1. This table shows the high foliage activity of trietazine. Applied to the soil however simazine proved more active than trietazine (table 2).

Table 1.
Greenhouse study of post-emergence activity (% weed control) of simazine and trietazine (mean result on Brassica sp. Chenopodium album and Stellaria media)

	Dosage lb/acre				
	1/4	1/2	1	2	4
simazine	7	8	4	18	15
trietazine	79	92	86	97	97

Table 2.
Greenhouse study of pre-emergence activity (% weed control) of simazine and trietazine (weeds: Chenopodium album and Stellaria media)

	Dosage lb/acre				
	1/9	1/3	1	3	9
simazine	43	92	100	100	100
trietazine	26	20	100	100	100

The relative soil residual activity of simazine and trietazine, comparing both with desmetryne as a standard, was studied in another experiment (table 3). Three rates of simazine, trietazine and desmetryne were mixed in the top two inches of a medium loam soil placed in large buckets. These were kept watered and barley and peas planted four weeks later.

The result (shown in table 3) indicated a high level of residual activity of simazine, a very low level of the methyl-mercapto triazine, desmetryne, while trietazine occupied an intermediate position.

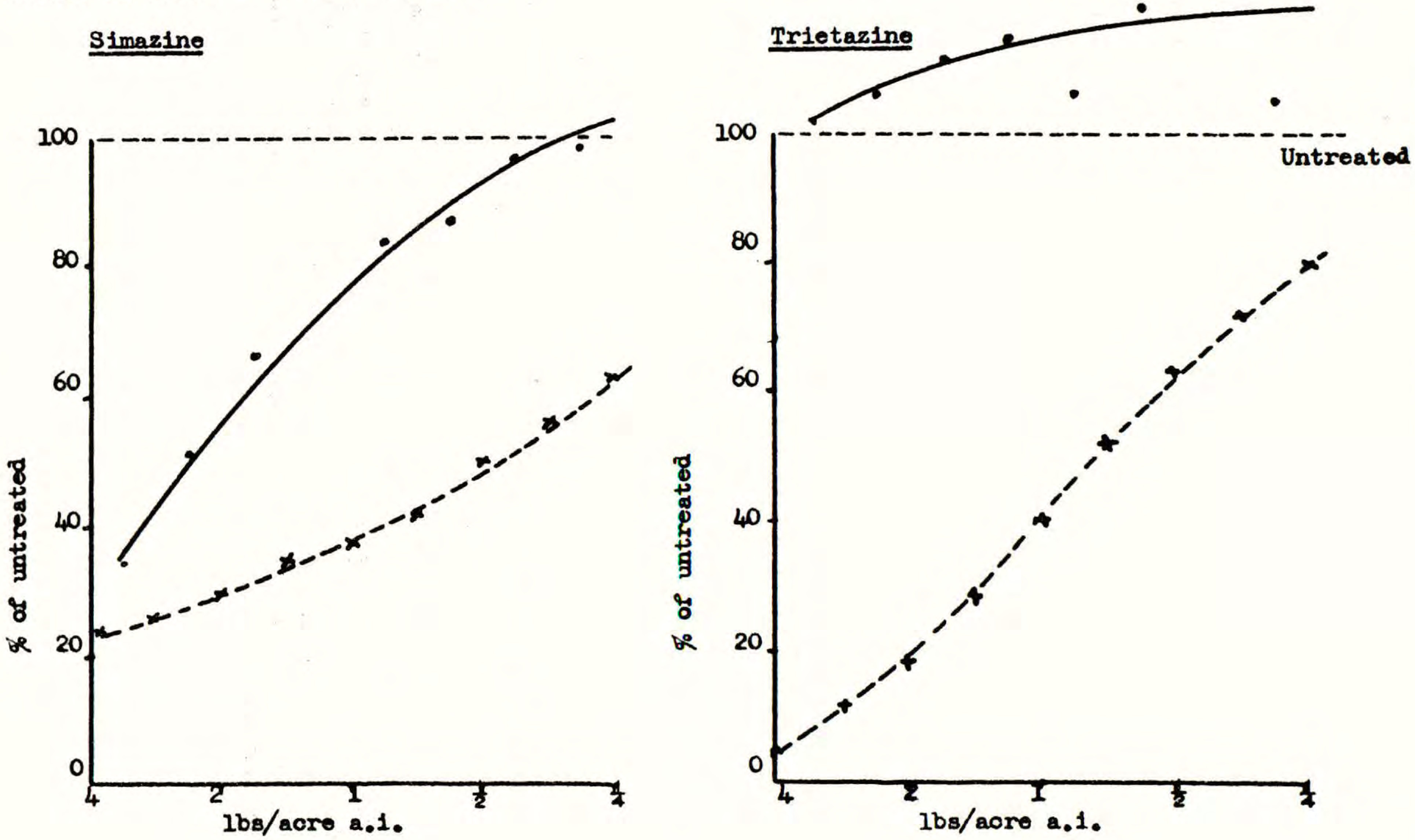
Table 3.
Residual effect of simazine, trietazine and desmetryne on test plants planted (in the greenhouse) one month after incorporation of the herbicide

	Barley (% kill)			Peas (% kill)		
	1	2	4	1	2	4
simazine	100	100	100	60	65	85
trietazine	10	70	99	0	5	62
desmetryne	0	25	97	0	0	10

Figures 1 and 2. Potato yields and weed control. Mean of 5 logarithmic experiments in 2 years

Potato yield...Mean tuber weight/plant as %
of cultivated control ————————

Weed control...Weed volume as %
of untreated control — — — — — — — —



Finally yield dose response curves were obtained under field conditions in logarithmic trials (see figures 1 and 2).

These figures show:

a) the greater crop safety of trietazine as compared with simazine, thus confirming greenhouse evidence.

b) a significantly better weed control with trietazine. This can be ascribed to the fact that the majority of weeds had emerged at the time of application, thus enabling trietazine to exert its superior post-emergence activity as demonstrated in greenhouse experiments.

The implications of these findings regarding the use of chloro triazines alone as against mixtures with methyl-mercapto triazines will be raised in the discussion.

2. The relative value of 2-methyl-mercapto substituted s-triazines

This group of triazines is characterised by two main properties:

a) their soil persistence is in general very much shorter than that of 2-chloro or 2-methoxy substituted triazines, and at rates of 1 to 2 lbs. per acre they can be expected to be inactivated after one to two months.

b) most methyl-mercapto triazines show a fairly high foliage activity.

The objective of our investigations was to choose the most active and if possible the most selective methyl-mercapto triazines for weed control in potatoes.

Differences between the methyl-mercapto triazines pre-emergence on weeds and potatoes, although significant, were not as striking as the differences when these compounds were applied to the foliage of young weeds. (See table 4). Among the more commonly known methyl-mercapto triazines, prometryne showed a remarkably low activity when compared with ametryne, desmetryne, simetryne or related compounds after foliage application.

Table 4.

Relative activity of 4 methyl-mercapto triazines on cleavers, mayweed and chickweed. (The figures represent % kill)

Species:	Cleavers (Galium aparine)					Mayweed (Matricaria spp.)					Chickweed (Stellaria media)				
Rate lb/acre:	½	1	2	4	8	½	1	2	4	8	½	1	2	4	8
prometryne	-	3	6	9	13	-	18	6	8	22	-	25	28	48	63
desmetryne	43	68	78	90	-	12	47	71	85	-	25	73	72	92	-
ametryne	28	44	50	70	-	36	48	34	85	-	43	58	58	68	-
simetryne	28	44	61	82	-	19	50	37	47	-	28	58	72	83	-

The high activity of some methyl-mercapto triazines on cleavers (Galium aparine) is of particular interest. This species is almost completely resistant to most chloro triazines as well as to prometryne, one of the most widely tested methyl-mercapto triazines. The possibility of effectively controlling cleavers at an early development stage by selective rates of desmetryne or ametryne could be demonstrated in practical field experiments over two years.

A number of methyl-mercapto triazines were included in the logarithmic yield trials as described under chloro triazines in both 1963 and 1964. A high level of crop safety as well as good weed control was consistently obtained, at rates between 1½ and 4 lb. a.i./acre.

Space does not allow the inclusion of the full range of data obtained in these trials.

None of the methyl-mercapto triazines reduced potato yield even at the highest rate of 4 lb. per acre. The marked difference in foliage activity as shown in table 4 was confirmed although the degree of the differences varied considerably from experiment to experiment. The interaction of foliage and soil activity is probably partly responsible for this variation.

3. Results from two years' yield experiments

As already indicated under Method and Materials the yield experiments carried out over two years had basically the same experimental design. There were two differences:

1) "unweeded" and "surface hoed" controls were omitted in the 1964 trials;

2) a different range of chemical treatments was used in the two years, since the experience gained in 1963 led to a selection of different treatments for the following year.

Tables 5, 6 and 7 summarise the yield data obtained.

Table 5.

Yield results of two main-crop experiments in 1963

Treatment	Dose/acre a.i.	Relative values in % of "farmer controls" Bressingham (Medium loam) Majestic	Stowbridge (fen) King Edward
Standard ("farmer control")	-	100.0 (14.5 tons/a)	100.0 (13.2 tons/a)
"Untreated"	-	83.8	107.5
"Surface hoed"	-	114.3	113.1
prometryne	16 oz.	104.7	107.5
prometryne	32 oz.	108.9	112.7
simazine/prometryne	6/16 oz.	103.6	106.3
simazine/prometryne	12/32 oz.	93.4	118.4
simazine/prometryne/MCPA	6/16/8 oz.	107.5	109.3
prometryne/trietazine	32/12 oz.	110.5	104.9
desmetryne	16 oz.	110.5	112.8
desmetryne	32 oz.	111.3	108.9
Significant Differences			
I For comparison between any pair of treatments other than "farmer controls"			
	P = 0.1	12.5	17.4
	P = 0.05	15.0	20.8
II For comparison between one treatment and farmer control			
	P = 0.1	10.2	13.8
	P = 0.05	12.3	16.5

Table 6.

Yield results 1964 - 8 experiments on early potatoes

Treatment	Dose/acre active ingredient	Relative values as % of "farmer control"							
		Ockendon (silt)		Gamlingay (very sandy)	Sawston (light sandy)	Chesterford Park (heavy loam)			
		Craig's Royal	Homeguard	Ulster Chieftain	Craig's Royal	Arran Pilot	Ulster Prince	Ulster Chieftain	Home-guard
Standard (farmer control) Tons/acre	-	100.0 *(7.3)	100.0 *(8.3)	100.0 *(12.0)	100.0 *(14.4)	100.0 *(6.8)	100.0 *(7.4)	100.0 *(7.1)	100.0 *(5.9)
simazine/prometryne	6/26 oz.	97.2	81.8	102.0	122.0	117.3	114.2	98.5	117.5
simazine/prometryne	12/52 oz.	95.7	84.0	81.5	73.3	98.5	114.2	93.5	99.1
trietazine/desmetryne	10/12 oz.	82.7	88.0	100.8	129.1	127.1	113.5	118.5	114.8
trietazine/G 36393	10/12 oz.	95.9	83.0	94.9	124.1	122.9	96.2	98.2	123.1
ametryne	16 oz.	93.3	92.1	84.0	138.0	127.1	110.4	103.6	116.2
ametryne	24 oz.	94.4	90.5	77.4	136.6	122.6	113.5	113.1	113.5
Significant Differences									
I For comparison between any pair of treatments, other than "farmer controls"									
P = 0.1		14.6	16.7	17.0	14.9	10.8	14.9	11.1	13.6
P = 0.05		17.5	20.1	20.5	18.0	13.0	17.9	13.4	16.3
II For comparison between one treatment and "farmer control"									
P = 0.1		12.7	14.5	13.9	14.9	9.4	12.9	9.6	11.8
P = 0.05		15.2	17.5	16.7	18.0	11.3	15.5	11.5	14.2

* Control yield in tons/acre

Table 7.

Yield results 1964 - 6 experiments on maincrop potatoes

Treatment	Dose/acre active ingredient	Relative values as % of "farmer control"					
		Downham Market (light sandy) King Edward	Chesterford (heavy clay) King Edward	Chesterford (heavy loam)			
				Red King	King Edward	Majestic	Dr. McIntosh
Standard (farmer control) Tons/acre	-	100.0 (15.2)*	100.0 (12.1)*	100.0 (7.8)*	100.0 (8.3)*	100.0 (11.0)*	100.0 (12.2)*
simazine/prometryne	6/26 oz.	64.0	102.3	92.1	99.1	109.4	106.5
simazine/prometryne	12/52 oz.	17.5	95.6	83.4	74.3	98.1	96.8
trietazine/desmetryne	10/12 oz.	94.0	97.4	123.5	107.7	116.2	102.5
trietazine/G 36393	10/12 oz.	99.7	97.4	108.9	105.6	107.0	109.2
ametryne	16 oz.	86.0	103.1	115.9	111.8	106.3	104.8
ametryne	24 oz.	99.6	99.8	115.9	108.4	109.4	96.6
Significant Differences							
I For comparison between any pair of treatments, other than "farmer controls"							
P = 0.1		13.5	6.9	11.2	8.5	9.0	10.3
P = 0.05		16.2	8.3	13.5	10.3	10.9	12.3
II For comparison between one treatment and "farmer control"							
P = 0.1		12.4	5.6	9.7	7.3	7.8	8.9
P = 0.05		14.9	6.7	11.7	8.7	9.4	10.7

* Control yield in tons/acre

DISCUSSION

In the discussion the present position on the value of chloro triazines, methyl-mercapto triazines and combinations will first be reviewed. Considering chloro triazines alone we were able to provide evidence to show that trietazine had advantages over simazine in both weed control and crop safety. Trietazine however would have to be used at two to three times the dosage of simazine to give the equivalent residual weed control. At such a high rate (2-3 lbs. a.i. per acre) trietazine did not affect the potato yield in our logarithmic trials. The superior foliage activity of trietazine over simazine is another factor in its favour.

It should be made clear that the above statements on the use of the chloro triazines alone are of limited direct value under British conditions, since the practical use of chloro triazines alone is not contemplated. However the results indicate a place for trietazine as an additive to a methyl-mercapto triazine.

The investigations on methyl-mercapto triazines confirmed the high safety factor of these compounds on potatoes, as well as their rapid foliage action on emerged weeds. Their short residual effect has the advantage of eliminating any danger to succeeding crops, but may allow a re-infestation of weeds in wet seasons a few weeks after application, in which case late cultivation may be indicated.

Several methyl-mercapto triazines (e.g. desmetryne, ametryne) were found to have a higher activity than prometryne on a number of broad-leaved weeds. The outstanding example is Galium aparine which can be well controlled at young stages with ametryne or desmetryne.

Turning to combination products the standard mixture of simazine and prometryne (6 + 26 ozs. per acre a.i.) should first be considered. This mixture was used on several thousand acres in 1964. Weed control, with few exceptions, was extremely good. Crop safety was equally satisfactory except in a few cases on light sandy soil on the variety King Edward which was found to be the most susceptible variety tested. The yield results reported in this paper agree with the general pattern of performance.

An overall analysis of the yield evidence in 1964 shows new candidate combinations such as trietazine/desmetryne and trietazine/G 36393 as well as ametryne alone to give somewhat higher yields than the standard simazine/prometryne mixture.

The safety of the new mixtures is particularly well demonstrated in the Downham Market experiment. In this experiment a severe yield reduction occurred after application of the standard simazine/prometryne combination. An analysis of the conditions leading to this bad result indicated a combination of three factors: light sandy soil, the potato variety King Edward, and heavy rains after prolonged drought leading to surface root formation, and thus to an active uptake of the triazine. Furthermore, blight prevented recovery of the affected potatoes. It is of interest that the yield was unaffected by the new triazine combinations containing trietazine or by ametryne.

In the Ockendon experiment on the variety Homeguard the yield by most chemical treatments was below that of the "farmer controls". This, in the authors' opinion, cannot be ascribed to a damaging effect of the chemical since the high rate of simazine/prometryne has not yielded less than the same combination at the low rate. This experiment appears to represent a case where cultivation had a beneficial effect as compared with no cultivation.

In many of the yield experiments the opposite was true and chemical weed control gave significantly higher yields than cultivated potatoes.

There can be little doubt that any individual yield result is determined by the interaction of a number of factors, the most important of which are: effect of cultivation, weed competition, crop sensitivity to the chemical, soil type and weather conditions.

Finally it should be mentioned that a number of important aspects such as the effect of the triazines on storage properties, taint, tuber discolouration, viability of tubers and the question of residues were investigated. No adverse effects of the triazines on any of these points were obtained. It is however not within the scope of this research report to deal with these investigations.

Reference

G. F. MILFORD and R. K. PFEIFFER (1962) Preliminary assessments of triazines for weed control in potatoes from pot experiments. Proc. 6th Brit. Weed.Cont. Conf. 2 681-689

EVALUATION OF A DINOSEB EMULSIFIABLE OIL FORMULATION FOR PRE-EMERGENCE WEED CONTROL IN POTATOES

R. Joice and J. Norris
A. H. Marks and Co. Ltd.

Summary Dinoseb as an emulsifiable oil formulation was sprayed onto drills at emergence of the potato. Satisfactory control of most annual broadleaved weeds was obtained and yields were increased. The limitations of the chemical are when perennial weeds e.g. *Agropyron repens* are present. Spraying after emergence of the potato was found to cause a retardation with resulting decreases in yield.

INTRODUCTION

Preliminary trials in 1962 indicated that a Dinoseb emulsifiable oil formulation applied at 1.8 lb Dinoseb per acre just prior to emergence of the potato provided adequate control of many broadleaved weeds. Under conditions of high weed density 2.25 lb Dinoseb per acre was necessary to maintain the level of control. More extensive trials were laid down in 1963 with the following objectives :

1. To evaluate weed control with rates 1.8, 2.25, 3.6 and 4.5 lb Dinoseb per acre and compare these where possible with untreated control, and a standard Dinoseb amine treatment of 4 lb per acre.

2. To determine the effect on yield of these treatments.

3. To evaluate the potential of this chemical when used under commercial conditions.

METHOD AND MATERIALS

Four trials were laid down to evaluate weed control and the effect on yield. In all experiments the Dinoseb emulsifiable oil formulation contained 0.9 lb Dinoseb per Imperial gallon dissolved in gas oil and an emulsifier and the Dinoseb amine formulation contained 1.85 lb Dinoseb per Imperial gallon in the form of mixed alkanolamine salts.

Trial 1

Plots 4 rows wide by 20 yds. long were laid down as a randomised block with 6 replications. The soil was a sandy loam and the potato variety was Record. The comparative treatments were the cultivated control and standard Dinoseb amine. Spraying was done with an Oxford Precision Sprayer at a total volume 50 gal. per acre.

Trial 2

The plots were 6 yard wide strips running throughout the length of the field. The treatments were randomised and replicated twice. The soil was a sandy loam and the crop variety Majestic. Comparative treatments consisted of a cultivated control and Dinoseb amine. The spraying was done with an Allman sprayer mounted on a Land Rover at a total volume of 60 gal. per acre.

Trial 3

The layout of plots and spraying methods was the same as in Trial 2. Soil type was a medium to heavy loam and the crop variety Redskin. The comparative treatment was again Dinoseb amine and a cultivated control.

Trial 4

The layout and method of spraying was as per Trial 2 and 3. The crop was Majestic grown on a medium loam. Comparative treatments were untreated control, cultivated control and Dinoseb amine. In this trial the chemicals were applied after emergence of the potatoes. The potatoes were from just emerged to 2 inches high.

Commercial Trials

Commercial trials were laid down at twenty-five sites on varying soil types viz Heavy loam 3; Medium loam 8; Sandy loam 3; Silt 2; Limestone Heath 2; Skirt (Silty Peat) 2; Fen 5. The application varied from 1.5 to 2.7 lb Dinoseb per acre.

RESULTS

The methods of assessing the results were slightly different for the four evaluation trials.

Trial 1

15 yard lengths of the two centre rows were used for the evaluation of weed control and estimation of the yield. Six similar lengths in the cultivation area were evaluated (3 on each side of the experimental block). The weeds were counted on the two rows and the weight of all tubers recorded.

Trial 2

Weed control was assessed visually on the basis 0 = no weed control, 10 = complete weed control. To enable this assessment to be made an unsprayed, uncultivated area was left at the end of each plot.

To assess the yield, 4 x 6ft. 3in. sample lengths of row were removed from each plot and weighed, a sample being taken from each of the four quarters of the plot. Similar samples were removed from the farm cultivated area.

Trial 3

Weed control was assessed by counting the large weeds in the 15 yard sample row lengths.

The yield of potatoes from each plot was assessed by harvesting 15 yard lengths of two rows. The 15 yard sample length of one row was located approximately one-third down the plot and the sample length of the other row two-thirds down the plot.

Trial 4

The results of both yield and weed evaluation were assessed in the same way as Trial 3 except that a 30 yard length was sampled in each of two rows.

Commercial Trials

These were assessed visually and judged as to whether they were satisfactory or not.

The weed evaluation data for the trials 1-4 is shown in Tables 1-4 respectively. In Tables 1 and 4 the Total Weed Population counts are expressed as a % of the cultivated control and in Table 3 as a % of Dinoseb amine. The yield data, expressed as a % of the cultivated control, of all four trials is shown in Table 5 and the results of the Commercial Trials are summarised in Table 6.

Key for the weeds recorded in Tables 1-4 inclusive

U. urens	- Urtica urens - Annual nettle
S. media	- Stellaria media - Chickweed
C. album	- Chenopodium album - Fat hen
C. pastoris	- Capsella bursa-pastoris-Shepherd's Purse
P. convolvulus	- Polygonum convolvulus - Black Bindweed
P. persicaria	- Polygonum persicaria - Redshank
R. crispus	- Rumex crispus - Curled Dock
A. patula	- Atriplex patula - Common orache
P. aviculare	- Polygonum aviculare - Knotgrass
R. raphanistrum	- Raphanus raphanistrum - Runch
C. arvense	- Cirsium arvense - Creeping Thistle
V. chamaedrys	- Veronica chamaedrys - Germander Speedwell
	Matricaria spp - Mayweed spp

TABLE 1
Weed Counts for Trial 1

Treatment	Rate lb Dinoseb /ac	No. of Individual Species : U. urens	S. media	C. album	C. pastoris	P. convolvulus	Total weed population
Farm Cultivated		49	10	6	12	1	100.0 = 78
Dinoseb amine	4.0	17	4	-	-	-	26.9
Dinoseb Oil	1.8	8	3	2	-	-	16.7
"	2.25	7	2	-	-	-	11.5
"	3.6	6	3	2	1	-	15.4
"	4.5	4	2	-	-	-	7.7

TABLE 2
Weed Control Scores for Trial 2

Treatment	Rate lb Dinoseb /ac	Weed Control Score	Notes
Untreated control	-	0.0	C. album, P. convolvulus, R. raphanistrum, V. chamaedrys, P. persicaria, P. aviculare, S. media, G. aparine Matricaria spp.
Farm cultivated	-	9.0	Very good control of all weeds.
Dinoseb amine	4.0	7.5	Good control of most weeds - Agropyron very dense infestation.
Dinoseb Oil	1.8	6.5	Good control of most weeds - Agropyron very dense infestation.
"	2.25	7.5	Very good control of C. album, good control of Polygonum spp., and S. media. Agropyron very dense infestation.
"	3.6	6.0	Good control of most species. Agropyron very dense infestation.
"	4.5	6.5	Very good control of C. album, moderately good control of other species.

TABLE 3
Weed Counts for Trial 3

Treatment	Rate lb Dinoseb /ac	No. of Individual Species : C. album	P. persicaria	S. media	R. crispus *	U. urens	Total weed population
Dinoseb amine	4.0	32	21	2	1	4	100.0 = 60
Dinoseb Oil	1.8	21	19	-	4	-	73.3
"	2.25	4	24	3	1	-	53.3
"	3.6	17	11	-	1	-	48.3

* seedling

TABLE 4
Weed Counts for Trial 4

Treatment	Rate lb Dino-seb/ac	No. of Individual Species : A. patula	S. media	P convolvulus	P. aviculare	R. raphanistrum	C. arvense	Total weed population
Farm cultivated	-	95	4	55	12	2	6	100.0 =174
Dinoseb amine	4.0	1	1	1	-	-	-	1.7
Dinoseb Oil	1.8	12	13	2	-	3	-	17.2
"	2.25	8	19	-	-	2	-	16.7
"	3.6	4	7	-	-	-	-	6.3

TABLE 5
Yield data for Trials 1-4 Inclusive

Treatment	Rate lb Dinoseb /ac	Yield of Tubers: Trial 1	Trial 2	Trial 3	Trial 4
Cultivated control	-	100.0=18.2 tons/ac	100.0=15.3 tons/ac	100.0=12.9 tons/ac	100.0=16.1 tons/ac
Dinoseb amine	4.0	103.9	96.47	103.1	95.0
Dinoseb Oil	1.8	105.4	90.8	107.0	88.2
"	2.25	105.4	77.1	114.0	90.7
"	3.6	102.8	90.8	103.9	94.4
"	4.5	111.5	-	-	-
Untreated control	-	-	-	-	63.4

TABLE 6
Summary of Commercial Trials

Soil Type	No. of Trials	No. of satisfactory controls
Heavy Loam	3	3
Medium Loam	8	6
Sandy Loam	3	2
Silt	2	1
Limestone Heath	2	2
Skirt (Silty Peat)	2	2
Fen	5	4

DISCUSSION

Weed control

The weed control obtained with Dinoseb oil formulation at 1.8 and 2.25 lb Dinoseb/ac was better than for normal cultivations except when a heavy infestation of couchgrass was present. In two trials the weed control with these dosage rates was superior to Dinoseb amine at 4.0 lb per acre. In only one trial was the amine superior to the oil formulation.

Weeds satisfactorily controlled by Dinoseb oil at 1.8 and 2.25 lbs Dinoseb/ac were :

Atriplex patula
Capsella bursa-pastoris
Chenopodium album
Galium aparine
Matricaria spp.
Polygonum aviculare
Polygonum convolvulus
Polygonum persicaria
Raphanus raphanistrum
Stellaria media
Urtica urens
Veronica chamaedrys

Effect on the yield of tubers

Of the four trials two showed an increase in yield and two a reduction in yield. In Trial 2 the reduction in yield was due to direct competition from couchgrass. When a dense infestation of this weed occurs cultivations are necessary to keep it under control. The reduction of yield in Trial 4 was due to the application being made after the emergence of the potatoes. The foliage was scorched and the plants were retarded temporarily.

Commercial Trials

From these trials it appears the chemical may be used over a range of soil types and be expected to give satisfactory weed control when applied at the correct time.

One of the unsatisfactory results was due to bad timing of the application and another due to ridging up a few days prior to spraying. The remainder were due to a second germination of weeds.

From all experiments it was concluded that 2.25 lb Dinoseb per acre as the oil formulation gave a satisfactory control of annual dicotyledenous weeds. When applied at emergence of the potato no reduction in yield will occur. If couchgrass is present cultivations are necessary or some form of chemical couchgrass control should be considered.

Acknowledgements

The authors wish to thank J. W. Chafer Ltd., for their assistance with Commercial trials and all farmers who co-operated in the trials.

THE USE OF LINURON FOR THE CONTROL OF ANNUAL WEEDS IN POTATOES

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Summary The herbicidal activity of linuron and various aspects of its use in potatoes have been investigated in an extensive trials programme during the last four years. From the results obtained and from commercial usage in almost all arable districts, it may be concluded that linuron at rates of 1 - 2 lbs. a.i. per acre (actual rates depending on soil type and maturity class of crop variety) will give effective control of annual weeds at least until the potato haulms meet and inhibit further weed growth. Thus 1.0 lb. per acre will suffice for an early variety on a light sandy loam, while 2.0 lbs. are required for maincrops on heavy clay loams. At these rates susceptible weeds, e.g. *Chenopodium album*, have been suppressed until harvest under widely differing seasonal conditions. Under conditions favourable to rapid growth of weeds and potatoes, even lower rates per acre have given effective weed control, such as 0.5 lb. a.i. on light soils when earlies were harvested before full maturity.

Timing of application is important in relation to the range of weed species killed, pre-emergence of weeds being more effective against some, e.g. *Matricaria* spp. Application is not recommended at or after emergence of the crop.

At rates up to 2.0 lbs. a.i. per acre pre-emergence, potatoes have shown an adequate margin of safety and this is true of the twenty important commercial varieties tested.

Where linuron is used at the rates recommended without cultivations, yields can be expected to exceed those from the normal sequence of cultivations; except on very high yielding sites. On average, yield increases from trials in 1962-64 were found to be of the order of 20%.

No adverse effects on tuber quality such as "greening" or second growth of the usual types, or changes in tuber size-distribution can be attributed to linuron. Similarly flavour after cooking or processing appears to be un-affected. Sprout development of "seed" tubers is normal and these give rise to normal crops.

The danger of linuron residues in the soil injuring succeeding crops is considered negligible in practice, since so far no damage has been found, even on experimental areas where up to 4 lbs. a.i. per acre has been used.

INTRODUCTION

Since the Du Pont Company (United Kingdom) Ltd. introduced linuron to Britain in spring 1961 the performance of this herbicide has been investigated by Farm Protection Ltd. in more than 150 replicated field trials on major crops over a wide area. One third of these trials have been on potatoes, mostly grown according to local custom; in addition to these many semi-commercial strip trials have been carried out using normal farm sprayers. The results show linuron to be an efficient herbicide for the control of annual weeds and highly adaptable to the widely varying methods of potato production.

The control of annual weeds in potatoes is considered here as a problem by itself, quite distinct from any created by the presence of perennial weeds such as species of Agropyron, Rumex, Cirsium and so on, or by special weeds such as Avena fatua. It is suggested that a growing crop valued at £120 - £150 per acre is no longer the place for the mechanical destruction of perennial weeds by cultivations possibly injurious in other ways, especially since inter-row cultivations without complementary hand labour cannot eradicate such weeds from where they do most harm - along the potato drills. While accepting that chemical control of weeds allows the omission of all post-planting cultivations, this paper does not speculate on other modifications to traditional methods rendered possible and likely to result from fundamental studies. It may be permissible, however, to suggest a return to the older practices of later planting of sound tubers in seed-beds more thoroughly prepared than those many growers consider suitable to-day. The first requirement for a high yielding crop is a full plant stand in conditions conducive to vigorous growth, as neither chemicals nor cultivations can restore the potential yields lost in frequent gaps.

METHOD AND MATERIALS

Small Plot Trials

Throughout 1961 - 64 application was by Oxford Precision Sprayer using 5 nozzles at 13½ inch spacing to give a spray swathe 6 feet wide. Allman flat fan nozzles Nos. 1, 2 or 3 were used at 18 - 30 p.s.i. according to calibration to give the desired gallonage per acre.

1961 - 100 g.p.a.	1963 - 40, 50 & 80 g.p.a.
1962 - 40, 50 & 100 g.p.a.	1964 - 40 g.p.a.

All these trials were simple randomised blocks replicated 3, 4 or 5 times and while some variation in plot size occurred the standard throughout was one 12' x 22'8" ≡ 1/160th acre, accommodating 5 rows 28" apart. Nearly all trials were located in farmers' crops grown according to individual preference except for omission of cultivation on experimental areas.

Weed assessment was initially by quadrat counts and visual scores; but the former method was seldom possible in 1963/64.

Yields have been estimated by lifting two $7\frac{1}{2}$' strips at random from rows 2 and 4 in each plot. Plants were counted; but not stems. Tubers were graded over riddles of $1\frac{1}{4}$" and 2" square mesh.

In all trials linuron was applied as a wettable powder of 50% active concentration. The rates of linuron applied in lbs. a.i. per acre were:

1961	1962	1963	1964
0.4	0.75	1.5	1.0
0.8	1.0	2.0	1.5
1.2	1.5	3.0	2.0
2.4	2.0	4.0	3.0
			4.0

A greater number of rates have been employed each year, since linuron has been compared alone and in mixture with other herbicides such as dinoseb, diuron, monolinuron, MCPA, Banvel-D and dachtal: also with and without Du Pont Surfactant W.K.

Extension Trials

These have varied from $\frac{1}{8}$th acre plots replicated two or three times, to single plots of $\frac{1}{2}$ - 2 acres sprayed at 25 - 75 gallons per acre. Equipment ranged from standard tractor mounted farm sprayers to contractors' large trailer machines. Rates of linuron applied ranged from 0.5 - 2.0 lbs. a.i. per acre.

RESULTS

1961

From three main trials on medium to heavy soil types it was found that commercially acceptable control of the annual weeds present was obtained with rates around 1 lb. a.i. per acre. There was no discernible effect on haulm from the top level of 2.4 lbs. per acre on the two varieties tested: King Edward VII and Majestic.

1962

The promising results of the preceding year justified a larger series of trials being laid down in 1962 on a greater variety of soil types using a dosage range of 0.75 - 2.0 lbs. a.i. Results indicated that, under the exceptionally poor growing conditions of this year, relatively higher rates were required to give acceptable control of the dense and varied weed infestations present, up to 2 lbs. a.i. being necessary on the more absorptive clays. Perennial weeds, which were irregularly distributed over all sites and a late emergence of Avena fatua on one, showed only temporary checks to growth.

No visible symptom of crop damage could be detected at any level of treatment in most trials, which were again confined to Majestic and King Edward VII varieties with a few others in extension trials: e.g. Epicure, Redskin and Kerr's Pink. There were two exceptions where application took place after potatoes started to emerge (5 - 10% emerged plants).

Table 1.

1962 Yield Results

Trial Location	Soil Type	Potato Variety	Estimated mean yields of seed and ware - Tons/acre: Rates linuron in lbs ai/acre				Controls		Percentage difference from cultivated controls	
			0.75	1.0	1.5	2.0	A	B	1 lb	2 lbs
									%	%
Wisbech Cambs 1	Med.silty loam	Kg.Ed.VII	13.6	11.6	10.4	12.2	7.7	14.3	-19	-14
Wingland Fen Lincs 2	Lt.loamy silt	Majestic	6.1	5.0	5.3	6.2	4.9	3.7	+35	+67
Lutton Lincs 3	Clay loam	Majestic	11.6	13.6	12.5	11.8	9.4	13.0	+5	-9
Pinchbeck Lincs	Silty loam	Majestic	12.1	11.7	14.6	14.0	11.0	9.9	+18	+41
									$\bar{x}$ = 10%	$\bar{x}$ = 21%

A - Unweeded control.

B - Cultivated control - normal practice.

1. Heavy infestation of Avena fatua over half trial site with perennial weeds in remainder.

2. Crop failure from frost damage (to cultivated area) and seed "misses".

3. Very blanky crop.

Table 2.

1963 Yield Results

Trial Location	Soil Type	Potato Variety	Estimated mean yields of seed and ware - Tons/acre: Rates linuron in lbs ai/acre 1.5	2.0	3.0	4.0	Controls A	B	Percentage difference from cultivated controls 2.0 lbs ai/ac %
Colchester Essex	Med.loam	Red Craigs Royal	11.1	13.6	12.0	10.2	7.2	10.1	+35
Colchester Essex	Med.loam	Kg.Ed.VII	13.8	13.9	13.7	12.7	7.5	13.6	+2
Salticoats Ayrshire	Lt./Med. loam	Epicure	10.2	11.4	10.1	10.4	10.7	10.3	+11
Wemyss Bay Ayrshire	Med.loam	Epicure	11.1	12.8	11.1	13.2	9.2	10.2	+25
Ardleigh Essex	Heavy clay loam	Dr.McIntosh	16.6	16.7	16.0	13.8	10.6	15.7	+6
Inchture Perthshire	Heavy clay loam	Majestic	11.5	11.5	9.7	9.9	10.7	9.0	+28
Arbroath Angus	Lt.sandy loam	Dr.McIntosh	17.1	18.5	15.0	17.8	17.8	16.2	+14
Colchester Essex	Clay	Craigs Royal	11.9	11.8	12.1	11.4	7.3	-	-

$\bar{x}$ of 7 sites + 17%

A - Unweeded control

B - Cultivated control - normal practice

Table 3.

<u>1964 Yield Results</u>

Trial Location	Soil Type	Potato Variety	Estimated mean yields of seed and ware - Tons/ac: Rates linuron in lbs ai/acre 1.0	1.5	2.0	3.0	4.0	Controls A	B	Percentage difference from cultivated controls: Rates linuron in lbs ai/ac 1.0 %	2.0 %
Aslackby Lincs	Clay loam	R.Craigs Royal	10.8	11.6	13.9	10.9	13.1	10.1	10.4	+4	+26
Maxey S.of P'boro	Med.loam on gravel	Kg.Ed.VII	10.0	9.6	10.1	10.1	9.4	10.8	-	-	-
P'hanworth Lincs	Sandy loam	Majestic	13.9	13.5	14.2	12.8	11.9	12.2	-	-	-
Newburgh Fife	Med. lt. loam	R.Craigs Royal	9.6	11.2	11.5	9.1	10.5	10.7	8.8	+9	+30
Meigle Perthshire	Med.sand/ silt loam	Kg.Ed.VII	18.1	16.8	16.5	18.5	15.4	10.5	18.6	-3	-12
Torksey Lincs 1	Med.sandy loam	Majestic	10.7	8.8	9.9	-	10.0	7.7	6.0	+80	+67
W.Pinchbeck Lincs 2	Silty loam	Majestic	4.4	5.4	3.9	6.1	4.4	1.2	2.6	+70	+51
N.Harby Lincs	Lt.sandy loam	Pentland Crown	19.2	19.5	18.1	16.7	17.4	7.3	19.5	-1	-7
St.Neots Beds 3	Loamy sand with gravel	Majestic	12.0	10.5	-	-	-	5.2	10.1	+17	-
N.Harby Lincs 3	Lt.sandy loam	Pentland Crown	24.6	20.6	-	-	-	-	-	-	-
										$\bar{x}$=25%.	$\bar{x}$=26%.

A - Unweeded control. B - Cultivated control - normal practice.

1. Very patchy soil. Crop affected by drought and perennial weeds.
2. Frequent "misses" from seed failure. Cultivations did not control <u>Mentha sativa</u> (patches) or <u>Urtica urens</u> (overall).
3. Surfactant trial - no high rates of linuron.

Reductions occur in the two high yielding crops. Highest increases occur at very low yields.

Table 4.

Response of weeds to linuron

At rates of 1-2 lbs. a.i. per acre, to give commercially acceptable weed control, at least until the potatoes meet in the rows.

Pre-emergence

VS 95-100% suppression
S 75-95% suppression
MS 50-75% suppression
I Up to 50% suppression
R No useful suppression

Post-emergence

S Complete or nearly complete kill
MS Effective suppression with partial kill
MR Temporary suppression
R No useful effect

Sd Seedling stage - cotyledon to 2-3 true leaf stage
Yp Young plant stage

	Pre-emergence	Post-emergence			
		Sd		Yp	
Weed	1 - 2 lbs	1 lb	2 lbs	1 lb	2 lbs
Anagallis arvensis	VS	S	S	S	S
Anthemis cotula	VS	R	MR	R	R
Capsella bursa-pastoris	VS	S	S	S	S
Chenopodium album	VS	S	S	S	S
Echium vulgare	VS	S	S	S	S
Fumaria officinalis	I	R	MR	R	R
Galium aparine	S	MS	S	MR	MS
Galeopsis tetrahit	VS	S	S	S	S
Lamium purpurem	VS	S	S	S	S
Matricaria matricarioides	VS	MR	MR	R	R
Matricaria maritima spp inodora	VS	R	MR	R	R
Papaver rhoeas	VS	S	S	S	S
Poa annua	MS-S	MS	MS	MR	MS
Polygonum aviculare	MS-S	MR	MS	MR	MR
Polygonum convolvulus	S	S	S	MS	S
Polygonum lapathifolium	VS	S	S	S	S
Polygonum persicaria	VS	S	S	S	S
Raphanus raphanistrum	VS	S	S	S	S
Senecio vulgaris	VS	MS	S	MR	MS
Silene album	VS	S	S	S	S
Sinapsis arvensis	VS	S	S	S	S
Spergula arvensis	VS	S	S	S	S
Stellaria media	VS	S	S	S	S
Thlaspi arvense	VS	S	S	S	S
Urtica urens	VS	S	S	S	S
Veronica spp	S	MS	S	R	MR
Vicia sativa	VS	S	S	S	S
Viola arvensis	VS	S	S	S	S

General chlorosis indicated that sprouts about to emerge could also be affected and although recovery was fairly rapid, earlier application was clearly desirable.

Estimated yields from four of these trials given in Table 1 show at the 2 lb. a.i./acre rate % increases over cultivated controls at two sites and % decreases at the other two. At Wisbech, where reduction of yield is shown at all rates, severe competition from A. fatua on half the site masked the substantial increases on the other three replicates. At Wingland Fen the trial area was unaffected by heavy frosts, which together with poor 'seed' ruined the remainder of this field; but the full yield potential could not be realised by the low plant population. A very irregular distribution of plants seriously affected results at Lutton, while Pinchbeck was an extremely weedy site.

1963

Increased dosage rates in the range 1.5 - 4.0 lbs. a.i. per acre were employed in a much larger series of trials distributed over many soil types. A total of 16 commonly grown varieties was recorded from all trials in 1963, again with no visual damage at any rate. On one very light heath sand in Suffolk Majestic haulm showed slight veinal chlorosis at 4 lbs. a.i. per acre and great variation in growth. A very heavy infestation of couch grass combined with erratic distribution of fertiliser appeared to be the main cause of irregular development.

Weed control was exceptionally good at all rates and for 6 - 8 weeks after spraying zero scores were recorded at the majority of sites for all treated plots. 1.5 lbs. a.i. per acre consistently gave commercially acceptable results up to harvest date at every site. Speedwell emerged on some plots at the second Colchester site too late to interfere with the crop. At Wemyss Bay application was to a very cloddy seed bed in spite of which weed control was complete - except for a very sparse infestation of Lolium perenne - until harvest and although frequent cultivations were carried out the remainder of the field was weedy all season.

Yields were obtained from 8 trials and are given in Table 2. Each of the 7 with cultivated controls gave increases from 2.0 lbs. a.i. per acre, which averaged 17% above yields from cultivations. At 1.5 lbs. a.i. per acre only one site just failed to surpass such yields. At Inchture and Arbroath cultivations may have been responsible for lower yields than those of unweeded controls. At Saltcoats very few cultivations were required.

1964

A further large programme of trials was carried out using 5 rates of linuron in the range 1 - 4 lbs. a.i. per acre and the list of varieties treated reached a total of twenty three. Again the 1.5 lbs. rate gave commercially acceptable weed control in all trials and even the 1 lb. rate gave excellent to commercially acceptable control in most trials.

Under the conditions obtaining in 1964, some slight veinal chlorosis and retardation of haulm growth occurred in certain trials at rates of 3 and 4 lbs. a.i. per acre. Occasionally the variety King Edward VII exhibited a mild and temporary yellowing of the whole foliage after treatment near to emergence.

Ten trials were harvested and results given in Table 3 show yield increases from 2.0 lbs. a.i. per acre over yields of cultivated controls at four sites and decreases at two where also 1.0 lb. a.i. per acre gave decreases. This rate gave increases at five sites. On average, both rates gave about 25% increase in yield.

DISCUSSION

Detailed assessments of the weed control obtained in these trials during 1961-64 are omitted from this paper since linuron is now known to be an active herbicide and its effects on potato yields may be of greater interest.

Considering yields over the three years for which results are available it is seen that the rates recommended to give commercially acceptable weed control i.e. 1 - 2 lbs. a.i., generally increased yields obtained over those from normally cultivated areas. Taking for example the rate of 2 lbs. a.i. per acre, out of the 17 trials in which comparisons were made with cultivated controls there was an increase in yield in 12 and no reduction in 1 trial.

Reductions occurred in only 4 trials and were of relatively small size. The maximum reduction - 14% at Wisbech 1962 - was caused by a severe infestation of A. fatua over about half the trial area while on the other three replicates the yields from 2.0 lbs. a.i. exceeded those of cultivated controls. If the yields from the 2 lbs. a.i. rate are compared as percentage increases or % decreases on the yields of the commercially cultivated controls and the % differences averaged, it is seen there was an average increase of 21% in 1962, of 17% in 1963 and of 26% in 1964. These results suggest that on average an increase in yield of about 20% may be expected from the use of 2 lbs. a.i. per acre on crops yielding 9 - 12 tons per acre from normal cultivations.

Taking the percentage differences at all sites, the tables show that the larger % increases in yield occurred where overall yields were low, while small % increases or small % decreases came from the high yielding sites. This may be because good growing conditions, which favoured high yields also enabled the potatoes to overcome more easily damage sustained from cultivations.

The yields recorded from rates of 3 and 4 lbs. a.i. per acre show that there is a good margin of safety at recommended dosage levels. Variety does not appear to be important in relation to tolerance of applications pre-emergence of the crop; but King Edward VII has exhibited a mild and temporary yellowing of foliage at a few sites in 1964. Depth of soil cover and timing of application may be more important factors, however, than normal dose rates with this variety.

In many trials involving mixtures of linuron and other herbicides yields have generally been very satisfactory even after the appearance of deformative effects on foliage, usually of a temporary nature. Such growth responses were very common of course with mixtures containing MCPA. No consistent advantage in weed control was found with the mixtures tried, however, and further discussion is unnecessary here. Similarly the addition of a surfactant occasionally improved kill of certain moderately resistant species of weeds; but at the temperatures generally prevailing at spraying time, increased speed of kill to only a small extent, and appeared to offer no consistent advantage.

There was some evidence of an increase in the proportion of larger tubers at all dosage rates compared to samples from the cultivated controls, particularly in extension trials. Harvest date and timing of haulm destruction are obviously important factors in determining tuber size and can seldom be altered in trials on farmers' crops. Quality of tubers has not been directly affected by linuron in any trial nor has the proportion of green tubers been increased where no cultivations took place after planting. With very few exceptions, drills were not harrowed down after planting and where reasonably shaped, gave the tubers adequate cover.

Turning to weed control, linuron has proved to be very versatile in use against a wide range of annual weeds and Table 4 has been derived from many observations. This shows the responses of commonly-occurring weeds to doses of linuron in the range 1.0 - 2.0 lbs. a.i. per acre. Chosen according to soil type such doses can be expected to give commercially acceptable weed control until at least the potato haulms meet in the rows and suppress further weed growth. Thus on lighter soils such as sands and silts containing 3 - 8% organic matter 1.0 lb. a.i. per acre is sufficient for early varieties or maincrops harvested at immature stages of growth. On stronger soils e.g. heavy loams and "skirtland" silty-clays 2.0 lbs. a.i. per acre are necessary to control weeds until harvest. Like most residual herbicides linuron's performance is influenced by soil type and climatic conditions. Soil type naturally has a greater influence on pre-emergence than on post-emergence applications of linuron. For instance, on soils with a low adsorbtive capacity for linuron, generally those of open texture and low in organic matter or clay content, small doses can kill very susceptible weeds for long periods. Thus on a Norfolk sand, plots receiving 0.25 lb. per acre remained weed-free for 10 weeks. Conversely duration of effect and extent of kill are markedly reduced on heavier soils of high adsorbtive capacity. This is so on highly organic soils but the results on fen peats are still much better than those expected. The reasons for this are unknown. While adequate soil moisture undoubtedly improves the action of linuron applied to a soil surface, trial results show that it is less dependent on rainfall than the closely related diuron.

Table 4 shows certain changes in the responses of some species when application is post-emergence. Seasonal conditions strongly influence effects here, temperature being particularly important in relation to the time taken for weeds to show symptoms of injury. In the range 10 - 15°C fourteen days may elapse before death of susceptible weeds. Nearer 20°C a much quicker kill is obtained, while at 25°C effects may be spectacular the day after application and even well developed plants can be killed. The susceptibility of some species appears to increase under warmer conditions e.g. _Polygonum convolvulus_ and _Senecio vulgaris_. This "contact" action (not readily distinguishable in field trials from action through the soil) is useful in controlling infestations of susceptible weeds; but where more resistant weeds are present especially _Matricaria_ spp or even _Polygonum aviculare_ application should be pre-emergence of weeds or as early as possible after appearance. The residual action of linuron against later germinating weeds may be impaired by uneven spray deposit on the soil surface, especially if weeds form a dense cover. For similar reasons, linuron is frequently at a disadvantage when applied in mixture with non-persistent but truly contact herbicides close to emergence of the crop. Normally pre-emergence applications of linuron prevent the growth of a much wider range of species than can be killed after emergence, a fact which is most important in timing treatments in potatoes. Where soil is never disturbed there is increasing evidence of earlier applications giving longer periods of freedom from weeds than those resulting from later applications. Between the extremes of treatment truly pre-emergence of weeds and delay until just before crop emergence there is a range of situations in which linuron will give weed control for a satisfactory length of time. Obviously an infestation of only susceptible weeds allows considerable latitude in timing. A common occurrence on some soils is the sudden emergence of a "flush" of seedlings, all fairly uniform in growth. Under such circumstances the resistance of certain species appears to be less than usual and early application of an appropriate dose of linuron causes virtual elimination of weeds. Similar variations abound in which the versatile action of linuron can be exploited; but detailed study of field records indicates that a knowledge of the weed flora expected on any particular soil is important in ensuring a successful choice of treatment.

Overall spraying of linuron post-emergence of potatoes should be avoided, otherwise severe chlorosis is inevitable and; although the haulm generally recovers its normal appearance, retardation of growth may be reflected perhaps in lower yields. If efficient shielding were available to permit directed spraying of the drills, split applications could achieve very high performance at lower dosages.

Timing apart, the recommendation of dosage rates would be relatively simple were potato growers of one mind on the value or otherwise of cultivations, or on exactly what term of weed control is wanted. Inevitably, individual preferences are likely to vary enormously for some years. Previous recommendations of 1.5 - 2.0 lbs. linuron per acre, according to soil type or rate of crop maturity, were based on consistently good weed control without cultivations, even under adverse conditions of season or soil tilth. Such rates are wasteful where growers insist on "ridging up" at the usual stage and 0.5 - 1.0 lb. a.i. per acre could often give the desired results. Where ridges are properly formed after planting and left untouched this additional ridging operation is usually unnecessary and sometimes detrimental to yield. Again, rates of 0.5 - 1.0 lb. per acre can be adequate for early varieties in a season favouring rapid emergence and growth of haulm. The very adverse conditions experienced in the spring of 1962 discouraged reliance on dosage below 1.5 lb. a.i. per acre; but results obtained at these low rates of 0.5 - 1.0 lb. a.i. in 1963 and 1964 show linuron to be highly adaptable to many of the variations in practice which arise from individual preference. No injury has occurred at any site from linuron residues in the soil even where ryegrass mixtures or brassicas have followed early potatoes treated at 4 lbs. a.i. per acre.

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STATUS AND PROSPECTS OF WEED CONTROL WITH METHOXY-UREA COMPOUNDS IN POTATO GROWING TAKING INTO CONSIDERATION THE RESIDUE PROBLEM

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In intensive potato growing, the labour shortage increasingly necessitates a curtailment of mechanical plant cultivation measures. The potato crop, on the other hand, must be largely free from weeds so that automatic potato harvesters can be used without giving trouble. Weed infestation, hitherto only considered to be a factor resulting in diminishing yield, has become an economical problem as regards labour since it obstructs harvesting operations.

In growing seed potatoes, too, demands are being made - though for reasons of plant hygiene - to curtail the hoeing and earthing work and to completely dispense with post-emergence weed control by means of a weeder in order to check the transmission of virus diseases by contact. It is of great moment if post-emergence weeding is dispensed with because the risk of weed infestation at the time of potato emergence is increased by a number of new cultivation methods. As planting is carried out at an earlier date and potato germination is influenced by pre-germination and germ stimulation, potatoes and the bulk of the weeds emerge at about the same time. Since the weeder has been dispensed with, weed control in the growing of seed potatoes has become a serious technical problem which has placed weed control with chemicals into the foreground of interest.

Because of its uncertainty of success and inadequate long-term effect calcium cyanamide - though exerting a herbicidal effect - could not solve the weed problem. The hormone weed killers were either not effective enough or not quite without risk. The known contact herbicides DNOC and Dinoseb no longer meet the demands of practice in spite of their excellent effect on weeds as, generally, their long-term effect does not suffice to prevent later weed infestation. By present standards, only such herbicides are of practical value which prevent weed growth for a sufficiently long time and thus, apart from facilitating the harvest, increase the yield or, at least, do not reduce the yield on account of their phytotoxicity. Their persistence in the soil must be limited in such a way that crop rotation and particularly the cultivation of sensitive crops after early potatoes is not interfered with.

Among the more recent herbicides, two compounds from the methoxy-urea group, viz. Monolinuron* and Linuron* come very close to this aim. They are translocation herbicides. They are taken up by leaves, sprout and roots, are mainly conducted acropetally and take part in processes of photosynthesis. This can clearly be demonstrated by a simple test on tomatoes, potatoes or other plants by putting a sleeve containing active ingredient anywhere around the sprout as is shown in the photos. All parts of the plant above the sleeve containing active ingredient die starting from the edge inwards while showing symptoms of chlorosis. All parts of the plant below the sleeve remain completely healthy and capable of assimilation.

Table I shows that both compounds have an excellent weed effect on annual seed weeds which lasts for several weeks or months depending on the quantity applied. The weed spectrum of both compounds is almost identical except for slight differences. Monolinuron only has a markedly superior effect on annual gramineae. It is also slightly superior to Linuron in its pre-emergence effect. Linuron, on the other hand, has a considerably greater effect on weeds that have already emerged. Even weeds in later stages of development can be killed with 1.0 kg Linuron per hectare as can be seen from the post-emergence test on potatoes in Table 2. It must be admitted, however, that the potatoes also suffer greater damage.

Apart from showing a good herbicidal effect, these two substances are distinguished by a favourable persistence in the soil which, however, is unusually short for urea compounds. Persistence tests in Table 3 show that using wild mustard (Sinapis arvensis) as a sensitive test plant, the persistence of 1.0 kg Monolinuron per hectare in sandy loam under normal weather conditions is about 1 1/2 to 2 months, that of 1.0 kg Linuron per hectare about 2 to 3 months. Consequently, Linuron is more persistent under the same experimental conditions. These differences in persistence may perhaps be traced back to the different physico-chemical properties of the two products. With 580 ppm at 25°C Monolinuron is relatively easily soluble in water and has a pronounced effect in the gas phase which is easily detectable and measurable in tests on plants. With 56 ppm at 25°C the more persistent Linuron is considerably less soluble in water and does not exhibit this effect in the gas phase.

In the pre-emergence process both compounds are well tolerated by potatoes and some other crops. On account of its more rapid decomposition and its superior weed effect, particularly in dry weather, Monolinuron will perhaps be preferable for weed control in potato growing under European conditions of climate and cultivation. The lowest possible persistence, due to product degradation, that just meets practical requirements is as essential for crop rotation as for the residue problem of the active ingredient in the harvested crop. In many countries potatoes are counted among the basic foodstuffs. In accordance with the Foodstuffs Law in Germany and in some other countries they must not contain foreign matter which also includes plant protection agents.

The results from a number of tests for residues in potatoes are shown in Table 4. Harvested crops were tested from plots that had been treated with quantities between 1.0 to 2.0 kg of Monolinuron and Linuron, respectively, at various times before and after emergence of the potatoes. In the crop of treated potatoes no residues could be detected by the analytical method of Dalton which is at present the most sensitive method for detecting methoxy-urea compounds. The values found lie within the dispersion range of the detection limit which is at 0.04 ppm. Nor could any residues be detected in the crop of those tubers for seed which had been dipped for 5 sec. in an 0.5% or 0.38% suspension of Monolinuron. It also follows from Table 5 that the potatoes thus treated show neither damage nor growth inhibition. Recently, USDA laid down a tolerance of 1.0 ppm Linuron in potatoes.

Provided Monolinuron or Linuron is applied according to instructions before the emergence of the potatoes, quantities of 1.0 to 1.5 kg do not cause any damage or reduction in yield. In 1962, about 4,000 hectares and in 1963 about 10,000 hectares of potatoes were treated with Monolinuron. An excellent weed control, mostly right up to the time of harvesting, is obtained. The average results of experiments in Table 6 give statistically significant increases in crop yield as compared with potatoes that were not chemically treated but worked mechanically as usual. In contrast, chemically untreated potatoes that were not worked mechanically show considerable and statistically significant decreases in yield.

Damage is caused and yields are diminished if potatoes that have already emerged are treated with Linuron and Monolinuron. The later the post-emergent treatment the greater the visual damage and reduction in yield as is impressively illustrated by the results of a test series with different timing of treatment and different varieties shown in Table 7.

The application of Monolinuron and Linuron will always be critical at a time when the potatoes begin to emerge. Decreases in yield can only be avoided if it is possible first to cover by careful earthing the potatoes already emerged and then to spray. Monolinuron or Linuron are, therefore, not suitable for post-emergence spraying which is particularly desirable on binding soil easily tending to incrustation. Only the pre-emergence process can be recommended for weed control in potatoes. This, however, requires a slight change in customary cultivation technique. The last earthing of the potatoes must be carried out before emergence of the potatoes. After Monolinuron or Linuron treatment any further mechanical working of the soil must be dispensed with. On light soil, this is possible without affecting the growth of the potatoes. It is merely important that the last earthing before treatment is carried out very carefully since the number of tubers turned green increases with potatoes earthed insufficiently or not at all. This is illustrated by an experiment - though under very extreme conditions - in Table 8. In this test the potatoes were planted with the potato planting machine. Earthing was not repeated before treatment in order to allow an unimpeded weed emergence on the marshy soil prior to spraying. Thus, a good and lasting weed control has been achieved but the amount of tubers turned green from plots with chemical weed control exceeded by far that from plots worked mechanically. Although this drawback is compensated by a considerably higher yield, the increase in tubers turned green could have been prevented by careful earthing of the potatoes after planting.

With binding soil tending to incrustation, conditions are somewhat more complicated than with lighter soils. To keep the soil loose it will have to be cultivated mechanically between planting and chemical treatment, if necessary. On heavy soils, the last earthing of the potatoes should be carried out as late as possible followed by weed control with Monolinuron or Linuron. The risk of mud and incrustation can be further diminished by selecting the most suitable variety. Leafy varieties which provide early and good cover of the soil are to be preferred on heavy soils. They protect the soil from driving rain and provide a good tilth. If, on heavy soils, dangerous incrustation should result from precipitation after chemical treatment with Monolinuron or Linuron, the soil may be loosened by careful hoeing. The weed effect of the products will hardly suffer as a result of this procedure.

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Tab. I

Sensitivity of weeds towards Monolinuron and Linuron

(M = Monolinuron; L = Linuron)

Weeds species	0.5 kg/ha		0.5 kg/ha		0.5 kg/ha	
	M	L	M	L	M	L
Anagallis arvensis L.	1	1	1	1	1	1
Capsella bursa pastoris Moench	1	1	1	1	1	1
Galinsoga parviflora Cav.	1	1	1	1	1	1
Plantago major L.	2	1	1	1	1	1
Matricaria chamomilla L.	–	2	1	1	1	1
Spergula arvensis L.	1	1	1	1	1	1
Polygonum convolvulus L.	–	1–2	1	1	1	1
Sonchus arvensis L.	–	3	1	2	1	1
Stellaria meda Dill.	–	2	1–2	1–2	1	1
Urtica urens L.	–	2	1–2	1–2	1	1
Thlaspi arvense L.	2	2	1–2	1–2	1	1
Chenopodium ssp.	2	2	1–2	1–2	1	1
Raphanus raphanistrum L.	2	2	1–2	1–2	1	1
Sinapis arvensis L.	2	3	1–2	2	1	1
Poa annua L.	1–2	3	1	2	1	1
Polygonum ssp.	–	2–3	2	2	1–2	1–2
Galeopsis ssp.	–	–	1–2	2	1–2	2
Chrysanthemum ssp.	–	3	2	1–2	1	1
Senecio vulgaris L.	3	2	2	1–2	1–2	1
Lamium purpureum L.	2–3	3	1–2	2	1	1
Geranium ssp.	–	3	2	2	–	–
Veronica ssp.	3	3	2–3	2–3	2	2
Fumaria officinalis L.	–	4	3–4	3–4	3	3
Galium aparine L.	4	4	4	3	4	2–3
Vicia ssp.	3	4	2–3	3	2	2–3

Degree of sensitivity:

1 = very sensitive (0 – 10%)*)	3 = moderately sensitive (30 – 60%)*)
2 = sensitive (10 – 30%)	4 = slightly sensitive (60 – 90%)

*) Survival compared with untreated

Tab. II

Weed control in potatoes with Monolinuron and Linuron

(Effect on weeds and crop plants in postemergence weed control)

Variety of potato: Gunda   Date of planting: 20. 4. 1963

Date of application: 21. 5. 1963   Stage of development of weeds: 4-5 leaf-stage

potatoes: 5-10 height (cm)

Site of trials: Hattersheim (M)   Type of soil: sandy Loam

Products	a.i. kg/ha	Effect on weeds injury rating 0 - 10 *) 55 days after treatment							Effect on crop plant	Yield (rel.)
		Sinapis arvensis	Chenopodium album	Polygonum spec.	Galium aparine	Stellaria media	Sonchus arvensis	Galeopsis spec.		
Monolinuron	1.5	6	7	5	4	8	7	6	2	91
Linuron	1.5	10	10	10	7	10	10	9	4	87
Untreated	—	0	0	0	0	0	0	0	0	100

*) 0 = no effect
10 = complete kill

Tab. III

Persistance field tests with Monolinuron and Linuron.

Site of trials: Hattersheim (M). Type of soil: sandy Loam
Application: 1kg a.i./ha in 600 L of water sprayed on uncovered soil, then superficially mixed in
Size of plot: 25 m^2
Date of treatment: 1. 7. 1961
Plant tested: Sinapis arvensis L.
Rainfall during tests: 158.7 L/m^2

Date of seeding	Days after treatment	Injury rating 0 – 10*) at 1.0 kg/ha Monolinuron after days 14	Monolinuron after days 42	Linuron after days 14	Linuron after days 42
1. 7. 1961	0	8	10	7	10
10. 7. 1961	10	7	8	7	10
1. 8. 1961	31	4	5	6	8
14. 8. 1961	44	2	1	4	6
1. 9. 1961	62	0	0	3	2
19. 9. 1961	80	0	0	1	0
1. 10. 1961	93	0	0	0	0

*) 0 = no effect
10 = complete kill

Tab. IV

Residue tests as to Monolinuron and Linuron in potatoes

Site of trials	Type of soil	Variety of potato	Date of planting	Date of appl	Rainfall L/m^2	Products	a.i. kg/ha	ppm a.i. according to Dalton method (sensitivity 0.04 ± 0.01 ppm)
Hattersheim (M)	Sandy loam	Sieglinde	20.4.1963	–	130.5	untreated	–	0.04 ± 0.006
Hattersheim (M)	Sandy loam	Sieglinde	20.4.1963	14.5.1963	130.5	Monolinuron	1.5	0.03 ± 0.006
"	" "	"	"	"	"		2.0	0.03 ± 0.006
"	" "	"	"	27.5.1963	123.7		1.5*)	0.03 ± 0.006
"	" "	"	"	"	"		2.0*)	not detectable
Raffach	–	Benedetta	27.5.1963	27.5.1963	–		1.5	0.06 ± 0.01
"	–	Lerche	"	"	–		1.5	not detectable
Ismaning	marshy soil	Maritta	25.5.1963	25.5.1963	–		2.0	< 0.02 ± 0.006
Hattersheim (M)	Sandy loam	Sieglinde	20.4.1963	14.5.1963	130.5	Linuron	1.5	0.07 ± 0.02
"	" "	"	"	"	"		2.0	0.07 ± 0.02
"	" "	"	"	27.5.1963	123.7		1.5*)	0.04 ± 0.02
"	" "	"	"	"	"		2.0*)	not detectable
Raffach	–	Benedetta	27.5.1963	27.5.1963	–		1.5	not detectable
"	–	Maritta	"	"	–		1.5	not detectable

*) postemergence treatment

Tab. V

Influence of tuber treatment (dipping) of pregerminated seed potatoes with Monolinuron as to growth, yield and residue.

Variety of potato Delos (pregerminated)
Site of trials: Ismaning / Bavaria
Date of treatment: 25. 5. 1963 Number of tubers: 25 Date of planting: 25. 5 1963

Products	a.i. concentration %	Length of treatment (sec)	Date of planting	Number of treated tubers	Injury-rating of potatoes 0 - 10	Influence on the growth of potatoes	Residue values ppm according to Dalton method (sensitivity: 0.04 ± 0.01 ppm)
Monolinuron	0.5	5	25. 5. 1963	25	0	none	< 0.02 ± 0.006
Monolinuron	0.38	5	25. 5. 1963	25	0	none	< 0.02 ± 0.06
Untreated	–	–	25. 5. 1963	25	0	none	0.03 ± 0.06

Tab. II

Influence of weed control with Monolinuron and Linuron on potato yield. Evaluation of 56 pre-emergence tests by the method of differences in relation to untreated plots worked mechanically.

Products	Number of test results	a.i. kg/ha	Kind of soil cultivation	Yield (rel.)	Difference %	Degree of significance
Untreated	56	–	Normal mechanical cultivation of the soil	100	–	–
Untreated	7	–	No mechanical cultivation of the soil	88.5	- 11.5	P < 0.1 (9.09 %)
Monolinuron	28	1.0 - 1.5	" "	106.0	+ 6.0	P < 0.5 (5.45 %)
Linuron	10	1.0 - 1.5	" "	110.1	+ 10.1	P < 0.5 (9.83 %)
Monolinuron ¾ + Linuron ¼	18	1.0 - 1.5	" "	106.8	+ 6.8	P < 0.5 (4.33 %)
Total number of trials	56	1.0 - 1.5	" "	107.0	+ 7.0	P < 0.01 (5.97 %)

Tab. VII

Weed control in potatoes with Monolinuron and Linuron

Influence of the time of treatment on yield (rel. to untreated)

Yield (rel.)

Variety	Time of treatment	Stage of development of potatoes	Monolinuron kg/ha			Linuron kg/ha			Comparat. prod. (Simazine)	
			1.0	1.25	1.5	1.0	1.25	1.5	0.5	0.6
Carla	4 days after Planting	Prior to emergence	105.4	107.7	107.1	107.1	106.7	104.4	104.9	97.6
Sirtema	11 " " "	" " "	103.5	105.6	104.1	102.3	113.4	118.0	101.5	110.9
Saskia	14 " " "	" " "	113.2	106.4	111.6	107.5	104.6	107.9	104.6	100.9
Sirtema	17 " " "	Earthed on emergence then treated	100.9	105.1	100.9	108.6	106.9	108.3	95.1	100.9
Carla	18 " " "	Earthed after emergence then treated	99.9	98.6	95.6	93.6	92.0	90.9	90.3	89.8
Saskia	20 " " "	Earthed after emergence when plants are 5-10 cm high then treated	96.8	93.9	96.6	95.5	88.5	91.4	90.0	91.9

Tab. VIII

Influence of chemical weed control on potato yield and proportion of tubers turning green

(Test results with Monolinuron and Linuron in relation to untreated plots worked mechanically)
Site and type of soil: Ismaning / Bavaria - marshy soil.
Date of planting: 16.5.1962 Date of treatment: 30.5.1962 immediately before emergence of the potatoes

Cultivation of soil in untreated plots: hoed 3 times, earthed 2 times
in treated plots: potatoes planted with planting machine. No further mechanical cultivation of the soil.

Products	a.i. kg/ha	Effects on weeds *) injury rating 0 - 10	Yield kg/ha	Yield (rel.)	Tubers turning green: Total amound in % by weight	of these: extensively green %	moderatly green %	slightly green %
Untreated	–	9	27.600	100	17.2	11.1	38.1	50.8
Monolinuron	1.5 - 2.0	9	34.400	124.7	31.2	23.3	31.5	45.2
Linuron	1.5 - 2.0	9	33.170	120.2	33.6	18.6	34.8	46.6
Monolinuron + Linuron	1.5 - 2.0	10	34.310	124.3	29.0	16.5	42.1	41.4
Comparative prod. (Simazine)	0.5	6	28.000	101.4	31.7	19.2	38.4	42.4

*) Predominant weeds: Chenopodium album L., Sinapis arvensis L.
Galeopsis tetrahit L., Sonchus arvensis L.

0 = no effect
10 = complete Kill

C 3126 A NEW UREA-DERIVATIVE HERBICIDE IN POTATOES

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Summary N-(p-bromophenyl)-N'-methyl-N'-methoxyurea (Ref. No. C 3126) was tested on potatoes in Switzerland during 1964. Yield trials, time of application studies, variety trials, and logarithmic tests were carried out in order to evaluate herbicidal effectivness, crop tolerance and agronomic problems. The trial indicated that 1.5 - 2.5 kg a.i. per ha gave good weed control without any phytotoxic symptoms on the haulm or tuber yield. Satisfactory weed control can be obtained when the spraying is done immediately after planting the crop or after several cultivations. Lack of cultivation did not seem to affect yield seriously.

INTRODUCTION

It can be safely said that at the present time herbicides have found acceptance in the cultivation of potatoes. Not many years ago this was not the case. Progress in the search for new, and adaptation to the potato crop of already known herbicides, has been steady if not startling, and still there are problems. Efforts by experimenters both in industry and elsewhere are helping to solve little by little these many and complex problems.

Perhaps it is appropriate at this time to consider whether the accepted methods of cultivation of this crop are the most suitable in an agronomic situation that includes herbicides. Such a consideration must inevitably include experimental work, some of which may reveal the need for revised or even new cultural techniques.

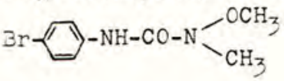
In the beginning a herbicide has to be tailored to the existing cultural, biological, and social circumstances. The nature of these circumstances depends on many factors: available machinery, soil type, irrigation, disease control, growth habit of the crop varieties, weed species, consumer habits, labour market and so on. Later as our knowledge increase we may move away from the accepted practises into methods which may now appear progressive and radical but in their own time will be perfectly logical and acceptable

In our own developmental work on a new potato herbicide we have compared established and revised cultural methods. Some of the results, we believe, are of general interest, regardless of the chemical used.

METHODS AND MATERIALS

In green house screening trials during 1962/63 one compound showed good selectivity and herbicidal action. It has the following chemical-physical characteristics:

Chemical name: N-(p-bromophenyl)-N'methyl-N'-methoxyurea

Structural formula: 

Water solubility: 330 ppm

Molecular weight: 259

Formulation: 50% WP

Toxicity: (acute oral) Mouse LD_{50} > 1000 mg/kg; Rat LD_{50} > 1000 mg/kg.

In limited field tests in 1963 good herbicidal properties were noticed along with a satisfactory crop tolerance. In these first field tests a similar compound, which had a water solubility of 90 ppm, was also tested. This compound, however, was exteremely toxic to crop plants in high rainfall areas, demonstrating well that water solubility and "selectivity" in pre-emergence applications are two different phenomena.

This year, C 3126 has been tested in several European countries but the trials described below refer to experiments conducted in Switzerland.

1. Yield trials

At three locations, Otterbach (Basel), Zeiningen (Aargau), and Vouvry (Valais) trials were conducted involving the following treatments (Active ingredient):

1. Hand weeded control
2. C 3126 1 kg/ha (0,89 lbs/acre)
3. C 3126 2 kg/ha (1,78 lbs/acre)
4. C 3126 3 kg/ha (2,67 lbs/acre)
5. C 3126 4 kg/ha (3,56 lbs/acre)

6.-8. Competitive products belonging to the urea and triazine groups.

At two of these locations, Otterbach and Zeiningen, each of these treatments was applied at two different times:

A. Immediately after laying of the tubers and ridging

B. Shortly before the emergence of the potatoes.

At Vouvry only method A was under investigation.

At Otterbach and Zeiningen the experimental area was divided into 16 cultivation strips which ran N. - S. and 5 blocks that ran E. - W., so as to give plots 40 m^2 in area. The times of application A and B were assigned at random to pairs of the cultivation strips. Within each block the 8 treatments were randomised, firstly between all the A strips and then between all the B strips. The resulting randomisation was restricted but such a plan was necessary to enable the cultivation of the B plots with ordinary farm machinery, without at the same time disturbing the A plots. All the A plots were left undistrubed throughout the growing period whereas the B plots received the customary cultivations, such as one harrowing followed by one or two ridgings. In the B plots the chemicals were applied shortly before the emergence of the potatoes. After spraying no more cultivations were carried out. The potato haulm was killed with "Reglone" and the plots were harvested individually.

Several details of the experiments are set out in Table 1. The soil was moist at all spraying dates and sufficient moisture was present during most of the growing season.

TABLE 1. DETAILS OF THE SITES

Site	Otterbach	Zeiningen	Vouvry
Soil	humus, light	medium, loam	sandy
Variety	Sirtema	Bintije	Sirtema
Planting date	April 16th	April 17th	May 1st
Application date A	April 21st	April 22nd	May 5th
Application date B	May 13th	May 16th	-
Weed growth date A	pre-emergent	pre-emergent	pre-emergent
Cultivations: date A	none	none	none
Cultivations: date B	harrowing, ridging	harrowing, ridging	-
Harvesting dates	July 20-23rd	August 24-26	August 26-27

Table 2 is a list of the weeds present in the experiment, the prevalent species are underlined.

TABLE 2. WEEDS PRESENT IN THE EXPERIMENTAL AREAS

Otterbach	Zeiningen	Vouvry
Stellaria media	Polygonum persicaria	Stellaria media
Urtica ureus	Raphanus raphan.	Capsella bursa-pastoris
Galinsoga parviflora	Daucus carota	Plantago major
Sonchus spp	Galium aparine	Rorippa sylvestris
Chenopodium album	Plantago lanc.	Polygonum lapatifolium
Chenopodium polyspermum	Fumaria officin.	Sinapis arvensis
Solanum nigrum	Stellaria media	Chenopodium album
Senecio vulgaris		Dactylis glomerata
		Poa annua

2. Time of Application Studies

Time of application studies were made at Otterbach in a field of potatoes, variety Bintije, that was planted on April 27th and ridged on May 15th. The following 4 treatments were applied at each of 7 spraying dates (Plot size 20 m^2):

1. Control no treatment
2. C 3126 1 kg a.i. per ha (0,89 lbs/acre)
3. C 3126 2 kg a.i. per ha (1,78 lbs/acre)
4. C 3126 3 kg a.i. per ha (2,67 lbs/acre)

Some details of this experiment are given in Table 3.

TABLE 3. DETAILS ON APPLICATION STUDIES

Time of Application		Soil Condition	Development stage of:	
			Potatoes	Weeds
A	April 28	dry	pre-emergent	-
B	May 2-5	dry	pre-emergent	cotyledons
C	May 9	moist	pre-emergent	1st true leave
D	May 15	moist	some appearing	some old weeds
E	May 20	moist	emerged,3cm high	2-4 true leaves
F	May 25	dry	5-10 cm high	4-6 true leaves
G	June 3	moist	over 15cm high	developed

A similar experiment was conducted at the Vouvry site where the above treatments were applied at 5 dates to the same variety, Bintije.

Observations were made on the experiments on 3 different occasions.

3. Variety Trials

At the Otterbach location the following varieties were planted on April 23rd: Sirtema, Ersteling, Bintije, Urgenta, Maritta, and Benedetta. On the 15th of May when the potatoes of the early varieties were just appearing the following treatments were applied (Plot size 20 m^2):

1. Control
2. C 3126 1,5 kg a.i. per ha (1,34 lbs/acre)
3. C 3126 3,0 kg a.i. per ha (2,67 lbs/acre)
4. C 3126 6,0 kg a.i. per ha (5,34 lbs/acre)

Parallel to these variety tests logarithmic trials were carried out for the purposes of comparing the two methods of application.

Several times during the growing season, in all experiments, notes were taken on weed control and on phytotoxic effects on the potatoe plant.

Phytophthora infestans and the Colorado beetle were kept under control by several sprayings. No fertilizers were applie[d] either before or during the growing season.

In the Yield tests the plots were harvested by hand and the yield of large and small tubers was measured. Samples for taste tests and residue analysis were separated. The yield data were analysed statistically as a randomised block design.

RESULTS

1. Yield Tests

(a) Effect on weeds

For each plot an assessment was made of general weed cover in terms of untreated and unweeded parts of the experimental area. In Table 4 the assessment figures, averaged over replications, are reproduced. Chemical compounds from other firms are not included in the table. The performance of these was within expectation.

TABLE 4. EFFECT OF TREATMENTS ON WEEDS IN YIELD TESTS (Non-linear scale from 1 (best) to 9 (no control))

		Weed Assessment	Otterbach Date A	Otterbach Date B	Zeiningen Date A	Zeiningen Date B	Vouvry A
Control	(not weeded)		9	9	9	9	9
C 3126	1 kg a.i./ha (0,89 lbs/acre)	1	4	-	4	-	1*
		2	5	4	5	2	1
		3	8	4	4	2	-
C 3126	2 kg a.i./ha (1,78 lbs/acre)	1	2	-	2	-	1
		2	3	2	2	1	1
		3	5	2	2	1	-
C 3126	3 kg a.i./ha (2,67 lbs/acre)	1	2	-	2	-	1
		2	2	2	2	1	1
		3	4	2	2	1	-
C 3126	4 kg a.i./ha (3,56 lbs/acre)	1	1	-	2	-	1
		2	1	1	1	1	1
		3	2	1	1	1	-

* These figures do not include Dactylis glomerata which was not controlled.

(b) Visual Effects on Potatoes

In all three locations no visual damage on the potato was observed in plots treated with C 3126, even though the late spraying in at least one location (Otterbach) was done at a time when 5% of the plants were already emerged.

(c) Yield Data

Each plot of 5 x 8 m consisted of 8 rows. The two border rows were discarded leaving 6 rows of 8 metre length for harvesting. Table 5 gives the tuber yields in tons per hectare and in parenthesis in tons per acre for each treatment.

TABLE 5. YIELDS OF POTATO TUBERS (in tons per hectare and acre)

	Otterbach Date A	Otterbach Date B	Zeiningen Date A	Zeiningen Date B	Vouvry Date A
Hand weeded control	23.08 (9.16)*	24.61 (9.77)	32.0 (12.7)	37.5 (14.9)	45.7 (18.1)
C 3126 1 kg a.i./ha	23.11 (9.17)	30.40 (12.07)	34.4 (13.7)	32.3 (12.8)	41.7 (16.5)
C 3126 2 kg a.i./ha	25.17 (9.99)	29.37 (11.66)	30.9 (12.3)	31.1 (12.3)	42.3 (16.8)
C 3126 3 kg a.i./ha	26.57 (10.55)	29.20 (11.59)	31.8 (12.6)	31.7 (12.6)	40.7 (16.2)
C 3126 4 kg a.i./ha	31.77 (12.61)	24.01 (9.53)	25.9 (10.2)	26.7 (10.6)	39.3 (15.6)
	25.94 (10.30)	27.51 (10.92)	30.4 (12.1)	31.9 (12.7)	41.9 (16.6)

* English tons

An Analysis of Variance was carried out according to the following partition scheme:

Variance due to Treatments with 9 d.f. (5 treatments at 2 dates)

Variance due to Chemicals with 4 d.f. (4 chemicals + 1 control)

Variance due to Dates (A,B) with 1 d.f. (2 application dates)

Variance due to Interaction with 4 d.f.

TABLE 6. ANALYSIS OF VARIANCE ON TUBER YIELD (plot basis) AT 3 LOCATIONS

	Otterbach	Zeiningen	Vouvry
mean square due to treatments	475.8 N.S.	351.4 N.S.	-
mean square due to chemicals	255.1 N.S.	651.7 *	108.6 N.S.
mean square due to dates (A,B)	280.8 N.S.	180.0 N.S.	-
mean square due to interaction (dates + chemicals)	745.3 *	94.0 N.S.	-
mean square due to error	238.0	192.6	66.5

* Significant at the 5% level

N.S. Not significant

2. Time of Application Studies

Assessments of weed control were made on May 25, June 2, and June 22. The assessment figures are set out in Table 7. These figures are an estimate of general weed cover in terms of an untreated plot, an untreated plot being given the figure 9 for weed cover.

TABLE 7. WEED CONTROL AT 7 APPLICATION DATES AND 3 ASSESSMENTS

Time of Application	C 3126 1 kg a.i./ha			C 3126 2 kg a.i./ha			C 3126 3 kg a.i./ha		
	1.	2.	3.	1.	2.	3.	1.	2.	3.
A	4	5	6	3	3	5	3	3	2
B	3	4	4	2	3	4	1	1	2
C		2	3		1	2		1	1
D		2	3		1	1		1	1
E		2	4		1	1		1	1
F		2	2		1	1		1	1
G		-	-		-	1		-	1

At each of the above dates phytotoxicity on the potatoes was evaluated. The data are not reproduced in detail since only the last 3 dates of application produced any effect. This effect was in the form of yellowing of the leaves directly after spraying; the yellowing completely disappeared within a few days. At the Vouvry location phytotoxic effects of the post-emergent spraying dates were a little more severe and disappeared at a slower rate, but there also the disappearance was complete.

3. Variety Trials

None of the 6 varieties, even when treated with 6 kg a.i. per hectare, showed any symptoms of phytotoxicity on the potatoes. The 6 kg/ha rate represents an overdose of almost 200%. Weed control at the 3 and 6 kg a.i. rate was excellent. The tests with the logarithmic sprayer confirmed the results obtained in the plot experiments.

DISCUSSION

1. Weed Control

All tests indicated that an excellent weed control could be obtained when applying at least 2 kg a.i. C 3126 per hectare. Occasionally and especially at late dates of application 1 kg a.i. per hectare would suffice. If weed control over an extended period of time, say immediately after planting till harvesting, is desirable, higher rates can be used without harmful effects. It appears that at lower rates a small number of weeds escaped and once established free from competition, those weeds then persisted till harvest. In places where Galinsoga parviflora is a problem germination throughout spring and early summer may occur. In such places the need for high rates applied early in the season is indicated. This can be deduced from the differences between the weed control assessments for date A and date B in the yield tests (see Table 4). With respect to weed control, date B needed less chemical than date A for a season long control. However, one should not forget that at least 2 cultivations for the sole purpose of controling weeds preceeded the spraying of the herbicide at date B. Had the test been on late varieties more cultivations would have been necessary. Important is the fact that the cultivations if done for the sole purpose of controlling weeds could be done away with by applying the herbicide earlier and at a slightly higher rate.

Ridge cultivation of potatoes is not the most convenient for spraying with a soil herbicide if the ordinary spraying boom is used. Winds would prevent an even distribution on both sides of the ridges and weeds would appear on the lee-ward side of the ridge. By bending the boom or changing the angle of the nozzles partial correction could be achieved.

2. Phytotoxicity on the Crop

When, as in the yield tests and variety trials the applications are carried out before the crop emerged, soil protection of germinating tubers and young sprouts was obtained. C 3126 showed no visible damage in any of the numerous yield test plots nor in the variety trials where an overdose of almost 200% was applied. It must be kept in mind very clearly that the absence of visible damage on vines does not necessarily mean there is no decrease in yield. This point will be dealt with in the discussion on the yield tests.

In the time of application studies the first 3 application dates were pre-emergent and the other 4 were post-emergent. Even when the potatoes were 15 and more centimetres high the yellowing of the leaves which occurred after spraying disappeared very quickly. The rate of disappearance depended on environmental conditions.

One fact becomes quite apparent, namely that C 3126, when sprayed on emerging or emerged potatoes, will not reduce stands and cause permanent damage to the plants. Whether this tolerance holds for other varieties, soils and climates remains to be seen.

3. Yield Tests

The yields in tons per hectare in Table 5 are within the normal range of yields for potatoes in Switzerland. The growing season was quit favourable with ample rain and no frosts. The two methods of application, herbicide with cultivation and herbicide without cultivation, when considered over all treatments did not give any difference at either location. Including the 3 herbicides of other firms the average yield of all A-plots was 27.07 tons and of all B-plots 27.27 tons per hectare at the Otterbach location. At the Zeiningen site the difference was even less.

The two methods of application at Zeiningen gave identical yields. At Otterbach the late application generally showed higher yields with the exception of the 4 kg rate which depressed the yield considerably, thus resulting in a significant interaction variance. Possibly the late application of twice the normal rate of C 3126 had a detrimental effect on tuber yield. At Zeiningen both the early and late application of 4 kg a.i. per hectare depressed yields, while at Vouvry on a sandy soil no decrease at the 4 kg rate was observed. Therefore,applying twice the recommended rate, in some instances depresses yield, in others no difference was observed and in one an increase of over 20% was noted. It should be noticed that even though a detrimental effect on yield was found in 3 cases there were never any visible signs of damage in the plots treated with 4 kg per hectare C 3126. This demonstrates the necessity of evaluating phytotoxicity on the crop by using yield as the test criterion and not only visible damage on leaves or haulms.

Further experiments are needed to establish the critical level of C 3126 and time of application with respect to influence on tuber yield.

WEST OF SCOTLAND TRIALS OF POTATO HERBICIDES, 1961-1964

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Summary West of Scotland field trials of a wide range of herbicidal treatments for potatoes have shown applications when the first potato shoots are breaking through the soil to be more effective than applications earlier or later than this. Of the emergence sprays prometryne, linuron, and a 26:6 prometryne/simazine mixture all at 2 lb. (active) per acre gave highly satisfactory weed control, and the yields from the prometryne and linuron treated plots equalled those from the cultivated control plots over 8 and 6 centres respectively. Only 2 such yield comparisons were available at the time of writing for the prometryne/simazine mixture. The investigation is continuing.

INTRODUCTION

In 1960 Robertson (1960) and Wood et. al. (1960) reported successful herbicidal control of weeds in potato crops in central and eastern Scotland. In 1961 the West of Scotland Agricultural College commenced trials to assess the efficiency of a range of herbicidal treatments, and their effects on potato yields under the generally higher rainfall conditions of the west. This work will be reported more fully elsewhere once the trials are completed.

METHODS AND MATERIALS

Trials were laid out as duplicate randomised blocks, plot size 6 drills x 9 yd. long, with 1 yd. discards between plots. Spraying was by Oxford Precision or Drake and Fletcher sprayers at a volume rate of 40 gal. per acre. The herbicides used included:

Desmetryne	- a 25% w.p. supplied by Messrs. Fisons Pest Control Ltd.
Dinoseb	- amine salt supplied by Messrs. A.H. Marks and Co. Ltd.
Dinoseb/oil	- a formulation supplied by Messrs. A.H. Marks and Co. Ltd.
Linuron	- a 50% w.p. supplied by Messrs. Farm Protection Ltd.
Paraquat	- as 'Gramoxone' supplied by Messrs. Plant Protection Ltd.
Prometryne	- a 50% w.p. supplied by Messrs. Fisons Pest Control Ltd.
Simazine	- a 50% w.p. supplied by Messrs. Fisons Pest Control Ltd.
Trietazine	- a 50% w.p. supplied by Messrs. Fisons Pest Control Ltd.

Records of weed control were obtained by visual 'scoring' of weed growth on each plot, and where possible by species counts on two 1 sq. ft. quadrats randomly located within each plot. Occasionally the dense growth of weeds such as chickweed made quadrat counts impossible. Yields were estimated by harvesting the four centre drills from each plot.

RESULTS/

RESULTS

The present summary reports only those treatments for which at least three yield figures are available, except where there is a clear relationship to other treatments in the series. Only treatments applied when the potato shoots were just breaking through the soil are included; treatments at planting or after emergence of the potatoes generally either gave poor weed control or reduced crop yields. Herbicide rates quoted are in lb. active ingredient per acre except in the case of the prometryne/simazine mixture which is oz. active material per acre. Table 1 shows the main weeds at each site (sites identified by county only) as well as the less important but widely distributed species. Weeds occurring only in patches are omitted. Table 2 indicates the general level of weed control achieved, by treatments, at each site, and is based on weed 'scores' generally taken 3-6 weeks after treatment. Table 3 summarises information on weed control obtained from direct observations on weed kill and from the quadrat counts made on individual plots. The potato yields given in table 4 include ware and seed sizes, i.e. all tubers over $1\frac{1}{4}$" riddle.

DISCUSSION

Table 1 emphasises the importance of Polygonum persicaria and Stellaria media as weeds of potato crops in western Scotland. Urtica urens is often troublesome in early potato fields, as for example the three Wigtownshire trials. After 1962 some effort was made to avoid sites with Agropyron repens infestations, although this was not always possible.

Table 2 tends to understate the degree of weed control obtained, which was often towards the upper limit of the ranges defined. No herbicide treatment was wholly successful at all sites, but on the other hand there was no centre where one or other of the treatments tested did not give satisfactory weed control. Some 'occasional' failures can be traced to presence of a weed which is not well controlled by the herbicide (e.g. U. urens, which is not controlled by dinoseb, at Wigtownshire sites 1962 and 1963) but at other centres this is not so and it seems likely that weeds which had not germinated, or had not emerged at spraying may have survived treatment. Very heavy rain within a few hours of spraying the Renfrewshire trials in 1964 probably reduced the weed control at these sites.

Table 3 supplements the data of table 2 and again tends to understate weed control in that the new and re-growth of weeds which can occur when a herbicide has little or no residual effect was responsible for some of the right-hand column values.

The severe yield reductions where weeds were allowed free growth serve to emphasise the importance of weed control by one means or another (table 4). Yield data from duplicate plots are not sufficiently accurate to permit the detection of small differences at individual centres and studies of a different type would be necessary to determine treatment effects on crop yield in the absence of weeds. Isolated low yields in this table are of little significance, and it is of interest that where there exists a reasonable number of comparisons, mean yields from the herbicide plots compare with those from cultivated controls.

Generalising/

Table 1. Weeds in each trial as main species (+) and as well distributed but less numerous species (o)

	1961		1962				1963					1964					
						E			E	E	E				E	E	
	Ayr	Renfrew	Ayr	Renfrew	W. Perth	Wigtown	Renfrew	W. Perth	Wigtown	Dunbarton	S. Argyll	Renfrew (a)	Renfrew (b)	W. Perth	Wigtown	S. Argyll	Dumfries
Agropyron repens	+	+	+		+						+						+
Chenopodium album	+	+	+			o											o
Fumaria officinalis							o							+			o
Galeopsis tetrahit				+	+			+			+			+		+	
Matricaria matricarioides						o								o			o
Poa annua			o	+					+	+		+		+	+	+	
Polygonum aviculare			o									+		o			o
Polygonum persicaria	+	+	+	+	+	o	+	+		+	+	+	+		+		+
Ranunculus repens				+						+	+						o
Rumex acetosella											+						
Senecio vulgaris						+											
Sinapis arvensis			+	+										+			o
Spergula arvensis					+	o	+			+	+		+				o
Stellaria media	+	+	o	+		o	+	+	+	+		+	+	+		o	+
Urtica urens						+			+						+		
Viola tricolor														+			

E indicates an early potato crop

Table 2. Overall level of weed control achieved by herbicides. (G= 80% and over F= 60-80% P= less than 60% control)

	1961		1962				1963					1964					
	Ayr	Renfrew	Ayr	Renfrew	W. Perth	Wigtown	Renfrew	W. Perth	Wigtown	Dunbarton	S. Argyll	Renfrew (a)	Renfrew (b)	W. Perth	Wigtown	S. Argyll	Dumfries
Desmetryne 2							F	G				F			G		G
Dinoseb 4 (+ TCA 10 in 1961)	G	G		G	G	F			F	F	P						
Dinoseb/oil 2½ (2 in 1963)									P	G	F	F	P	F	G	P	F
Linuron 2							F	G	G	G	P	F	G	F	G	F	G
Paraquat 1				G	G	P	P	G	P	G	P						
Prometryne 2				G	G	G	P	G	G	G	F	G	G	F	G	F	G
Desmetryne 1 + paraquat ½												F	F	G	G	G	G
Desmetryne 2 + paraquat 1							F	G									
Linuron 2 + paraquat 1							G	G									
Simazine ½ + paraquat ¾			G						F	G	G						
Trietazine 1 + paraquat ½												F	F	G	G	G	G
Trietazine 1 + paraquat ¾			G						F	G	G						
Prometryne 1 + linuron 1												G	G	G	G	P	G
Prometryne 26 oz. + simazine 6 oz.												G	G	G	G	F	G

Table 3. The control of individual weed species by herbicides; left and right hand figures indicate number of trials in which control exceeded 80% and was less than 80% by plant number, respectively.

	Agropyron repens	Chenopodium album	Fumaria officinalis	Galeopsis tetrahit	Poa annua	Polygonum aviculare	Polygonum persicaria	Ranunculus repens	Sinapis arvensis	Spergula arvensis	Stellaria media	Urtica urens
Desmetryne 2		1 0	1 0		2 2	0 1	2 0			1 0	2 0	1 0
Dinoseb 4	0 1	1 0		1 0	0 5	1 0	3 0	1 0	1 0	1 2	1 1	1 1
Dinoseb 4 + TCA 10	0 2	1 0			1 0		1 1				1 0	
Dinoseb/oil 2	0 1	1 0			0 2		1 1			1 1	0 1	0 1
Dinoseb/oil 2¼		1 0	1 0		0 3		1 3		1 0	0 1	1 2	0 1
Linuron 2	0 1	3 0	0 2	1 1	3 3	2 0	5 1	0 1	1 0	3 0	5 1	1 1
Paraquat 1	0 1	1 0	1 0	1 2	3 3		4 0	1 0		4 1	4 2	0 2
Prometryne 2	0 2	4 0	2 0	1 0	3 4	1 1	8 0	1 1	2 0	5 1	8 0	2 1
Desmetryne 1 + paraquat ½	1 0		1 0		0 2		3 1	0 1	1 0	1 0	1 1	1 0
Desmetryne 2 + paraquat 1		1 0	1 0	1 0	2 0		1 0			1 0	2 0	
Linuron 2 + paraquat 1		1 0	1 0	1 0	1 0		1 0			1 0	2 0	
Simazine ½ + paraquat ¾	0 2	0 1		2 0	4 0		3 0			2 0	3 0	1 0
Trietazine 1 + paraquat ½	1 0	2 0	1 0		5 0		3 2		1 0	2 0	1 1	1 0
Trietazine 1 + paraquat ¾	0 2	2 0		1 0	2 0		3 0	1 0	1 0	1 0	2 0	1 0
Prometryne 1 + linuron 1			1 0		2 0		5 1		1 0	1 0	3 1	1 0
Prometryne 26 oz. + simazine 6 oz.	0 1		1 0			0 1	1 3		1 0	1 0	2 0	1 0

Table 4. Potato yields, tons per acre

	1961	1962			1963				1964			
	Ayr	Ayr	W. Perth	Wigtown	Renfrew	Wigtown	Dunbarton	S. Argyll	Wigtown	S. Argyll	Dumfries	Comparisons with cultivated control (= 100)
Control, cultivated	14.6	12.8	16.3	8.4	9.2	7.1	14.1*	9.6	-	16.8	12.8	100
Control, uncultivated	12.6	4.4	10.3	5.8	4.2	6.7	12.2	7.1	8.5	14.3	7.6	70 (10)
Desmetryne 2					8.6				9.8		11.8	93 (2)
Dinoseb 4 (+ TCA 10 in 1961)	13.1		14.5	9.3		7.1	13.8	10.8				98 (6)
Dinoseb/oil 2¼ (2 in 1963)						6.9	14.3	10.6	8.9	12.3	11.4	92 (5)
Linuron 2					9.8	6.0	14.9	11.9	6.1	15.5	11.5	100 (6)
Paraquat 1			14.9	9.4	8.7	6.3	14.1	9.7				98 (6)
Prometryne 2			15.3	8.7	7.9	7.5	14.6	11.6	7.5	14.9	12.4	99 (8)
Desmetryne 1 + paraquat ½									8.4	13.0	13.1	88 (2)
Desmetryne 2 + paraquat 1					9.5							103 (1)
Linuron 2 + paraquat 1					10.2							111 (1)
Simazine ½ + paraquat ¾		11.6				5.0	14.0	11.4				96 (4)
Trietazine 1 + paraquat ½									9.6	15.2	10.7	88 (2)
Trietazine 1 + paraquat ¾		11.7				7.6	15.6	12.0				108 (4)
Prometryne 1 + linuron 1									9.0	12.8	11.8	83 (2)
Prometryne 26 oz. + simazine 6 oz.									7.9	13.5	10.9	82 (2)
Standard error (difference)	±1.5	±2.0	±1.4	±1.0	±1.6	±0.9	±0.8	±1.4	±1.0	-	±0.9	

* Estimate only

Generalising from the data of tables 1-4 it can be suggested that a purely contact herbicide, such as paraquat, is often inadequate for weed control in potatoes under west of Scotland conditions. Weeds which have not emerged at spraying will not be controlled, and a further generation of weeds may follow spraying. The residual effects of the dinoseb and dinoseb/oil treatments were too small to remove them from the contact herbicide class, and these materials and paraquat gave erratic results.

Desmetryne showed a useful range of weed control and deserves further study. Linuron and prometryne each gave satisfactory weed control over a wide range of conditions, although linuron was notably unsuccessful in controlling Fumaria officinalis, a weed which occurred as an occasional plant on several linuron treated plots although 'recorded' only in 2 trials. Mixtures of desmetryne, simazine, trietazine and linuron with paraquat gave no 'poor' results (table 2) and were perhaps rather more consistent in their action against individual weed species than where paraquat was not used (table 3). The prometryne/linuron and prometryne/simazine mixtures both show considerable promise in terms of weed control, but the commercial possibilities of all mixtures except prometryne/simazine remain somewhat obscure.

Practical recommendations based on the results of these trials would favour prometryne, linuron or the prometryne/simazine mixture all at 2 lb. (total) active material per acre. Linuron would not be chosen where Fumaria officinalis is an important weed, but apart from this, considerations of availability and cost per acre could govern choice.

Acknowledgments

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YIELD RESPONSE TO CHEMICAL WEED CONTROL IN POTATOES

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Summary Weed control in potatoes by pre-emergence application of various chemicals was compared with "normal" farm husbandry. Control of annual weeds by chemicals was generally good except for Polygonum aviculare, Fumaria officinalis, Veronica sp., and Avena fatua. Perennial grass weeds (Agropyron repens and Agrostis gigantea) were not satisfactorily controlled. The yield of the crop following chemical treatment was equal to or greater than that from plots where the weeds were controlled by cultivation except in one trial where "couch grass" was troublesome.

INTRODUCTION

Field scale trials have been carried out over the last three years to investigate the possibility of replacing mechanical methods of weed control in potatoes by the use of pre-emergence weed killers. Weed control by chemicals has been compared with that obtained by cultural methods and the effect on yield of the two systems of husbandry has been investigated.

In the North East of Scotland, potatoes are grown almost entirely for "seed" production. Ware production is incidental and is to a large extent deliberately restricted by early haulm destruction which is also necessary to reduce blight in the tubers. Early potatoes are grown for ware in certain coastal areas.

The soils on which potatoes are grown are usually of a light, sandy nature, although in South Kincardineshire a large acreage is grown on a medium heavy red soil. Potatoes are rarely grown on clay soils.

The annual weed flora of the area is typical of an arable system of husbandry but there are certain species such as daynettle, Galeopsis sp., yarr, Spergula arvensis, knotweed, Polygonum aviculare, bugloss, Anchusa arvensis and corn marigold, Chrysanthemum segetum, which have above average incidence. Perennial weeds such as creeping thistle, Cirsium arvense and docks, Rumex sp., are not generally troublesome but coltsfoot, Tussilago farfara, is occasionally encountered.

Perennial grass weeds, chiefly "couch", Agropyron repens, and bent, Agrostis gigantea, are present throughout the area, especially on the lighter soils where potatoes are mostly grown and even on supposedly "clean" fields generally become evident in the absence of cultivation.

In this area unsprouted "seed" is usually planted and there is an interval of 4-6 weeks between planting and emergence of shoots. During this time there is generally profuse emergence of annual weed seedlings, cereal seedlings and a few shoots of "couch grass". During a normal season with a fairly dry early Summer period, there is little further annual weed growth, but where it is present, "couch grass" generally appears freely after crop emergence. In a wet year, late development of chickweed, Stellaria media, is often troublesome.

NORMAL HUSBANDRY

In these trials chemical weed control was compared with cultivation, the nature of which was entirely decided by the farmer. The number and timing of the cultivations was very variable and could not be directly related to the soil type or severity of the weed infestation. In the results (Appendix 1) it has been classified as heavy, normal or light. Normal cultivation in North East Scotland would involve planting by hand or machine followed by ridging up immediately, or after a few days' delay; later the ridges would be harrowed down, if possible under dry conditions, at the first signs of annual weed growth, and ridged up again shortly afterwards. A second harrowing down usually takes place just before emergence in the belief that it assists early shoot emergence. One inter-row cultivation would be carried out soon after emergence followed by final earthing up when the haulm is well developed.

The implements used during this programme are very varied; mounted "saddle back" harrows are quite common but flat harrows and other implements are sometimes used to knock down ridges. Inter-row cultivation would generally be done with the normal type of mounted tined cultivator. A certain amount of hand hoeing between the plants in the ridges is still carried out, especially where "couch grass" is troublesome.

Light cultivation, which, if judiciously timed under dry conditions, usually gives quite an acceptable control of annual weeds, might consist of a single harrowing down just before crop emergence followed by ridging within a day or two.

Heavy cultivation would involve harrowing down and ridging twice before emergence, and inter-row grubbing before and after emergence.

In general, except for sites at which chickweed, Stellaria media, was prevalent, mechanical weed control was equal or superior to that achieved by chemicals.

CHEMICAL WEED CONTROL

Initially, application of residual materials immediately after planting was tried. On medium soils some success was achieved, but on light soils none of the materials (simazine, atrazine, prometryne, linuron and a diuron-CIPC mixture) gave satisfactory persistent weed control. In all later trials the chemicals were applied as late as possible before emergence of the potato shoots, the crop having been planted and ridged and then left completely undisturbed. In the 1964 trials paraquat $\frac{1}{2}$ lb. a.i./ ac. plus linuron 1 lb. a.i./ac. was used as a standard treatment and was compared with a variety of other chemical treatments which were selected according to the nature of the weed problem at individual sites.

Paraquat alone at $\frac{1}{2}$ lb. a.i./ac. proved capable of killing all annual weed seedlings which were present at the time of spraying except for any well-developed plants of knotweed, Polygonum aviculare, which survived in spite of severe scorch of the outer leaves. Cereal seedlings, tufts of annual meadow grass, Poa annua, and cocksfoot, Dactylis glomerata, were also killed. The foliage of "couch grass" which had emerged at the time of spraying was also killed. This treatment was only used at centres where there was a considerable weed growth before crop emergence and at these sites no serious difficulties were encountered with further weed emergence. Although a slightly improved control was obtained with the addition of linuron at 1 lb. a.i./ac., the considerably increased cost of this treatment did not appear to be justified. Where there was little or no weed emergence before the crop, linuron alone at $1\frac{1}{2}$-2 lb. a.i./ac. and a proprietary prometryne/simazine mixture at 4 lb./ac. were used. Both appeared to give a good suppression of annual weed growth except knotweed, Polygonum aviculare, but did not exercise any control of "couch grass". Fumitory, Fumaria officinalis, and speedwell, Veronica sp., occurred sporadically and did not appear to be checked by any of the residual materials. At one observational centre, wild oat, Avena fatua, was encountered. Plants present at the time of spraying were killed by paraquat but later germinating seedlings escaped.

Key to chemical treatments

Para. = 8 oz. paraquat/ac. except at Tillycorthie where 8 oz. paraquat + 8 oz. diquat was used.

Lin. = 24 oz. linuron/ac. except at Craibstone 1963 and 1964 where 32 oz./ac. was used.

Para. + Lin. = 8 oz. a.i. paraquat + 16 oz. a.i. linuron/ac.

Pro./Sim. = 26 oz. prometryne + 6 oz. simazine/ac. except at Rosskeen where 13 oz. prometryne + 3 oz. simazine + 8 oz. paraquat/ac. was used.

Res. = Craibstone 1962 32 oz. CIPC + 6.4 oz. diuron/ac.
Craibstone 1963 24 oz. CIPC + 9.6 oz. diuron/ac.
Aldroughty 1963 16 oz. CIPC + 6.4 oz. diuron + 8 oz. paraquat/ac.

Sim. = 16 oz. simazine/ac.

Serious crop damage due to chemicals was only experienced at one unreplicated trial site on heavy clay soil where a diuron/CIPC mixture gave symptoms very similar to those of blackleg disease.

Chlorosis due to paraquat occurred frequently on shoots which were just emerging at the time of spraying but this effect soon disappeared as the new foliage was formed.

More vigorous haulm growth on chemically treated plots was sometimes observed and it was at these centres that increases in yield were obtained. Earlier maturity and natural collapse of foliage following chemical treatment was observed at one centre (Rosskeen) on an early variety.

EXPERIMENTAL TECHNIQUE

The trials were all carried out on a field scale, plots 4 drills wide the full length of the field being used, in a randomised block layout with 4 replicates. There was a single discard row between each plot. Spraying was by a Land Rover-mounted Vigzol sprayer with modified bypass hydraulic agitation calibrated to deliver 40 gal./acre. The sides of the ridges straddled by the Land Rover were partially crushed and it was frequently noted that subsequently a strip of annual meadow grass, Poa annua, and/or annual weeds developed here in spite of the chemical treatment.

Yield was usually determined by hand digging a 10 yd. wide strip across the whole series of plots, no separation into ware, seed and chats being attempted, but it was observed that where chemical treatment had given an increased yield, this appeared to be due to the presence of larger tubers. At Tillycorthie, 2 drills only of each plot were completely lifted with a potato harvester. At Balspardon and Rosskeen, the tubers were gathered by pickers behind a digger. The standard error of the treatment mean of these two trials proved exceptionally high.

RESULTS

In Appendix 1 the data relevant to 13 replicated field scale trials is summarised. Appendix 2 gives the chemical treatments used at each centre, yield as a percentage of that obtained in the cultivated plots, an arbitrary assessment of weed control, and some indication of the weed species which survived chemical treatment.

Assessment of weed control

Ex. = excellent weed control (9+)

G. = good weed control (7-9)

F. = fair weed control (5-7)

U. = unsatisfactory weed control (below 5)

(10 = complete control   0 = no control)

DISCUSSION

There are many factors which will decide the acceptability of chemical weed control as an alternative to established methods of husbandry; the purpose of this study has been to investigate whether a reliable increase in yield can be expected from this new technique.

Substantial yield increases were recorded as at Craibstone 1962, Aldroughty 1963, Balnastraid 1964. These would be of sufficient magnitude to more than repay the cost of chemical treatment.

In 1964, however, at most of the centres, there was no significant increase in yield following chemical treatment in spite of good or excellent weed control. From these results, it would appear that, when cultivation is kept to a minimum adequate to control the weeds present, chemical weed control cannot be confidently expected to produce any yield response in the crop.

Yield decreases have been recorded as at Cairngall 1964 where it seems that competition from the "couch grass", which was not controlled by the chemical treatment, seriously reduced crop yield. In an unreplicated trial at East Balhalgardy 1963, not shown in the results, yield from chemical plots was lower than cultivated ones in spite of excellent weed control. This site was on heavy clay soil, the season was a very wet one and it is suggested that here yield reduction was due to inadequate soil aeration in the absence of cultivation.

The origin of the yield increases is not easy to determine. Weed competition was undoubtedly a serious factor at Craibstone 1962 where cultivation failed to control chickweed. At Aldroughty 1963 cultivation was heavy and it is possible that damage to roots was a serious factor. Root damage seems unlikely to be the cause of the difference between treatments at Balnastraid 1964 where a very minimum of cultivation was carried out. Here it is suggested that there is a possibility of moisture loss associated with soil disturbance at the beginning of a prolonged drought period being of importance.

Although occasionally partial failures of weed control by chemicals were experienced, it generally appears possible to control annuals successfully except for knotweed, Polygonum aviculare, fumitory, Fumaria officinalis and speedwell, Veronica sp., either by use of a contact herbicide when weeds emerge before the crop, or residual materials when weed emergence is delayed. Annual meadow grass, Poa annua, self-sown cereals and grasses persisting after ley can be satisfactorily controlled by paraquat. "Couch grass" cannot be satisfactorily controlled by existing chemicals as the main flush of shoots emerges after the potato haulm.

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The author wishes to acknowledge the help of farmers who gave facilities for these trials and the assistance rendered by colleagues on the North of Scotland College of Agriculture staff.

Appendix 1

SITE	VARIETY	SOIL TYPE	PLANTED	SPRAYED	CULTIVATION	POTENTIAL WEED PROBLEM
1962						
CRAIBSTONE	Craigs Royal	Medium	27 Apr.	17 May	Light	Dense chickweed
1963				(17 May Res.)		
CRAIBSTONE	Majestic	Medium	2 May	11 June	Normal	Annuals
ALDROUGHTY	Craigs Royal	Light sandy	17 May	29 May	Heavy	Annuals and couch
1964						
CRAIBSTONE	Majestic	Medium	27 Apr.	28 May	Normal	Chickweed and other annuals
ALDROUGHTY	Pentland Dell	Light sandy	21 Apr.	27 May	Heavy	Annuals
BALNASTRAID	Majestic	Light sandy	8 Apr.	18 May	Light	Annuals
				(13 Apr. Lin.)		
BALSPARDON	Duke of York	Sandy high O.M.	14 Mar.	28 Apr.	Normal	Annuals
ROSSKEEN	Foremost	Light	26 Apr.[I]	6 May	Light	Annuals
DYTACH	Majestic	Medium clay	17 Apr.	22 May	Normal	Couch patches few annuals
FINTRY	Up-to-Date	Medium	24 Apr.	27 May	Light	Chickweed
CAIRNGALL	Majestic	Light sandy	8 Apr.	12 May	Heavy	Dense couch mixed annuals
SLAINS PARK	Majestic	Medium stony	13 Apr.	25 May	Normal	Chickweed and other annuals
TILLYCORTHIE	Kerr's Pink	Medium	16 Apr.	25 May	Light	Chickweed and other annuals

[I] sprouted seed

Appendix 2

Site	Cultural weed control	Yield tons/ac.	Sig. diff. %	Weed control and yield (% of cult. control)						Resistant species
				Para.	Para. + Lin.	Lin.	Pro./ Sim.	Res.	Sim.	
1962										
CRAIBSTONE	U. (chickweed)	11.9	12.4	-	-	-	-	Ex.128*	Ex.98	None
1963										
CRAIBSTONE	G.	10.8	9.4	-	Ex.93	G.92	-	G.101	-	Polygo[illegible] aviculare
ALDROUGHTY	Ex.	12.9	4.0	-	G.102	-	-	Ex.113*	-	Polygonum aviculare
1964										
CRAIBSTONE	F. (chickweed)	11.8	14.6	-	-	U.103	U.105	-	-	Annuals
ALDROUGHTY	Ex.	20.4	5.5	G.105	G.101	-	-	-	-	Polygonum aviculare
BALNASTRAID	G.	14.9	4.3	G.115*	G.113*	-	-	-	-	Polygonum aviculare
BALSPARDON ‡	G.	9.1	27.6	-	F.106	U.x	-	-	-	Annuals
ROSSKEEN	G.	14.5	26.4	-	G.103	-	G.96	-	-	Fumaria officinalis
DYTACH	F. (couch)	10.9	8.3	-	F.104	F.104	-	-	-	"Couch" grass
FINTRY	Ex.	15.2	8.1	-	Ex.101	-	Ex.99	-	-	None
CAIRNGALL	F. (couch)	17.1	2.8	-	U.92*	-	-	-	-	"Couch" grass Matricaria sp. annuals
SLAINS PARK	G.	16.3	7.8	-	G.102	G.98	-	-	-	Fumaria officinalis Veronica sp.
TILLYCORTHIE	F.	14.9	11.0	G.100	G.112*	-	-	-	-	Polygonum aviculare Fumaria officinalis

* significant increase or decrease in yield x no yield taken ‡ crop irrigated

HERBICIDE TRIALS WITH POTATOES AT MYLNEFIELD, 1963 - 4

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Summary The use on the potato crop of a number of recently introduced herbicides, alone and in mixtures, was compared with two regimes of cultivation.

Control of annual weeds during the growing period of the crop was provided by several of the herbicides tested, but none were superior to the 6.0 lb per acre rate of dinoseb that has been found effective in previous work at Mylnefield. Good results were obtained with dinoseb in oil, linuron, monolinuron, solan, DPA, a simazine/prometryne mixture, and a paraquat/diquat mixture used alone or with linuron or prometryne.
Linuron alone was ineffective against *Fumaria officinalis*.

None of the yield differences with these materials or with cultivation were significant at the 5% level.

Growth of tubers and foliage appeared to be normal after all the above herbicides had been used, but no tests were made for taint or residues.

INTRODUCTION

The experiments here described were a continuation of work carried out in the period 1959 - 61 and reported by Wood et al. (1960) and Stephens (1962). This indicated that the weed-controlling effect of normal post-planting cultivations could be replaced by the use of a mixture of dinoseb amine and dalapon, without loss of yield or alteration of flavour. Later work (unpublished) showed that, at Mylnefield, dinoseb alone was as effective as a mixture of dinoseb and dalapon. Other herbicides, including simazine, atrazine and trietazine, were reported to be less satisfactory. It was later shown by Holly (1962) and Milford and Pfeiffer (1962) that several new herbicides showed considerable promise for use in potatoes. Dinoseb has proved itself effective over a number of years, but because of its poisonous and unpleasant nature a cheap effective but non-poisonous replacement is highly desirable.

The present paper describes trials in 1963 and 1964 of some newer herbicides, including linuron, monolinuron, prometryne, DPA, solan, dinoseb-acetate and dinoseb formulated in oil. In experiments I and III two levels of cultivation were used, consisting of (i) a routine programme of 6 - 8 operations, and (ii) the minimum cultivation actually required for weed control. Two tractor cultivations were sufficient for the latter purpose in both years.

The experiments reported are:

Experiment I (1963) - a replicated trial comparing linuron, paraquat + prometryne, paraquat + linuron, prometryne + simazine and MCPA + linuron with dinoseb-amine, and two cultivation regimes; varieties: Home Guard, Duke of York and Redskin.

Experiment II (1963) - a replicated screening trial in which experimental herbicide treatments were compared with the standard dinoseb-amine treatment and with a treatment in which weeds were allowed to grow unchecked from the time of planting; varieties: Home Guard and Redskin.

Experiment III (1964) - a replicated trial comparing four commercially-available potato herbicides used according to the manufacturers' recommendations, and three other herbicide treatments, and two regimes of cultivation; varieties: Arran Pilot, Craigs Royal and Majestic.

Experiment IV (1964) - a replicated screening trial comparing dinoseb-amine and dinoseb formulated in oil, and a number of new or experimental materials; varieties: Arran Pilot and King Edward.

METHODS AND MATERIALS

All the trials were conducted at Mylnefield on a free-draining sandy loam or medium loam. Scottish-grown Grade A seed was used throughout, and in 1964 this was graded to between $1\frac{1}{2}$ and $2\frac{1}{4}$ in. Fertilizer was applied mechanically to the open drills before dropping the seed by hand at a fixed number per plot. At planting, the soil was formed into shallow ridges, and in 1963 the herbicide-treated plots were thereafter left uncultivated. In 1964 the soil was wet at planting and the ridges made were poor and cloddy. Fresh ridges were run-up 10 days later, and the plots were then left uncultivated until harvest. The second ridging after planting destroyed the first flush of weeds, but a fresh germination soon occurred.

Herbicides were applied overall by Oxford Precision Sprayer at a volume-rate of 40 gal per acre. Spraying ridged land with a horizontal boom led to uneven distribution of the spray across the width of the plots, but in practice this did not lead to a noticeably irregular pattern of weed control.

Except where otherwise stated, all the sprays were applied when the first few potato shoots were emerging, and no attempt was made in any treatment to prevent the spray from reaching the crop foliage.

The chemicals used in the treatments are shown in detail in the tables of results.

RESULTS

The yields obtained and mean weed counts taken are indicated in the tables below.

TABLE 1

Experiment I 1963. Record of Yields in tons/acre

Size of plot harvested: 9 sq. yd.

	Treatment		Duke of York			Home Guard			Redskin		
			Ware	Seed	Total	Ware	Seed	Total	Ware	Seed	Total
1.	dinoseb-amine	6.0 lb/ac	4.4	4.3	8.7	5.6	3.2	8.8	6.0	3.5	9.5
2.	prometryne + Gramoxone W [1]	1.0 lb/ac 2.0 pt/ac	4.6	5.0	9.6	6.5	2.3	8.8	6.2	3.1	9.3
3.	linuron + Gramoxone W [1]	1.0 lb/ac 2.0 pt/ac	5.0	4.5	9.5	6.0	2.2	8.2	7.3	3.0	10.3
4.	prometryne + simazine	1.45 lb/ac 0.55 lb/ac	5.3	4.3	9.6	5.1	2.9	8.0	5.9	3.8	9.7
5.	linuron	2.0 lb/ac	5.3	4.1	9.4	6.0	2.6	8.6	6.4	2.9	9.3
6.	normal cultivation		4.5	4.3	8.8	6.1	3.2	9.3	6.3	2.9	9.2
7.	light cultivation		5.1	4.0	9.1	4.3	2.6	6.9	6.5	2.5	9.0
8.	MCPA (potassium)+ linuron	1.0 lb/ac 1.0 lb/ac	5.4	3.2	8.6	4.3	2.8	7.1	5.6	3.5	9.1
	standard error/plot		1.3	0.8	1.3	1.2	0.8	1.3	1.4	0.8	1.4
	significance of F test		N.S.	1.0%	N.S.	5.0%	N.S.	5.0%	N.S.	N.S.	N.S.

[1] Gramoxone W. = proprietary mixture containing paraquat + wetter

TABLE 2

Experiment II 1963. Record of Yields in tons/acre

Size of plot harvested: 9 sq. yd.

Treatment			Stage	Home Guard Ware	Home Guard Seed	Home Guard Total	Redskin Ware	Redskin Seed	Redskin Total
1.	Dinoseb-amine	6.0 lb/ac	1	6.6	2.4	9.0	7.5	2.8	10.3
2.	Dinoseb-acetate	5.32 lb/ac	1	6.0	2.4	8.4	7.8	3.7	11.5
3.	DPA	1.5 lb/ac	3	5.7	1.8	7.5	8.2	3.6	11.8
4.	DPA	3.0 lb/ac	3	5.4	2.0	7.4	6.8	2.3	9.1
5.	DPA	4.5 lb/ac	3	5.1	2.4	7.5	7.3	3.5	10.8
6.	DPA	4.5 lb/ac	4	2.0	2.2	4.2	4.5	2.7	7.2
7.	EPTC	6.0 lb/ac	1	4.7	2.9	7.6	7.2	3.9	11.1
8.	EPTC + linuron	6.0 lb/ac 2.0 lb/ac	1	5.7	2.5	8.2	7.8	3.1	10.9
9.	Prometryne + simazine	2.9 lb/ac 1.1 lb/ac	1	5.3	2.1	6.4	8.5	2.9	11.4
10.	Linuron	4.0 lb/ac	2	5.6	2.3	7.9	7.9	3.0	10.9
11.	MCPA (potassium)	2.0 lb/ac	4	2.9	3.5	6.4	5.6	3.4	9.0
12.	MCPA (potassium)	2.0 lb/ac	3	4.7	1.8	6.5	6.3	3.0	9.3
13.	MCPA (potassium)	1.0 lb/ac	3	5.6	2.3	7.9	5.8	4.0	9.8
14.	No cultivation			6.6	3.1	9.7	6.5	4.1	10.6
	Standard error/Plot			1.7	1.0	1.5	2.9	1.1	2.6
	Significance of F test			5.0%	5.0%	5.0%	N.S.	N.S.	N.S.

Time of application
Stage 1 Just prior to potato emergence
Stage 2 At early potato emergence
Stage 3 At 50% potato emergence
Stage 4 At 100% potato emergence

TABLE 3

Experiment III 1964. Record of Yields in tons/acre and Weed Numbers

Size of plot harvested: 8 sq. yd.

	Treatment		Craigs Royal			Majestic			Arran Pilot			Mean of 3 varieties
			Ware	Seed	Total	Ware	Seed	Total	Ware	Seed	Total	Weeds/sq. ft. (7 days after spraying)
1.	dinoseb in oil	2.25 lb/ac.	7.1	4.1	11.2	6.5	2.7	9.2	7.1	5.6	12.7	1.6
2.	Camparol [1]	2.0 lb/ac.	5.7	3.7	9.4	7.0	3.0	10.0	6.7	5.5	12.2	3.1
3.	linuron	2.0 lb/ac.	7.4	4.0	11.4	7.0	3.3	10.3	7.8	5.8	13.6	2.5
4.	Preeglone Extra [2]	2.0 pt/ac.	5.7	4.1	9.8	5.4	3.1	8.5	6.6	5.6	12.2	5.0
5.	Preeglone Extra	4.0 pt/ac.	7.4	3.6	11.0	5.9	2.8	8.7	6.1	5.2	11.3	3.0
6.	Preeglone Extra + linuron	2.0 pt/ac. 1.0 lb/ac.	7.0	3.4	10.4	7.5	3.0	10.5	7.2	5.7	12.9	3.3
7.	Preeglone Extra + prometryne	2.0 pt/ac. 1.0 lb/ac.	6.4	4.7	11.1	7.0	3.1	10.1	7.0	5.7	12.7	2.9
8.	light cultivation		6.1	4.0	10.1	7.7	2.7	10.4	7.1	4.9	12.0	21.6
9.	normal cultivation		7.2	4.5	11.7	8.7	3.1	11.8	6.6	5.6	11.2	Nil
	standard error/plot		1.31	0.61	1.29	0.88	0.48	1.49	1.12	0.93	1.53	
	significance of F test		N.S.	N.S.	N.S.	0.5%	N.S.	N.S.	N.S.	N.S.	N.S.	

Ware size over 2 in. Seed size 1.25 in. to 2 in.

1. Camparol = proprietary mixture containing simazine + prometryne
2. Preeglone Extra = proprietary mixture containing paraquat + diquat + wetter

TABLE 4

Experiment IV 1964. Record of Yields in tons/acre and Weed Numbers

Size of plot harvested: 13.5 sq. yd.

	Treatment		Arran Pilot			King Edward			Mean of 2 varieties
			Ware	Seed	Total	Ware	Seed	Total	Weeds/sq. ft. (10 days after spraying)
1.	dinoseb-amine	6.0 lb/ac.	5.3	4.5	9.8	10.29	7.30	17.59	0.3
2.	dinoseb-acetate	2.0 lb/ac.	4.8	5.3	10.1	8.97	7.57	16.54	4.7
3.	dinoseb in oil+ linuron	1.03 lb/ac. 0.5 lb/ac.	6.2	5.2	11.4	10.26	7.59	17.85	1.0
4.	solan	4.0 lb/ac.	5.3	5.1	10.4	11.81	7.60	19.41	1.3
5.	monolinuron	1.0 lb/ac.	5.6	5.3	10.9	10.73	8.26	18.99	1.8
6.	monolinuron	2.0 lb/ac.	6.0	5.3	11.3	9.35	8.04	17.39	0.8
7.	DPA (Stam F-34)	4.0 lb/ac.	6.5	4.8	11.3	10.00	8.06	18.06	1.7
8.	no cultivation		3.7	4.4	8.1	4.21	5.26	9.47	16.1
	Standard error/plot		1.47	0.49	1.35	2.00	1.90	2.17	
	significance of F test		N.S.	N.S.	N.S.	0.5%	N.S.	0.1%	

DISCUSSION

The competitive effect of weeds has been shown to vary widely with situation (Nield and Proctor, 1962), and in the present trials the effect of uncontrolled weed growth varied from nil in 1963 to a reduction of about 50% in 1964. These differences in competitive effect of the weeds are not obvious in the early stages of the crop, so that it is unlikely that weed control measures can be delayed until their need is apparent. Instead, good weed control will be necessary as an insurance against the considerable loss of yield that weed competition can cause.

As weed growth in the potato plots was poor in 1963, few conclusions on the relative efficiency of the herbicides can be drawn for that year. In 1964 weeds germinated very soon after planting, and although the first flush was destroyed by the light moulding operation ten days after planting, it was rapidly replaced by further germination which produced a dense mat of weeds by the time the herbicides were applied. As the tables show, good control of annual weeds was given by solan, monolinuron, linuron, dinoseb-acetate, dinoseb-amine, dinoseb in oil, DPA, simazine/prometryne mixture, the higher rate of paraquat/diquat mixture and paraquat/diquat mixture with linuron or prometryne. Linuron alone was ineffective against fumitory (Fumaria officinalis), and would be unsuitable if used alone in land infested with this weed. Except for a few plants of fat hen (Chenopodium album) distributed randomly in all plots, and Fumaria officinalis in the linuron plots, weeds did not emerge above the potato canopy in the herbicide treatments listed above at any time up until harvest. Soil conditions for the residual activity of soil-acting herbicides were good, with damp soil at time of spraying followed by showers. Dinoseb formulated in oil, in which the amount of dinoseb is such that no very prolonged residual life can be expected, was as good as any other treatment except dinoseb amine at 6.0 lb/ac. (an uneconomically high rate) and 2.0 lb per acre monolinuron. Applied at or shortly after emergence, paraquat/diquat mixture without an added triazine or substituted urea was less effective than the best treatments even at the higher of the two rates used. Time of weed emergence depends upon many factors beyond the farmer's control, and these results indicate that under the conditions at Mylnefield a herbicide with short persistence would not always give good results. Although no soil persistency is claimed for solan, it gave results equal to those of dinoseb when applied at early emergence both in these trials and in others conducted at Mylnefield in 1961.

There is no indication from the experimental results in 1963 or 1964 that cultivation reduces the yield of early or main crop varieties of potato under the conditions at Mylnefield, and there is even a suggestion that the highest yields of Majestic were obtained from the most intensively worked of the two cultivation treatments.

The effect of the herbicides as such on the potato cannot be assessed from the trials reported, but in terms of yield it seems clear that the effect of weed competition in 1964 was greater than that of the herbicides at the rates used in these trials.

Acknowledgments

Thanks are expressed to the several firms who have supplied chemicals used in these trials.

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Research Summary

WEED CONTROL IN POTATOES - EXPERIENCES IN NORTHERN IRELAND 1963

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SUMMARY In 1963 the possibility of growing potatoes without carrying out any inter-row cultivations was investigated under Northern Ireland conditions. The efficacy of 10 herbicide treatments in controlling weeds in a crop of Ulster Ranger (maincrop) potatoes was observed in comparison with normal inter-row cultivations and with an uncultivated control, also, their effect on crop yield was recorded.

Weed Control during the season is recorded in Table I. At time of harvesting weed control was still excellent using 2 lb linuron or a combination of 1 lb linuron and 1 lb paraquat and also in the normally cultivated crop; very satisfactory weed control was obtained using 1 lb linuron, 1 lb desmetryne, 4 lb dinoseb or 1 lb paraquat; satisfactory control was obtained using 2 lb prometryne; somewhat less satisfactory weed control was obtained using ¾ lb simazine; poor weed control was obtained using 2 lb desmetryne immediately after planting and with 1 lb M.C.P.A. both of which were practically as bad as the uncultivated crop. (Rates in lb a.i./ac)

The highest total yields were obtained from the normally cultivated potatoes and those treated with ¾ lb simazine; the lowest yields were obtained from the uncultivated treatment (where the yield was half of the normally cultivated treatment) and from the M.C.P.A. and the 1 lb desmetryne applied immediately after planting. There was little difference between the other herbicide treatments none of which was substantially lower than the normally cultivated crop.

Number of Replicates used Four blocks of randomised treatments

Plot Size 6 drills x 17 yards long

Soil Type Micha-schist medium loam

System of Growing Crop 26 in. ridges 12 in. tuber spacing. Inter-row cultivation of normally cultivated treatment - 1 saddle harrowing, 1 grubbing, 1 hand hoeing and 1 moulding up only. The trial was planted 16-17th April, the simazine and desmetryne immediate post planting treatments were applied the following day, the pre-emergence herbicides were applied on the 20th May and the post emergence M.C.P.A. treatment was sprayed on the 29th May when the plants were 2-3 in. high. The potatoes were harvested on 8th and 9th October, the area weighed comprising 2 drills x 13 yards long.

Weather conditions The rainfall was about average (18½ in. for 6 months March - August) but was very widespread throughout the growing season giving vigorous weed growth generally.

Weeds Present The main weeds which were most prevalent were in order of importance as follows:- Stellaria media (Chickweed), Polygonum persicaria (Redshank), Spergula arvensis (Spurrey), Fumaria officinalis (Fumitory), Polygonum convolvulus (Bindweed), Polygonum aviculare (Knotgrass), with small amounts of barley cereal and a few other weeds.

Further trials in 1964 - which, unlike other areas, was locally similar in weather conditions to 1963 except for a slightly lower total rainfall - have shown broadly the same weed control properties for the herbicides as the 1963 trial. In 1964 1 lb simazine alone did not give control of weeds which would be commercially acceptable, neither did 2½ lb mono-linuron immediately after planting. Prometryne at 2 lb has not given as good control as 1½ lb linuron, 1 lb paraquat or 4 lb dinoseb applied pre emergence of crop. The most satisfactory control of weeds was achieved using a mixture of paraquat and linuron (¾ lb each) and by using an early post emergence spraying of 1 lb paraquat, no advantage was observed in a post emergence spraying of 1 lb linuron. (lb a.i./ac)

TABLE I

Herbicide Treatments and Weed Control

Treat-ment No.	Treatment	Rate of Herbicide a.i./acre	Stage of Application of Herbicide	Weed Rating (10 = 100% cover of weeds, 0 = Nil)	
				on 2nd June	on 15th June
1	Normal cults.			2	¼
2	Without cults.			3½	9¼
3	Simazine	¾ lb	Immed. post planting	1	1¼
4	Desmetryne	2 lb	Immed. post planting	2	3
5	Desmetryne	1 lb	Just prior to crop emerg.	0	⅜
6	Dinoseb	3.7 lb	" " " " "	0	¼
7	Linuron	1 lb	" " " " "	½	½
8	Linuron	2 lb	" " " " "	0	¼
9	Paraquat	1 lb	" " " " "	0	¼
10	Linuron + Paraquat	1 lb each	" " " " "	0	0
11	Prometryne	2 lb	" " " " "	0	¼
12	M.C.P.A.	1 lb	Post emerg. of crop	3	3

TABLE II

Tuber Yields and Degree of Greening
Mean Yields as % of normal cultivations yield

Code No.	Treatment	Ware Tubers			Seed $1\frac{1}{4}"-1\frac{3}{4}"$	Total Tubers	* Green Tubers as % of Total Tubers
		Over $2\frac{1}{4}"$	$1\frac{3}{4}"-2\frac{1}{4}"$	Total			
1	Control normal cults. Yield as tons/ac	100 (8.0)	100 (9.0)	100 (17.0)	100 (2.5)	100 (19.6)	22
2	Control without cults.	24	55	40	116	51	15
3	Simazine immed. post planting	103	98	100	90	99	24
4	Desmetryne immed. post planting	66	67	66	94	70	20
5	Desmetryne pre emerg.	87	94	91	112	94	18
6	Dinoseb pre emerg.	101	87	94	87	93	25
7	Linuron 1 lb pre emerg.	100	83	91	85	91	22
8	Linuron 2 lb pre emerg.	103	84	93	83	92	30
9	Paraquat pre emerg.	94	92	93	98	94	27
10	Linuron + Paraquat pre emerg.	95	94	94	93	95	24
11	Prometryne pre emerg.	86	88	87	95	89	24
12	M.C.P.A. post emerg.	66	75	71	89	73	23

* Any tuber showing any slight greening was included in total green tubers

Traditionally the potato crop in Northern Ireland has been one which has always been given extensive cultivations which were considered essential - particularly deep grubbing - to obtain the best yields. Farmers initially have been sceptical of leaving out inter-row cultivations entirely but the signs are that chemical weed control will be taken up particularly by the larger growers. With high rainfall in the late spring and early summer, sometimes delaying inter-row work, it is not always possible to achieve ideal weed control with normal cultivations and this is where chemical weed control may have an advantage, also the saving in labour at a time when the silage making is starting is another factor which will attract interest in this system of control of weeds.

Soil conditions and soil types are very variable throughout Northern Ireland - from light free draining soils to almost pure peat areas, where potatoes are commonly grown and this may mean that there will be a more limited use for soil acting herbicides than for those with a strong contact action. Foliage growth is generally very vigorous in Northern Ireland conditions and thus where weeds can be well controlled in the early stages the foliage will prevent regrowth until the crop is ripening down.

SOME IMPLICATIONS OF THE USE OF HERBICIDES IN THE POTATO CROP

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Summary A series of experiments concerning various aspects of herbicide use in the potato crop was carried out, and some of the results are discussed. The experiments were designed to study the effects of culture method, plant population and plant arrangement on yield.

Frequent and thorough cultivation of the crop during the early stages of growth is a common feature of potato production techniques. It is not surprising, therefore, that these techniques have, in some respects at least, been built around the need to cultivate: for example, perhaps the levels of plant population generally employed, and certainly the spatial arrangement of plants in a "rectangular" pattern (i.e., the distance between rows is usually about one and a half to three times as great as the distance between plants within the row) reflect the need to facilitate movement of man and machine within the crop, rather than any conviction that these practices are, in themselves, optimal. Similarly, culture of the crop in ridges, rather than on the flat, may be a matter of mere convenience that could well be dispensed with. Since an important function of the various cultivations is to control weeds, it is clear that the advent of herbicides for use in the potato crop necessitates a reappraisal of current general practice. It is not enough simply to replace inter-row cultivations with herbicides within the existing framework of production, since this framework may impose unnecessary restrictions - i.e. unnecessary if the need to cultivate is removed - on the growth of the crop, and so prevent realisation of the full potential offered by the use of herbicides. If the best possible use is to be made of herbicides, we need to know the answers to the following questions:

(a) Do inter-row cultivations have any effect on crop performance other than that resulting from control of weeds, and how do they compare with herbicides as a means of weed control?

(b) Are there any advantages to be gained from culture of the crop on the flat, and if so, are they sufficiently important to warrant abandonment of traditional methods in favour of some sort of bed culture?

(c) Are the plant population levels and plant distribution patterns in current use optimal? Or would higher populations more evenly distributed be preferable - does this again point towards bed culture of the crop?

The following is an account of some of the results we have obtained in attempting to answer these questions. The experiments concerned were carried out in 1963 and 1964.

(a) The effect of inter-row cultivation on yield

Since the potato crop is frequently cultivated in excess of the minimum required for reasonable weed control, it would appear that there is a widespread belief that cultivation confers some other benefit, although it is difficult to see what this might be. Considerable root pruning, and some foliage damage might be incurred, especially in the later stages; also, soil moisture loss is increased. On the credit side, it appears that inter-row cultivation of potato crops can cause an increase in the soil nitrogen level (Moore, 1937; Swanson and Jacobson, 1951) and the appearance of the cultivated and non-cultivated plots in our experiments lends support to this. It is possible that this effect might be of economic importance in some conditions, but there was no evidence that this was so in our experiments.

Pereira (1941) was among the first to look at the effect of inter-row cultivation on yield of potatoes, and his general conclusion that "throughout the trials the crop seemed to be remarkably adaptable and to grow well under a wide variety of cultural practices" could well apply to our own experiments. Pereira's data suggested that in the absence of weed competition (i.e. weeds removed by hand) cultivation reduced yield by about eight per cent; neither the depth nor the frequency of cultivation appeared to matter. Our own experiments, (in which weeds were controlled by application of herbicides to all treatments unless otherwise noted) gave comparable results (Table 1).

Table 1

The effect of various degrees of inter-row cultivation on total yield of tubers (tons per acre) in 1964. (In parenthesis the weight of ware sized-tubers as a percentage of the total)

No cultivation[1]	Basic cultivation[2]	Basic cultivation + one grubbing	Basic cultivation + 2 grubbings	$L.S.D._{.05}$
19.6 (90.4)	18.7 (91.3)	18.6 (91.2)	18.6 (92.0)	0.90

1 Figures in this column are the mean of three treatments which did not differ significantly: (a) unweeded control; (b) weeds removed by hand; and (c) weeds controlled by herbicide application.

2 Basic cultivation consisted of harrowing down the ridges just before emergence, and ridging up in early June; the additional grubbings were carried out to a depth of 4 inches.

It appeared to make no difference whether these cultivations were carried out early or late; one would expect soil moisture losses to be greater from early cultivation, and pruning effects to be more severe from late cultivation. With regard to the first, it could well be that the self-mulching properties of soils ensure that the soil moisture loss, even after two or three inter-row cultivations, is too small to be of any practical importance. With regard to root pruning and damage to foliage, Moursi (1954) has demonstrated that the potato has considerable powers of recovery from the former, and the latter may be unimportant if only the relatively unproductive lower leaves are damaged. It appears from our experiments that the yield-depressing effects of inter-row cultivation are more pronounced when crops are grown on the flat than on the ridge - both root pruning and damage to foliage are greater in the former.

In our experiments inter-row cultivations appear to have been as effectual as herbicides in controlling weeds (Table 2).

Table 2

The effect of weed control on total yield of tubers (tons per acre) in 1963 (In parenthesis the weight of ware sized-tubers as a percentage of the total)

No treatment	Herbicide[1]	Cultivation	$L.S.D._{.05}$
11.4 (86.3%)	13.9 (83.2%)	14.4 (86.0%)	1.10

1 8.7 oz. active Simazine and 23.3 oz. active Prometryne per acre.

Herbicide might be expected to do relatively better if the spring/early summer period were wet (this was not the case in either 1963 or 1964) because there would then be less opportunity for cultivation, and because the individual cultivations would be much less efficient in controlling weeds. Also, in comparing herbicides and cultivations, it should be borne in mind that the latter may show up relatively better in experiments than they might on a field scale, since it is possible in experiments to time cultivations for maximum weed control to an extent that would often be impossible on a field scale.

(b) Ridge vs Flat Culture

Ridge culture of potatoes has been criticised because the increase in surface area of a ridged as compared with a flat field, and the greater number of pre-planting cultivations necessary to secure the ridges, lead to increased evaporation losses. With regard to the first point, the increases in evaporation on ridged land would be less than the increase in surface area; concerning the second, it should be pointed out that with use of the rotavator the transition from flat ploughed surface to ridged and planted field can be so rapid that moisture loss is minimal - in effect, only one layer of moist soil is turned up.

An advantage of planting on the flat is that this offers greater opportunity for shallow planting and consequently for advancing the date of plant emergence. The earlier tuber initiation usually associated with this appeared to be the main factor involved in the greater yields obtained on the flat in our experiments (Table 3). However, the early emergence associated with shallow planting does quite often result in reduced yields: this could be expected to happen if chitted seed were planted shallowly somewhat earlier than usual because first, under these circumstances maincrops may be induced to behave as earlies, i.e., initially to produce tubers at the expense of haulm, and so ultimately to produce a smaller yield; and second, because the more forward plants resulting from shallow planting are more susceptible to frost damage.

Table 3

Effect of culture system on total yield of tubers (tons per acre) in 1963. (In parenthesis the weight of ware-sized tubers as a percentage of the total)

	Full ridge	Flat ridge	Flat	Flat + late ridge	$L.S.D._{.05}$
Amount of soil cover at planting	6 in.	3-4 in.	2-3 in.	2-3 in.	
Majestic	13.4 (84.5%)	13.7 (84.2%)	14.6 (84.4%)	13.8 (85.05%)	1.10
Ulster Torch	14.6 (81.2%)	15.8 (79.1%)	17.1 (80.9%)	15.1 (78.0%)	1.53

In any event, planting on the flat results in an increase in the proportion of greened and blighted tubers (Table 4), and this may offset any yield increase or aggravate any yield decrease that may occur. The high incidence of greened and blighted tubers on the flat may be overcome by (a) deeper planting (about 4 inches) or (b) by ridging from the flat after the plants are well established. The former may under some conditions greatly increase the difficulties associated with lifting as compared with shallow planting on the flat or ordinary ridge culture (Maughan 1964); and the latter causes reduction in yield (Table 3).

Table 4

Effect of culture method on the percentage of greened and blighted tubers in Ulster Torch (1963)

	Full ridge	Flat ridge	Flat	Flat + late ridge	L.S.D.$_{.05}$
Green	9.3	15.4	23.6	10.6	6.32
Blighted	4.98	4.07	7.05	2.88	1.959

(c) Plant Population and Plant Arrangement

Plant population experiments in the past have suffered from the following drawbacks:

(i) The range of populations employed was too limited.

(ii) The experiments were carried out on a constant row width basis, and consequently change in plant population was confounded with change in plant arrangement. The degree of "rectangularity" increased with increase in population and possibly limited the response to increase in population quite independently of any true population effect.

(iii) In population work too little attention has been paid to the effects of factors, such as seed size, seed storage treatment and variety, which, by affecting the number of stems per plant, or "hill", might be expected to modify the yield/plant population relationship.

In an attempt to remedy these shortcomings, an experiment which included all combinations of the following treatments was carried out in 1964: sixteen plant populations (5,000-50,000 plants per acre at intervals of 3,000 plants per acre; six seed sizes (½, 1, 2, 4, 6 and 8 oz. setts); two varieties (King Edward and Majestic) and three seed treatments designed to produce single, multi, and super-multi-sprout seed. All treatments were grown on the flat and "on the square" in a systematic design of the "fan" type (Nelder, 1962).

The following points emergy from preliminary collation of the data.

(i) In general, maximum total, ware and seed yields were attained at populations in the region of 17,000-20,000 plants per acre, and the economically optimum plant population appeared to be around 14,000 plants per acre - this latter was similar in 1963.

(ii) Above 2 oz. setts, seed size did not appear to have much effect on total yield. This was probably a result of the long growing season, which enabled the small-seed plants to catch up; it is likely that had the growing season been shorter the response to increase in seed size would have been greater. The difference in ware yield between the seed sizes was even smaller than that in total yield.

(iii) The total yield from single-sprout seed was similar to that from multi-sprout seed in the normal population range (i.e. up to about 15,000 plants per acre) but thereafter the performance of single-sprout seed was poorer than that of multi-sprout seed. In Majestic ware yield was similar for all three types of seed, but there was some indication, again in the range of normal plant populations, that use of single-sprouted seed was worthwhile in King Edward. This was also the case in 1963. The effect of sprout numbers on the yield of seed was surprisingly small: the seed yield of single-sprout plants was consistently the lowest, but there was no indication that seed yield benefited greatly from use of seed specially induced to produce a large number of sprouts.

(iv) The experiment involved a range of seed rates from about 1.4 cwt. per acre to 11 tons per acre, there being a considerable amount of overlap in seed rate between the various seed sizes. The results leave no doubt that the performance of small seed is, per unit of seed rate, better than that of large seed (c.f. Boyd and Lessells 1954). Surprisingly good total yields - 7-8 tons per acre, roughly one third of the maximum yields - were obtained from the lowest seed rate employed, viz. 1.4 cwt. per acre, achieved by planting 5,000 ½ oz. setts per acre. However, notwithstanding the greater efficiency of small seed, some dangers attend its use: its growth in the early part of the season is limited and tuber initiation is late, with the result that early cessation of growth through drought or blight can lead to very low ware yields.

(v) There was no variety/population interaction. Generally Majestic produced a slightly higher total yield, and more ware, but less seed than King Edward.

Concerning plant arrangement, there is considerable evidence that the rectangular plant distributions adopted in practice result in little or no loss of total or ware yield. Our own experiments, carried out with both King Edward and Majestic, with single and multi-sprout seed and over a wide range of plant populations (10,000, 25,000 and 50,000 plants per acre), and other work (Saunt, 1960) suggest that rectangularities of up to 1:4 (i.e., 7 in. between tubers in 28 in. rows) can be adopted with impunity.

Considering the series of experiments as a whole, there is no indication that any modification in technique made possible by the use of herbicides leads to a dramatic increase in yield. It is, however, apparent from other work that simple replacement of cultivations by herbicides can, on occasion, result in higher yields; presumably this is most likely to occur in wet weather when cultivations may be relatively ineffectual, and since such conditions cannot be forecast, there is a case for routine use of herbicides. There may also be a case from the point of view of limiting clod formation and so easing the separation of tubers and clods at lifting; this is an aspect which we were unable to evaluate, since we were working on a light gravelly soil where clod formation was no problem.

Ridge culture of the crop has much to commend it - lifting is easy and the tubers are well-protected. Culture on the flat or in beds both have disadvantages, difficulty in lifting and exposure of the tubers being the most serious of these. In addition, the scope offered by culture on the flat or in beds for increasing plant population and improving plant arrangement has proved to be of only limited importance in its effect on yield: the potato plant possesses a high degree of plasticity which tends to stabilize its yield under a wide range of practices.

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INVESTIGATIONS INTO THE USE OF HERBICIDES IN POTATO CROPS ON EXPERIMENTAL HUSBANDRY FARMS

F.E. Shotton
Terrington St. Clement E.H.F.

Summary Eight trials on three Experimental Husbandry Farms have compared one or more systems of cultivations with one or more herbicide treatments in the potato crop. Differences in the efficiency of weed control were small and did not appear to have influenced yields. In the majority of cases crops which had herbicides applied to ridges of normal size, created at or shortly after planting, outyielded crops kept clean by cultivations. In unsprayed crops, if cultivations were made less severe, the yields of maincrops but not earlies increased. Under chemical weed control large ridges produced higher yields with fewer green potatoes than low ridges. On two farms, when herbicides were used, potatoes grown in 3-row beds have been compared with potatoes grown in 28 in. rows: early yields showed some advantage from the bed system but the saleable yield of Majestics was not increased.

INTRODUCTION

The Experimental Husbandry Farms of the Ministry of Agriculture have been established in situations which permit their use for the study of farming problems under the main regional soil and husbandry conditions of England and Wales. This report is concerned with trials in which herbicides, considered to be suitable for weed control in potatoes, have been compared with systems of mechanical weed control in potato crops on four of these farms.

Preliminary work suggested that reasonable yields of potatoes and an acceptable level of weed control could be obtained when few or no post-planting cultivations were carried out and when herbicides were used to control weeds. It also indicated certain questions of a practical nature to which answers would be required if farmers were to adopt this technique of potato growing. The various farms have developed lines of work according to the requirements of their soil and situation and their available facilities.

METHOD AND MATERIALS

On all farms the herbicides used have comprised a range of both contact and residual chemicals which, with the exception of trietazine and prometryne, are commercially available. In most trials they were applied by tractor-drawn sprayers of commercial type. Plots were always at least 1/125th. acre in extent and the minimum harvest area was 1/250th. acre.

Weed assessments by quadrat counts have rarely been taken; scoring has been the more usual procedure. Yields of total tubers and saleable ware have been recorded for all experiments and in some experiments more detailed size grading and recording of green and diseased tubers have been undertaken. Soil type appears of probable importance in relation both to the use of soil-acting herbicides and to the stability of ridges put up at, or shortly after, planting and is as follows on the four farms on which trials have been conducted:

Bridget's E.H.F. Martyr Worthy, Hants

Chalky, silty loam with flints overlying chalk. On the experimental fields there was a minimum of 12 in. loam over the chalk. Ridges built up at planting are not liable to collapse during the growing season.

Gleadthorpe E.H.F. Welbeck Colliery Village, Notts

Loamy sand with numerous rounded pebbles overlying Bunter sandstone. This light soil has little structure and poor stability. The tendency for ridges to erode during the season is liable to be accentuated by overhead irrigation which is available and has been used in the experiments on this farm.

High Mowthorpe E.H.F. Duggleby, Yorks

Chalky, silty loam with flints overlying chalk. The soil has similar characters to that of Bridget's farm.

Terrington St. Clement E.H.F. King's Lynn, Norfolk

Medium to medium heavy silty loams over estuarine alluvium. Ridges built of this soil have good stability. A fine tilth will form a thin crust under rainfall and on the heavier soil ridges are liable to crack as the crop develops.

RESULTS

Table 1. presents yield data from eight replicated trials : results of unreplicated observations at Gleadthorpe, High Mowthorpe and Terrington are not included. Harvest data for four maincrop trials in 1964 are not available at the time of writing and details of these experiments are excluded. In the third column of Table 1. the method of weed control is stated and this is amplified to some extent by the remarks in the final column. Full details of all cultivations in all trials cannot be given but the first line for each experiment deals with crops which were cultivated in the way normally employed to achieve satisfactory weed control on the farm concerned. Modifications of the normal system were designed at Bridget's and Gleadthorpe to produce lower ridges with flattened tops and at Terrington to cause as little damage as possible to the developing crop. Such modified cultivation systems are designated "cultivations(b)" in Table 1. if cultivations alone were employed for weed control, or may appear in later lines of data for any experiment in which herbicides were employed as well as post-planting cultivations (e.g. experiment 1).

In experiments 5, 7 and 8 plots on which herbicides were used received no cultivations after planting; in experiments 3 and 4 ridges were built 3 or 1 day respectively after planting; the final ridge on sprayed plots in experiment 6 was established 20 days and in experiment 1, 33 days after planting and both were sprayed a few days later; in experiment 2 half of the sprayed plots were ridged up to form a "normal" ridge 9 weeks after spraying.

In no experiment were cultivations intentionally made excessively severe.

Tablo 1.

Treatments and Total Yields

No., Centre & Variety	Year	Weed control method	Herb. rate lb/ac.a.i.	Ridge form	Total Yield ton/ac. U[+]	I[•]	S.E./ treat. ±
Bridget's 1. Majestic	1963	Cultivations (a)	-	normal	11.7		0.73
		Linuron/paraquat	1+1	normal	12.1		
		Linuron/paraquat	1+1	low	9.3		
		Prometryne/paraquat	1+1	normal	10.9		
		Prometryne/paraquat	1+1	low	9.6		
Gleadthorpe 2. King Edward	1961	Cultivations (a)	-	normal	14.5	16.9	0.76
		Cultivations (b)	-	low	15.7	17.3	(vert.
		Dinoseb amine	4	normal	17.4	17.5	comp.
		Dinoseb amine	4	low	16.2	18.9	only)
3. King Edward	1962	Cultivations (a)	-	normal		17.5	0.68
		Cultivations (b)	-	low		17.9	
		Trietazine	$1\frac{1}{2}$	low		16.2	
		Trietazine/paraquat	1+1	low		16.5	
4. King Edward	1963	Cultivations (a)	-	normal	8.2	9.9	0.47
		Cultivations (b)	-	low	9.1	10.8	(vert.
		Linuron/paraquat	$1\frac{1}{2}+1$	normal	9.0	8.4	comp. only)
Terrington 5. King Edward	1962	Cultivations (a)	-	normal	13.7		0.45
		Paraquat	$\frac{3}{4}$	normal	15.9		
		Dinoseb amine	4	normal	15.8		
		Trietazine/paraquat	$1+\frac{3}{4}$	normal	16.9		
6. King Edward	1963	Cultivations (a)	-	normal	13.0		0.43
		Cultivations (b)	-	low	14.2		
		Linuron	2	normal	14.1		
		Prometryne	2	normal	14.6		
		Simazine	2	normal	10.9		
7. Arran Pilot	1963	Cultivations (a)	—	normal	8.4		0.54
		Cultivations (b)	-	normal	8.1		
		Linuron/paraquat	$1\frac{1}{2}+\frac{3}{4}$	normal	9.0		
		Paraquat	$\frac{3}{4}$	normal	9.4		
8. Arran Pilot	1964	Cultivations (a)	-	normal	12.5		0.37
		Cultivations (b)	-	low	11.6		
		Linuron	2	normal	11.5		
		Prometryne	2	normal	11.6		

[+]U = Unirrigated

[•]I = Irrigated

Table 1 (contd.)

Remarks

Expt No

1. a) Ridged with English bodies 7 weeks after planting.
   b) Ridged with English bodies 33 days after planting, sprayed 5 days later
   c) As (b) but top harrowed off ridge same day: sprayed 5 days later.
   d) As (b)
   e) As (c)

2. a) Ridged with English bodies 12 weeks after planting.
   b) Planting ridges harrowed down 3 weeks after planting.
   c) Sprayed 3 weeks after planting: ridged with English bodies 9 weeks later
   d) As (b), sprayed 2 days later.

3. a) Ridged with English bodies 10 weeks after planting.
   b) Ridged with German bodies 10 weeks after planting.
   c) Ridged with English bodies 3 days after planting: sprayed next day.
   d) Ridged with English bodies 3 days after planting: sprayed 5 weeks later.

4. a) Ridged with English bodies 8 weeks after planting.
   b) Ridged with German bodies 8 weeks after planting.
   c) Ridged with English bodies 1 day after planting: sprayed 4 weeks later.

5. a) Ridged with English bodies 13 weeks after planting.
   b) Planting ridge left undisturbed: sprayed 7 weeks later.
   c) As (b)
   d) As (b)

6. a) Ridged with English bodies 8 weeks after planting.
   b) Ridged with German bodies 5 weeks after planting.
   c) Ridged 20 days after planting: sprayed 3 days later.
   d) As (c)
   e) As (c)

7. a) Ridged with English bodies 8 weeks after planting.
   b) Ridged with German bodies 7 weeks after planting.
   c) Planting ridge left undisturbed: sprayed 3½ weeks later.
   d) As (c)

8. a) Ridged with English bodies 7 weeks after planting.
   b) Ridged with German bodies 7 weeks after planting.
   c) Planting ridge left undisturbed: sprayed 17 days later.
   d) As (c)

"English" ridging bodies have long curving mould-boards.
"German" ridging bodies have short, straight but adjustable wings and are designed to work at 6 m.p.h.

(a) Weeds

Chemical sprays gave an acceptable level of weed control in all trials. At Bridget's 1963 cultivated plots carried more Stellaria media than sprayed plots while at Gleadthorpe 1961 Chenopodium album was virtually eliminated by dinoseb but occurred on cultivated plots. At Terrington cultivated plots have normally been freer from weeds than sprayed plots: Polygonum convolvulus and Galium aparine were the most troublesome survivors and a relatively few plants tended to grow very large. These weeds were more effectively controlled in 1964 when June was wet and distribution of herbicide in the soil was assumed to have been improved by rainfall. In none of the experiments was it likely that the level of weed infestation of any treatment had any observable influence on yield.

(b) Total Yield

Examination of Table 1 shows that except in Terrington trial 6 in 1963, when simazine at 2 lb/ac.a.i. significantly reduced the yield of King Edwards, differences in yield resulting from the use of different herbicides applied to the same type of ridge have been small and non-significant. Larger differences in Bridget's trial 1 and Gleadthorpe trial 2 are associated with change of ridge form and the use of irrigation respectively.

Comparison of the yields resulting from the use of herbicides applied to normal ridges with those obtained by normal cultivations (cultivations (a)) will first be made by examining yields from crops grown without irrigation. This is possible in all experiments except Gleadthorpe 3. 1962. In 10 of the 14 possible comparisons herbicides gave higher yields than cultivations. The only significant differences are in experiments 2,5 and 6 where one, three and one of the herbicides respectively outyielded cultivations though the significant gain in experiment 2 resulted from a treatment which was ridged up after the spray had been applied. A significant reduction in yield from a heavy application of simazine in experiment 6 has already been noted. In experiments 4 and 7 non-significant gains of 0.6 to 1.0 ton/acre resulted from the use of herbicides. In experiment 1, when applied to normal ridges, one herbicide gave a slightly higher and one a lower yield than cultivations, while in experiment 8 the cultivation treatment produced a higher yield (n.s.) than herbicides.

When modified cultivations were compared with normal cultivations in the absence of herbicides in the three experiments (2,4 & 6) with maincrop varieties the modified techniques gave higher yields (n.s.) than normal cultivations. In two trials (7 & 8) with Arran Pilot at Terrington the reverse was the case.

(c) Ware Yields

Ware yields have been recorded in all experiments. They are not here presented but in general they follow the same pattern as total yields.

(d) Ridge Form

It has already been noted that in experiments 1 and 2 (unirrigated) low ridges gave poorer yields than normal ridges when herbicides were used. At Terrington in 1963 two further experiments investigated the effect of the height of the ridge created at planting under conditions of uniform herbicide treatment with the results given in Table 2.

Table 2.

Terrington E.H.F. 1963

Yield (ton/acre)

	Depth of soil covering setts at planting and left undisturbed until harvest 4 in.	6 in.	8 in.	4 in. then 8 in. +	S.E. ±
Majestic					
Total	15.2	15.0	16.3	16.1	0.43
Ware over $1\frac{3}{4}$ in.	11.1	10.8	12.8	12.1	0.42
Green tubers	1.5	1.4	1.0	1.2	-
King Edward ϕ					
Total	13.7	14.6	14.4	-	0.47
Ware over $1\frac{3}{4}$ in.	10.7	11.8	12.1	-	0.43
Green tubers	0.6	0.2	0.3	-	-

\+ this treatment was given 4 in. cover until potatoes started to emerge and they were then ridged up to 8 in. cover before being sprayed.

ϕ cover for King Edwards was 1 - 2 in. less than stated.

In both experiments total yield increased, green tuber yield decreased and, as a consequence, ware yield increased as the soil cover over the setts, and hence over the developing tubers, was increased. Gleadthorpe data for the yield of green tubers - from both sprayed and cultivated plots - are given in Table 3.

Table 3.

Gleadthorpe E.H.F.

King Edward

Yield of green tubers (ton/acre)

Year	Normal ridge	Low ridge
1961	1.1	2.2
1962	1.4	1.8
1963	0.5	0.6

The very high loss from green tubers in 1961 resulted from one rather severe harrowing with no subsequent rebuilding of the ridge. In later years the figures were comparable to those of the Terrington experiments.

(e) Bed cultivation

If efficient herbicides can eliminate the need for inter-row cultivations in the potato crop it may no longer be necessary to grow potatoes in rows 27 to 30 in. apart. An alternative system, that of planting three rows 14 in. apart within a slightly raised bed of total width 56 in., has been examined at Terrington in 1963 and 1964 on maincrops and at Gleadthorpe in 1964 on earlies. The Terrington experiments are plant population studies under conditions of chemical weed control with potatoes grown in either beds or rows in separate but immediately adjacent experiments and the results of two experiments, although strictly not comparable with one another, are presented for information. The Gleadthorpe experiment contained beds and rows as factors within one irrigation experiment.

Table 4.

Yield of potatoes grown from sett populations of 24,000/acre in either 28 in. rows, or in 56 in beds each containing 3 rows 14 in. apart: ton/acre

Terrington E.H.F. Majestic 1963

	Seed Size 2 in.	$1\frac{1}{2}$ in.	$1\frac{1}{4}$ in.	S.E. per treatment ±
Rows experiment				
Total	22.4	20.3	19.2	0.55
Ware $1\frac{1}{4}$ - 3 in.	18.2	16.9	16.1	0.56
Green tubers	3.0	2.1	2.1	0.22
Beds experiment				
Total	-	21.5	19.8	0.34
Ware $1\frac{1}{4}$ - 3 in.	-	15.9	14.5	0.38
Green tubers	-	4.6	4.3	0.23

Gleadthorpe E.H.F. Arran Pilot 1964

Ware yield Lifting date		Irrigation to F.C. when deficit reached 0.75 in.	1.5 in.	Not irrigated	S.E. per treatment (vert.comp) ≠ ±
Rows	22 June	1.7	2.3	2.0	0.24 ≠
	6 July	8.3	8.1	6.7	0.44 ≠
	20 July	12.9	11.3	10.3	0.35 ≠
Beds	22 June	2.7	2.5	2.5	≠ for vert.comp.
	6 July	9.7	8.5	6.3	beds v. rows on same date
	20 July	11.5	12.4	10.3	of lifting

Somewhat higher total yields were obtained from the potatoes grown in beds at Terrington but saleable ware was less than from rows due to a marked increase in the quantity of green tubers. At Gleadthorpe, while no better under unirrigated conditions, beds tended to give rather higher early yields up to the beginning of July under irrigation after which the mean yield became very similar whether the crops were grown in beds or rows.

DISCUSSION

These trials and other observations, in some cases on relatively large acreas of potatoes, have shown that weed control by herbicides in the potato crop is now a practical proposition. Differences in the efficiency of weed control by herbicides now commercially available has not been marked when each type has been used in appropriate circumstances. Prior selection in the light of weeds known to be present has tended to maintain a relatively high standard of effectiveness and in certain cases when it had been intended to employ a contact herbicide plans were changed if chitted seed was found to be emerging before the flush of weed seedlings appeared.

In the majority of cases in which herbicides have been applied to ridges similar in size to those put up by traditional cultivations, yields from the herbicide treatments have been greater than those from cultivated plots. When applied to low ridges or when crops were subsequently irrigated herbicides have frequently produced lower yields than normal cultivations.

When the yields from crops kept clean by cultivations or by herbicides differ, other than fortuitously, it must be assumed that one or other of the factors, cultivations or herbicides, is proving harmful or beneficial. No evidence of benefit to the potato crop from the direct effect of herbicides is known but W.R.O. trials at Gleadthorpe and Terrington have shown that crop yields may be reduced if soil acting herbicides are incorporated into the soil in which the crop is growing. This may offer an explanation for the reduced yields obtained when a soil acting herbicide was applied a) to ridges harrowed down 5 days previously in experiment 1 (though damage by the harrows might have caused this reduction), b) to irrigated crops on sandy soil in experiments 3 and 4, and c) at a high rate followed by heavy June rainfall (3.37 in.) in experiment 8.

As long ago as 1939 Rothamsted workers were showing yield reductions from cultivations in the potato crop (Russell. 1949). When cultivated crops have produced lower yields than crops left undisturbed since planting and sprayed with herbicide as in experiments 4,5,6 and 7, it is reasonable to assume that the yield differences are largely a measure of damage done by cultivations. This could take the form either of direct damage to roots, stolons or haulm, or could result from loss of soil moisture each time the soil is moved. The Gleadthorpe experiment 4 shows significant gains of 1.7 ton/acre from irrigation on both of the cultivated treatments but a slight loss on undisturbed plots sprayed with soil acting herbicide, suggesting that both loss of soil moisture from cultivations and some phytotoxicity from herbicides may have influenced yields in that experiment.

While it is generally accepted that pre-planting cultivations must be thorough and adequate to produce a good tilth, preferably free from clods, most potato growers now regard post-planting cultivations as being necessary for weed control or in order to create tilth from which to build the final ridge rather than being beneficial in themselves. There seems, however, one cultivation which is regarded rather differently. It is a strongly held belief of many potato growers that the ridges put up at planting should be harrowed - some believe they should be completely levelled - to encourage the crop to emerge quickly. If however herbicides are to be employed the ideal technique would seem to be to create at the time of planting a ridge of suitable height, configuration and tilth and do no further cultivations thereafter. This implies that the developing shoots must grow up through the covering soil.

Data from Terrington in 1963 shows that the emergence of Majestics planted in beds with only 2 in. of cover over the setts was up to 4 days ahead of seed of the same size planted in ridges with 6 in. of soil above them. When ridges of 4 in. were compared with ridges of 6 in. cover the difference was two days. Very quickly after emergence differences in haulm growth ceased to be apparent. Whether this slightly earlier emergence is of value cannot be detected from the trial data but any possible benefit appears to be more than offset by other factors; the yield from low ridges in unirrigated crops having in all casss been lower than from bigger ridges when both were kept clean by herbicides (Tables 1 & 2). Further, the quantity of green tubers increased under shallow cover and ware yields were further reduced.

This data is of great importance for it indicates that if herbicides are to be used a ridge of adequate size can be built at the time of planting and that healthy seed will find no difficulty in growing up through it+. A tendency for shoots to emerge from the side rather than the crest of pre-formed ridges has been observed but this need not be disadvantageous if no subsequent cultivations which might damage these shoots were carried out.

None of the trials has investigated in detail the effect of post-planting cultivations on the cloddiness of ridges at harvest. Observations in the 1962 Terrington experiment showed that post-planting cultivations created clods. In 1963 it was observed that when lifting on 3 October following heavy rain in late September the moisture content of soil from cultivated ridges was 14.3% while that of soil from uncultivated, sprayed ridges was 16.6%. This difference was sufficient to increase to some extent the quantity of soil adhering to the tubers from sprayed ridges and at these levels of soil moisture crumb particles formed aggregates which rode over the web of the elevator digger and, had a complete harvester been used, would have needed picking off to keep down the soil content of the stored crop. No evidence has been seen at any of the centres of uncultivated ridges setting into a solid mass which would make harvesting impossible.

The preliminary trials on potato growing in beds rather than rows suggest that this method of potato growing - although practicable under chemical weed control - will not necessarily bring yield advantages which will reflect in a greater weight of saleable maincrops though it may give higher early yields. The two trials reported make comparisons between crops grown from an equal weight of seed planted at high density. Some growers have obtained greater increases in early yields from potatoes grown in beds

\+ Observations at Terrington in 1964 suggest that this may not be true of Pentland Dell.

but have used higher seedrates in beds than in rows. This result is in no way surprising, and it is confirmed by the Terrington data, but such increases may also be obtained when the seedrate is increased in ridge-grown crops as Table 4. shows and, depending on the relative prices of seed and ware, may or may not be economic.

This is an interim report of trial series which, while conceived along similar lines have differed appreciably in the detail of their execution. The results show that weed control by herbicides in potatoes is possible and, if adequate ridges are created at or shortly after planting, yields are likely to be somewhat higher than when weeds are controlled by cultivations. The final yield of the crop is a summation of gains and losses resulting from the treatments to which the growing crop was subjected and a new treatment which produces an increase in yield - without adverse effects on quality - may be considered satisfactory and suitable for adoption into practice. This appears to be the case with herbicides in the potato crop. There are however a number of indications from these experiments that some soil acting herbicides may be causing yield reductions when associated with certain cultivation treatments, low ridges or high precipitation whether natural or artificial. If such effects are in fact occurring it is clearly desirable that attempts should be made to eliminate them either by the efforts of manufacturers to provide herbicides which do not have these adverse effects or of agronomists to define the conditions under which available chemicals may be used with relative safety.

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'BEDS', ROW WIDTHS, CULTIVATION, AND WEED CONTROL IN POTATOES

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Summary Work was started in 1957 on the growing of potatoes in 'beds', consisting of groups of 2, 3 or 4 rows, in an attempt to find ways of reducing the amount of clod taken up with the potatoes at harvest. It was found to be difficult to keep the tubers covered and protected from blight and greening, and there was overcrowding in the middle rows of the 'beds', giving reduced ware yields. Later experiments showed that at least 550 square inches were required per plant. 36 inch rows were tried but found to give an increased amount of clod, but rotary inter-row cultivation reduced the amount of clod. Two years work on the relationship between inter-row cultivation and chemical weed control, indicated that cultivation can reduce the amount of clod in the row but at a risk of loss of yield. Inter-row cultivation may still however be necessary until more suitable herbicides can be found.

INTRODUCTION

The standards for potato spacing both in and between the rows that are accepted at any time depend upon the prevailing uses of the crop and the cultivation and weed controlling resources of the farmer. In times when potatoes were grown primarily to provide a cheap food, and only horse drawn implements were available for cultivation, planting was done by hand and the spinner was the most elaborate piece of machinery used for harvesting the crop, 14 inch spacing in 28 inch rows was the most convenient arrangement of the plants; while to suit the available power and machinery the potatoes were grown in ridges for ease of lifting and for covering the growing tubers to protect them from the light and attacks of blight.

In recent years there have been many changes. The potato has been up-graded from a famine food to a luxury vegetable, washed, graded, and packed in polythene or processed to chips or crips. At the same time the resources of the farmer have been increased by the introduction of greater mechanical power, and methods of controlling growing conditions. While the supply of labour has become both short and expensive. As a result of these changes the traditional methods of growing the crop should be examined critically to see if the basic requirements of the crop can be met, while making use of the new techniques that are available.

The introduction of the complete potato harvester, in an attempt to overcome the difficulty of obtaining casual labour for picking, emphasised the problem of the separation of clods from potatoes, but since this could only be done by hand selection, large numbers of pickers were still required. Since there appeared to be little hope of achieving the separation of clods and potatoes by purely mechanical means, the Field Investigation Department, as it was then known, was asked in 1957 to examine means of easing the separation problem at harvest by cultural methods during the period of growing the crop, and 'bed' cultivation was suggested. The 'beds' were to consist of a grouping together of two, three, or four rows to form a wide band leaving wheel tracks on either side. It was hoped that at harvest more potatoes could be lifted for a given volume of soil, while the soil compacting and clod forming action of tractor and implement wheels would be restricted to an area which would not be lifted when the potatoes were harvested. Work by DAVIES (1954) on irregularity of planting suggested that provided the overall plant population was unaltered, any local over-crowding of the potato plants would not affect yield.

'Bed' Cultivation

Eight different forms of 'bed' cultivation were tried (Green 1962 a) having 56, 64, and 72 inches between centres and containing 2 to 4 rows spaced at 14, 21, and 28 inches, thus leaving tracks for implement and tractor wheels between the beds from 14 to 30 inches assuming that the wheels could come to within 7 inches of the centre of any potato plant. The eight forms of 'bed' were compared with potatoes spaced 14 inches in 28 inch ridges, giving 16,000 plants per acre. The results of the experiment (TABLE I) showed that the normal ridge method out yielded all the 'beds', except where the plant population was appreciably higher (treatments 4 and 9), while the yield of tubers over $1\frac{3}{4}$ inches was reduced for all 8 'beds'. TABLE II, giving the yields of individual rows for three 'bed' forms, shows that the reduction in yield occurred mainly among the larger sized tubers in the middle rows of the 'beds'. The more crowded 'beds' e.g. No.9 suffered most in this respect, but the relatively widely spaced 2 row 'bed' (treatment No.7) yielded nearly as well as the 'normal' method.

Table 1.
Comparison of 8 different forms of 'bed' cultivation with the normal method for spacing and yield

Treatment number	1 (normal)	2	3	4	5	6	7	8	9
Width of 'bed' in.		56	56	56	64	72	64	72	72
Rows per 'bed'		2	2	3	3	3	2	3	4
Width of rows in.	28	14	21	14	14	14	28	21	14
Spacing in rows in.	14	14	14	14	14	14	17	17	14
Plant population (X 16,000 per acre)	1.0	1.0	1.0	1.5	1.3	1.2	0.7	1.0	1.6
Yield tons/acre									
Tubers $< 1\frac{3}{4}$ in.	1.9	2.3	2.5	3.3	2.7	2.5	1.7	2.5	3.5
Tubers $> 1\frac{3}{4}$ in.	9.9	8.6	8.6	8.8	8.5	7.9	9.5	8.8	8.7
Total	11.8	10.9	11.1	12.1	11.2	10.4	11.2	11.3	12.2

Table 2.

Yield of potatoes by rows for treatments 9, 6 & 7

Treatment number	9					6				7		
Row number	1	2	3	4	Mean	1	2	3	Mean	1	2	Mean
Tubers $<1\frac{3}{4}$ in.	2.8	4.0	3.2	4.0	3.5	2.4	2.7	2.4	2.5	1.6	1.8	1.7
Tubers $>1\frac{3}{4}$ in.	10.0	7.2	7.2	10.4	8.7	8.7	5.4	9.6	7.9	9.2	9.8	9.5
Total	12.8	11.2	10.4	14.4	12.2	11.1	8.1	12.0	10.4	10.8	11.6	11.2

In addition to the lower yields there was considerable grenning of the tubers, since there was insufficient soil between the narrow rows to pull up into the ridges to cover them properly as the tubers developed. The difficulty of doing much in the way of inter-row cultivation resulted in the soil becoming very hard, many of the tubers were distorted, and weed growth was heavy in spite of hand hoeing.

Harvesting the crop presented some difficulties. For the estimation of yield the rows were lifted separately with a conventional elevator digger, but a wide share spanning the full width of the 'bed' was tried and found to work well under dry soil conditions, but when the soil became even slightly wet the draught of the share through the 'beds' became excessive.

Later experiments with 72 in. beds made up of three rows of 22, 20, and 18 in. rows, and two rows 36 in. apart were outyielded by the 'normal' method of 28 in. ridges. The reduction in yield was small in the middle row when the row spacing was 22 in. in the 'bed', but other experiments with potatoes grown on the flat in a square formation indicated that at least 550 square inches per plant was required for potatoes for optimum yield, with variations depending upon variety (GREEN 1962 b). The two row 'beds' with widely spaced rows yielded better than the three row 'beds', but while the main objects of bed cultivation were lost at this spacing, possible advantages from the use of widely spaced ridges were indicated.

Three varieties of potato viz. Majestic, King Edward, and Arran Peak, were compared in this experiment for relative suitability for 'bed' cultivation. The allegedly more compactly growing Arran Peak showed no advantages over Majestic, while the King Edwards were almost a complete failure due to the tubers not being adequately protected from blight infection.

In this second experiment on 'bed' cultivation the 'beds' were lifted with an experimental 2 row harvester which could only work very slowly due to the relatively large volume of soil that had to be taken up.

Wide Rows

Since 'bed' cultivation appeared to offer nothing towards the simplification of the harvesting problem and only introduced the disadvantage of reduced yield of saleable potatoes over conventional methods, the possibilities of 36 in. rows were investigated. Wide rows should allow more room for tractor and implement wheels and thus minimise the possibility of clod formation in the ridges due to side pressure. The greater rectangularity of plant spacing, given an equal plant population to

28 in. rows, however might be expected to reduce yield.

The formation of the widely spaced ridges presented some difficulty, but was achieved by the use of an American lister bottom - a heavy implement capable of forming 36 in. rows, and 28 in. rows as well by suitable adjustment. For comparison an experimental rotary ridger was used consisting of three pairs of contra-rotating 20 in. diameter spinners, that threw up the soil left and right of the furrow, pulverising the soil, and giving a positive movement of the soil onto the ridges.

Table 3.
Yield and clods at harvest

Type of ridger	Potatoes - t/acre			Clods - lb/ft		
	Row width in.			Row width in.		
	28	36	Mean	28	36	Mean
Lister bottom	12.8	12.5	12.6	1.9	3.7	2.8
Rotary	10.7	12.9	11.9	0.5	1.4	0.9
Mean	11.7	12.7	12.3	1.2	2.6	1.9

The wide rows yielded rather better than the narrow rows (Table 3), particularly of the larger sized tubers. Although the use of the rotary ridger depressed the yield in the narrow rows the weight of clods was $\frac{1}{3}$ of that in the rows where the lister bottoms had been used. There was considerable more clod in the 36 than the 28 in. rows due to the greater volume of soil and the deeper working of the implements. Frequency of cultivation had no marked effect in this experiment; it was concluded that 36 in. rows were not inferior to 28 in. rows, but for the best results ridging equipment would be required to form small widely spaced ridges rather than the large closely packed ridges as made by the lister bottoms. Rotary inter-row cultivation appeared to have distinct advantages over fixed implements in reducing the amount of clod in the ridge. Rotary cultivation might also be expected, by reason of the relatively greater soil movement to make the best use of the fleeting ideal soil conditions.

Cultivation and Chemical Weed Control

In the following year (1961) with the development of chemical weed control, it was decided to study the inter-relationship between cultivation between the rows with a rotary cultivator to reduce clod and a chemical spray to control weeds (GREEN 1962 c). The rotary cultivator was a prototype commercial machine consisting of a toolbar carrying tines, followed by a rotary cultivator turning on an axis across the direction of travel, with three small ridging bodies at the rear of the implement to form ridges from the pulverised soil (ANNON 1960).

The rotary cultivator was used at three different stages in the development of the crop between planting the seed and the tops meeting in the row, while the herbicides, DNBP and TCA, were applied at emergence. The resulting yields and clod populations (Table 4), indicated that any 'late' cultivation depressed the yield particularly of the larger sized tubers, while the amount of clod particularly of the larger sizes was relatively large when the cultivation was done at this time. This may have been due to the soil being wetter than at the 'late' period.

Table 4.
The effect of chemical weed control and the time of application of rotary cultivation

Treatments	Yield of potatoes t/acre	% > $2\frac{1}{4}$ in.	Clods t/acre	% > $2\frac{1}{4}$ in.
NO INTER-ROW CULTIVATION				
DNBP and TCA at shoot emergence	7.4	27	16.6	10.4
ROTARY INTER-ROW CULTIVATION				
Soon after planting potatoes (18th April)	6.9	29	9.4	8.5
At emergence (11th May)	7.7	34	9.5	6.3
As late as possible (16th June)	5.7	18	13.0	10.0
Soon after planting & emergence	8.4	39	7.6	7.9
Soon after planting and late	6.2	23	11.9	10.1
At emergence and late	7.3	25	12.1	9.9
Soon after planting, emergence and late	6.9	28	12.1	9.9
MEAN	7.1	28	11.5	9.6

Although the herbicides used were not particularly effective in controlling the weed growth, particularly thistles and late developing fat hen (Chenopodium album) the yield was above the general average for the experiment, but the clods were larger and more numerous than where the rows had been cultivated.

In the final year of the series (1962), the rotary inter-row cultivator was no longer available and the rows were cultivated instead at frequent intervals up to the time of shoot emergence with a spring tined cultivator pulled by a light tractor on narrow steel wheels ('C' treatments). This cultivation was compared with no cultivation up to emergence ('O' treatments), while both cultivation treatments were combined with four weed control treatments: (1) cultivation, (2) a soil acting herbicide ($1\frac{1}{2}$ lb Diuron in 30 gal/acre) soon after planting, (3) Diuron at emergence, and (4) a plant scorching chemical (1 lb Paraquat in 30 gal/acre) applied to individual weeds. Paraquat was applied at emergence to the third and fourth weed control treatment on the uncultivated plots to kill any existing weeds.

The 'C' plots were harrowed down three times, cultivated 5 times, and moulded up. The mechanical weed control treatment consisted of two harrowings down, and one cultivation under very dry conditions; more would have been done had not the soil become too wet to work shortly afterwards.

Table 5

Yield of potatoes and clod population - 1962 experiment

Treatments	Yield of potatoes t/acre	% tubers>$2\frac{1}{4}$ in.	Clod population t/acre	% clods>$2\frac{1}{4}$ in.
1 - 'C'	9.5	54	5.3	15
1 - 'O'	10.5	58	5.8	16
Mean	10.0	56	5.6	14
2 - 'C'	8.0	41	9.4	25
2 - 'O'	9.2	45	8.6	19
Mean	8.6	43	9.1	22
3 - 'C'	8.7	45	8.9	21
3 - 'O'	11.0	52	8.4	18
Mean	9.9	49	8.6	20
4 - 'C'	10.7	54	8.7	21
4 - 'O'	10.2	51	9.3	17
Mean	10.5	52	9.0	19
Mean 'C'	9.2	49	8.1	22
Mean 'O'	10.2	52	8.0	18
Mean	9.7	51	8.1	20

Diuron applied soon after planting while giving some reduction in the weed growth was not considered adequate, and the weeds were controlled in the manner of treatment 4. Treatment 3, although far from perfect in controlling weeds gave some control at least in the first 3 weeks or so after application. Yields were depressed on nearly all the Diuron plots.

The cultivation treatments depressed total yield and reduced tuber size while tending if anything to increase the size of the clods. The plots that received no cultivation averaged 10.2 t/acre against 9.2 t/acre where there had been cultivation up to the time of emergence, but the plots that had been cultivated after emergence only, yielded 10.5 t/acre.

Discussion

During the last two years there has been a revival of the interest in 'bed' cultivation following the work of BLEASDALE 1964, working on carrots and other vegetables including potatoes. Greatly increased yields have been obtained by giving the plants their optimum spacing regardless of conventional practice. Although the regular rectangular spacing that was possible with 'bed' cultivation made it possible to produce a preponderance of any given size grade, (pre-pack size for example) so far potatoes have not responded as well as some of the other crops studied, due to the 'special' requirements of potatoes; these 'special' requirements being the necessity to keep the tubers covered as they grow to protect them from light and blight infection, and be able to lift them usually under conditions of increasing soil moisture as the winter advances.

Wide rows, i.e. 36 or more inches apart, although extensively use in America and other countries, can not be expected to give either the optimum yield or a regular size of tuber, due to the rectangularity of the plant arrangement. Wide rows do however provide for some of the 'special' requirements of the crop, making it easier to keep the tubers covered reducing the length of row per acre to be harvested, and simplifying inter-row work (WESTON 1963).

Inter-row work can reduce the amount of clod in the row, but if done when soil conditions are unsuitable more clod can be formed than is broken down. On a heavy soil it would appear that the conditions for maximum clod breakdown and minimum clod formation are usually those when the soil looks too hard and dry on the surface for the cultivation to have any effect, but under these conditions cultivation probably allows valuable water to evaporate. The case for rotary cultivation against the use of fixed tine implements is largely unproven as yet, but certainly some rotary actions are better than others. In general inter-row cultivation tends to depress yield (PEREIRA 1941) and is therefore to be avoided, at least with clod reduction in mind. There is probably scope for more work on clod reduction during preparation of the ground before planting the potatoes, and ROBERTSON (1964) has obtained good results with the use of a rotary plough.

Chemical weed control has improved considerably of recent years, and will no doubt be further developed with the introduction of new herbicides and methods of application, but at the end of 1962 as far as the experiments at Silsoe were concerned, herbicidal sprays did not appear capable of giving sufficient control over many of the common weeds to be found in the potato field, and it appeared at the time that some backing would be required in the form of light surface cultivation. Diuron was an unfortunate choice in this experiment, and later chemicals are no doubt more effective weed killers and less poisonous to the potato.

Future developments in potato growing certainly lie in the direction of more widespread use of herbicides, and this will allow potatoes to be grown under conditions which will allow the potato plant to develop with the least restriction to yield the greatest possible weight of the particular size of tuber that the market demands. This implies some form of 'bed' cultivation, except that the 'bed' may be as wide as the spray boom. At the same time the 'special' requirements of the potato crop must be considered, and it seems that only ridges can supply these. Potatoes planted 24 in. in 24 in. rows with pairs of wider rows of not less than 28 in. three narrow rows apart for the spraying tractor wheels to run might fulfill the requirements.

The future is likely to show a demand for more uniform and better quality potatoes and many new forms of processed potatoes, which will all require the growing of more definite sizes and types. Apart from a need for improved varieties having definite characteristics, the method of growing will have to be more precise, with carefully controlled supplies of water and plant nutrients, accurate spacing, and efficient weed control. It will therefore be necessary to make periodic critical examinations of the current methods of production to ensure that the best use is made of machinery, power, and other resources to ensure that potatoes of the required type are produced in the most efficient manner.

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PLANT POPULATION AND CROP DENSITY IN RELATION TO THE USE OF HERBICIDES IN POTATOES

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Summary The effects of varying row width, seed spacing and seed treatment pre-planting were investigated in connection with the use of cultivations and herbicides for weed control in Majestic main-crop potatoes. Saleable yields and other considerations favoured the conventional 28 in row with 12-20 in spacing and multiple sprouted seed in the cultivated crop. In herbicide treated crops 20 in rows could lead to denser haulm canopy to aid chemical weed control without reducing saleable tuber yields. Blackleg disease was considerably reduced where the adoption of chemical means of weed control avoided disturbance of the crop post-planting in a wet spring.

INTRODUCTION

Crop vigour is an important ally in the war on weeds. Many of the newer herbicides that have been developed for the control of difficult weeds in cereals rely, for complete success, upon the competition from a vigorous crop once the initial growth retarding effect of the herbicide has waned. Herbicides currently being used for weed control in potatoes also have a limited effective life often too short to give lasting control of late developing weeds such as Chenopodium album. The vigour and density of potato haulm could therefore be of some importance in chemical weed control in potatoes and means of attaining an early canopy of crop foliage worth investigating.

A great deal has been written about the likely benefits from non-cultivation of the potato crop after planting. A ten per cent increase in yield has been indicated as being possible where disturbance of the potato ridge could be avoided: (Nield and Proctor 1962). Reduction in soil moisture loss and avoidance of root pruning are often quoted as worthwhile objectives. It has also been shown that the passage of tractor wheels over potato land during the process of inter-row cultivations, following earlier satisfactory tilth production, can increase the number of clods and render more difficult the separation of tubers on a potato harvester; (Robertson 1960). In West Germany the emphasis in the development of herbicides for weed control in potatoes has centred on the improvement in crop health, particularly the control of virus, following non-disturbance of the crop once it has emerged (Becker 1962). The toll from many diseases and pests could well be reduced where the need for post planting cultivations (in the potato crop) is eliminated.

It was with a view to exploring some of the aforementioned aspects of chemical versus cultural weed control methods in potatoes that an experiment was laid down in Hampshire, during 1964, on a commercial farm. The grower was interested in obtaining the maximum marketable yield of Majestic main-crop potatoes on land capable of high yields but where success with cultivations is governed very much by timely action when soil conditions are favourable. The land also has a high potential for vigorous weed growth.

METHOD AND MATERIALS

The experiment was sited on upper greensand over malmstone; the crop following wheat after ley. The soil, which has a pH 6.4 is rather low in organic matter. Planting, by hand, was carried out during the first few days of May the trial area having been fertilised with 120 units N, 120 units P and 216 units K per acre prior to baulking. The experimental design was based on a six random block system allowing for thirty six combinations per block of the following treatments:-

(i) Row width variation:- 12, 20, 28 and 36 in.
(ii) Seed spacing within the row:- 12, 16 and 20 in.
(iii) Seed treatment:- Apical sprout dominance, multiple sprouts and no sprouting.

Once-grown Majestic seed was used this having been sorted from bulk crop in store on the farm in January to provide an even seed sample in the $1\frac{1}{4}$-$1\frac{3}{4}$ in. size range. A third of the estimated seed requirement was put in bags and stored under dry, frost proof, conditions on the farm. An equivalent amount of seed was boxed and kept in a chitting store under controlled conditions. The remaining third was boxed and removed to a heated greenhouse to induce early sprouting. In late February the seed in the greenhouse was de-sprouted leaving one apical sprout the seed being then returned to the chitting store on the farm. The sprout condition of the seed, as planted, is shown in Table 1.

Table 1
Condition of sprouts, at time of planting, following three seed treatments

Seed Treatment	Sprout condition per tuber	Length of Sprouts	Average weight per 20 tubers
Stored in bags (not-sprouted)	30 per cent with weak, white sprouts - remainder dormant	$\frac{1}{4}$-$\frac{1}{2}$ in.	56 oz.
Multiple Sprouts	2-5 strong green sprouts	$\frac{1}{4}$-2 in.	$55\frac{1}{2}$ oz.
Apical Dominance	Majority of tubers with single multi-branched sturdy sprout	1-4 in.	$54\frac{1}{2}$ oz.

The weight of seed planted per acre varied according to the spacial arrangement in any one plot but taking the mean weight of se[illegible] tubers at 55 oz. per 20 tubers the extremes were as follows:-

12 in rows planted @ 12 in = 43,500 tubers/ac. = 67 cwt/ac.
28 in rows planted @ 16 in = 14,000 tubers/ac. = 21½ cwt/ac.
36 in rows planted @ 20 in = 8,700 tubers/ac. = 13½ cwt/ac.

Each plot consisted of four rows each 28 ft. length. Four of the blocks were kept clean of weeds, using hand-hoes, until late June when haulm growth restricted further cultivation. The other two blocks were sprayed with a recommended rate of a soil acting herbicide seven days after planting and no further measure for weed control was necessary the ridges remaining untouched after planting. Monthly rainfall, recorded at the farm, was as follows:- April 2.63 in.; May 2.59 in.; June 3.99 in.; July 1.14 in.; August 1.68 in. and September 0.39 in.

RESULTS AND DISCUSSION

Tuber yields are obviously of prime interest in an investigation of this type but the emphasis must obviously be on yields of saleable potatoes. Ware yields are therefore considered under two groups - top ware over 2¼ in. and total ware over 1⅝ in. Other factors, having a bearing on yield, were also studied and details recorded for various growth aspects are dealt with first.

1. Crop emergence

Plant emergence twenty-five days post-planting was recorded in the two centre rows of each plot. Table 2 shows that the 12 in row crop had a higher percentage plant emergence with all seed treatments probably due to slightly less cover of soil over the seed tubers. Apical dominance seed was ahead of the multiple sprouted seed but both seed treatments showed clearly the benefits of sprouting pre-planting in terms of early crop emergence.

Table 2
Percentage plant emergence 25 days post planting (mean data all blocks)

Row Width	12 in.				20 in.				28 in.				36 in.			
Seed Spacing	12.	16.	20.	Mean	12.	16.	20.	Mean	12.	16.	20.	Mean	12.	16.	20.	Mean
Seed Treatment	in.															
	%				%				%				%			
Apical Dominance	90.	93.	94.	92	83.	85.	94.	87	80.	83.	89.	84	78.	79.	82.	80
Multiple Sprouts	82.	89.	91.	87	76.	73.	66.	72	72.	70.	66.	69	74.	80.	70.	75
Not sprouted	3.	5.	4.	4.	2.	3.	5.	3.	3.	2.	3.	3.	5.	2.	2.	3.

Early crop emergence, when weed growth is slow, could of course restrict the use of contact herbicides such as paraquat. Full emergence, in all plots, was recorded on the 9th June - 40 days post-planting.

2. Weed control

A small area in a centre path was left unweeded as from the date of planting the crop. Here a dense growth of weed flourished during the trial period. The species included Chenopodium album; Stellaria media; Polygonum persicaria; Polygonum convolvulus, Capsella-bursa pastoris and Veronica spp. In the cultivated plots weed growth was restricted to a few weak Chenopodium plants which appeared in mid-summer, cultivations having ceased in late June. The herbicide treated plots - one block with $1\frac{1}{2}$ lb. a.i. linuron per acre, the other with 2 lb. a.i. of a prometryne/simazine mixture in 64 gall. water per acre - were remarkably free of weeds throughout the trial period. Conditions at this site in May/June 1964 were favourable for good results with soil residual herbicides and only a few plants of Equisetum arvense survived both treatments. Green algae is a common development on this type of soil in wet springs but the herbicide treated areas were completely free of such growth. The application of herbicides across all plots, without incurring wheel damage, was attained using a specially designed boom attached to a Land Rover p.t.o. driven pump. Cone, swirl, nozzles (D4), at 9 in pitch, gave an excellent spray pattern over the ridges much superior to that generally obtained with fan-type nozzles.

3. Disease control

A systematic disease assessment was carried out by the Plant Pathology department on the 21st July when the crop was in full flower. Although Leaf-roll virus (0.5-1.7%) and mosaic X and Y virus (0.2-1.0%) were observed in the trial area there was no consistent pattern of infection that could be related to any one treatment or combination of treatments. Symptoms of Blackleg bacterial disease (Erwinia atroseptica) were clearly visible in many of the cultivated plots but the herbicide treated blocks were relatively free.

Table 3

Assessment of Blackleg affected plants - 21st July

Mean data for six sub-blocks representing the four row widths

Cultivated Area Row width				Herbicide Treated Area Row width			
12 in.	20 in.	28 in.	36 in.	12 in.	20 in.	28 in.	36 in.
3.5%	4.1%	3.6%	3.7%	0.5%	0.5%	0.4%	0.7%

Infection, presumably carried on the tubers, caused more disease under conditions of high rainfall (June 4 in) on the cultivated plots than the undisturbed herbicide treated plots. The whole trial area was sprayed with Zineb polyethylene thirumsulphide on the 29th June and 13th July as a blight control measure. Blight symptoms appeared in late August throughout the crop but the disease had little effect on growth pre-harvest.

4. Stem population

The number of potato stems - or more correctly 'plants' - per unit area, in each plot, was recorded on the 1st September. This count of stems, in each of two centre rows per plot, was delayed until then to avoid damaging the crop at an earlier growth stage.

Table 4
Number of potato stems per square yard - pre-harvest

Seed Treatment	12 in. rows	20 in. rows	28 in. rows	36 in. rows
Apical Dominance	13.8	8.6	6.4	4.5
Multiple sprout	14.7	8.4	6.9	4.5
Not-sprouted	14.5	9.5	6.4	4.7

Row width had the greatest influence on stem numbers. Although sprout development was restricted initially in the 'apical dominance' seed further sprout growth after planting was obviously fairly rapid, but branching from the main sprout also accounts for the equivalent stem numbers to that found in areas planted with multiple sprouts or initially unsprouted tubers. Seed spacing did not have very much influence on stem numbers and there was no clear evidence that method of weed control had much bearing on stem numbers as seen pre-harvest. The degree of crop canopy which could aid chemical means of weed control is more likely to be governed by row width than any of the other factors examined in this study.

5. Greening of tubers

The aim at planting was to provide an even cover of 3-4 in soil over the seed tubers. There was however a tendency to draw a greater depth of covering over seed planted in the wide rows and difficulty in maintaining the desired cover over the narrow 12 in rows. When the produce of each plot was being sorted on the farm riddle a score for greening of tubers was recorded. This visual scoring was on a scale 0-10 where 0 = no trace of green on any tuber and 10 = each tuber carrying some green however small the area. In the produce from the cultivated crop that from the 12 in row crop was scored in the range 3-6; the 36 in row crop 1-3 and the 20 in and 28 in row crop 1½-4 with no consistent variation due to seed treatment or seed spacing in the row. In the herbicide treated blocks the 36 in row crop had the least number of green tubers 0-2 but in the other three row widths there was a wide variation from 1-10 with high scores outnumbering low scores in the 12 in row crop.

6. Crop tuber yields

The crop was harvested in late September under dry conditions the tubers lifting clean of soil. Two centre rows in each plot, after discarding end hills and reducing row length to 24 ft., were harvested for yield data. Tables 5, 6 and 7 indicate the effect of various treatments on ware and total tuber yields - expressed in tons per acre.

Table 5

Effect of Row Width on tuber yields - cultivated and herbicide areas

Tons per acre

Row Width	Ware over $2\frac{1}{4}$ in.		Ware over $1\frac{5}{8}$ in.		Total Tubers	
	Cultivated	Herbicide	Cultivated	Herbicide	Cultivated	Herbicide
12 in.	5.8	6.5	13.3	15.2	19.8	18.8
20 in.	6.6	8.2	14.1	16.3	17.5	19.6
28 in.	8.4	8.3	14.6	14.2	17.8	17.4
36 in.	9.1	9.8	14.9	15.0	17.7	17.1

Yields per row width are the mean yields for three spacings and three seed treatments.

The wider rows gave the highest yields of top ware (over $2\frac{1}{4}$ in.) particularly in the cultivated crop. The yield increases resulting from non-disturbance by cultivation were greatest in the 12 in and 20 in row crops in terms of ware tubers. In general the 20 in rows gave the most favourable yields in the herbicide treated areas.

Table 6

Effect on yield of varying seed spacing in the row

Tons per acre

Row Width	Seed Spacing	Ware over $2\frac{1}{4}$ in.		Ware over $1\frac{5}{8}$ in.		Total tubers	
in.	in.	Cultd.	Herbicide	Cultd.	Herbicide	Cultd.	Herbicide
28 standard	16	7.8	8.4	13.9	14.0	17.6	17.1
28	20	8.4	10.0	13.5	14.9	16.3	16.9
12	12	5.3	5.7	12.8	14.0	21.1	18.0
12	20	6.7	8.7	13.4	18.5	19.1	20.1
20	12	6.1	10.2	13.6	18.0	18.5	21.1
20	20	8.0	9.2	14.8	15.7	17.8	18.1
36	12	10.0	9.3	16.1	16.0	19.6	17.8
36	20	10.4	9.3	15.5	15.8	17.3	16.8

Above yields are mean yields from plots planted with multiple sprout seed.

With the standard farm treatment 28 in x 16 in there was very little difference in yield between cultivation and herbicide treatments. Wider spacing in the 28 in row did improve ware yield where chemical weed control replaced cultivations. Non-disturbance of the crop post-planting appeared to be more beneficial, in terms of tuber yields, in the narrow rather than the wide row settings. An interesting comparison was the yield levels from the 12 in row with 20 in spacing and the 20 in row with 12 in between seed as planted. In the cultivated area the yield of ware and total tubers were not widely different but the top ware yield in the herbicide treated area favoured the 20 in row rather than the 12 in row. In the very close planting 12 x 12 in total yield was much lower in the herbicide treated blocks than in cultivated plots. . There was very little difference in haulm die-back. There is therefore a suggestion that any herbicide phytotoxicity is more likely to influence yields in close planted crops rather than those planted on the more conventional pattern of spacing. This reduction in total yield was consistent for all seed treatments in close planted herbicide treated areas - see Table 7 below.

Effect of Seed Treatment on tuber yields in cultivated and herbicide plots

Tons per acre

Row Width	Seed Spacing	Seed Treatment	Ware over 2¼ in.		Ware over 1⅝ in.		Total Tubers	
in.	in.		Cultd.	Spray	Cultd.	Spray	Cultd.	Spray
28 standard	16	Multiple	7.8	8.4	13.9	14.0	17.6	17.1
12	12	Ap. Dom.	5.5	5.5	14.0	13.6	21.1	19.7
12	12	Multiple	5.3	5.7	12.8	14.0	21.1	18.0
12	12	Not sprouted	3.4	4.7	12.2	13.2	20.5	18.6
20	20	Ap. Dom.	7.8	8.0	15.3	15.4	16.9	18.1
20	20	Multiple	8.0	9.2	14.8	15.7	17.8	18.1
20	20	Not sprouted	5.3	6.4	12.1	13.2	15.9	17.7
36	20	Ap. Dom.	10.5	12.4	16.1	16.3	18.7	18.2
36	20	Multiple	10.4	9.3	15.5	15.8	17.3	16.8
36	20	Not sprouted	7.3	7.9	12.5	13.3	14.9	15.0

Sprouting of seed showed to advantage in terms of total and ware yield, at all spacings, in both cultivated and herbicide treated areas. Apical dominant sprouting showed benefits compared to the other seed treatments in the 36 in row crop but in terms of ware yield the multiple sprouted seed gained more from the replacement of cultivations by herbicides for weed control. in the narrow rows.

Early emergence in main crop Majestic potatoes, which can be encouraged by pre-planting sprouting, is clearly beneficial to saleable tuber yield whether the crop is being cultivated or treated with herbicides for weed control. On the other hand early emergence may necessitate the use of soil acting chemicals rather than those herbicides relying wholly or partly on contact action to control weeds. Any means of controlling disease in the potato field is worthy of further investigation and the use of chemicals to replace cultivations for post-planting weed control offers scope for a re-assessment of pest and disease control measures. Reducing the need for cultivations in the growing crop could well lead to improvement in crop health.

A dense growth of haulm could aid chemicals to control weeds in potatoes. The evidence from this one experiment, in one season, suggests that row width has the greatest influence, amongst those considered, on stem populations per unit area but other considerations of ease of planting and harvesting, coupled with the difficulties of maintaining adequate soil covering over the potatoes to prevent greening, tend to outweigh haulm density benefits in the very narrow 12 in row crop. A

20 in row, provided machinery could be adapted or redesigned to cope with such widths, would appear to provide a haulm density such as could aid herbicides to control weeds and provide maximum yield of saleable potatoes at this site. Where cultural means of weed control are persevered with there does not appear to be much advantage in deviating from the conventional 28 in row with seed spacing 12-20 in according to the variety of main crop potatoes being grown. A full report, together with statistical analysis of the data, on this and other experiments in potatoes, will be published in the Crop Husbandry Experiments Report 1964 N.A.A.S. South East Region.

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Research Summary

WEED CONTROL AND PLANT POPULATION STUDIES IN POTATOES.

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Summary. Experiments were carried out at Harper Adams College in 1963 and 1964 to compare chemical and mechanical treatments for weed control in potatoes, and in 1964 to study the effect of varying row widths and spatial arrangements in the crop when using chemicals for weed control. In 1963, prometryne, a mixture of prometryne and simazine, and a mixture of paraquat and simazine, all gave good control of annual weeds apart from cleavers (Galium aparine L) which was resistant. In 1964, control of annual weeds by six different chemical treatments, DNBP in oil, a mixture of diquat and paraquat, ametryne, linuron, prometryne, and a mixture of prometryne and simazine, was virtually complete. In both years, weed control by mechanical cultivations was adequate.

The number of ware sized 'green' tubers recorded just prior to harvest ranged from 0.2 to 0.8 per plant. There were more 'green' tubers following chemical treatments than after standard cultivations in 1963, but in 1964 the numbers were similar. In 1963, areas hand-weeded gave a higher total, and ware, yield than those either chemically or mechanically treated, but differences were not significant. Mid-season sampling in 1964 showed no significant differences between treatments in either the weight or number of tubers per plant. The evidence to date suggests that under our conditions, chemicals may provide an alternative to standard cultivations with the choice depending on cost and convenience. Final yield data for 1964 are given in a supplementary sheet.

EXPERIMENTAL METHODS. Chitted seed of Irish Certificate 'A' Majestic in 1963, and Foundation Stock, para-crinkle free King Edward in 1964, were planted in random block layouts to compare chemical and mechanical treatments with hand-weeded controls. Plots consisted of 7 rows each 12 yd. long.Row widths were 28 in. and spacing in rows 18-19 in. A pressurised knapsack sprayer fitted with an Oxford precision lance was used to spray the chemicals overall in 20 gal. of water per ac. in 1963, and 40 gal. of water per ac. in 1964. In 1963 the ridges were lightly harrowed down immediately after planting to round them off before spraying. Spraying was carried out each year when about 5% of the plants had emerged. In the plant population studies in 1964, chitted seed graded $1\frac{1}{4}$ in. to $1\frac{3}{4}$ in., and average weight 1.68 oz. was planted by hand. Details of the experiments are given in Table 1.

Table 1

Details of Experiments.

Year. Treatment and Exp. Design.	Dose lb/ac. (a.i. or a.e.)	Date applied	Date of weed assessment
1963 Planted 25/4			
Treatments:			
1. Standard Cultivations			14/6 & 11/8
2. Control (hand-weeded)			14/6 & 11/8
3. Prometryne + Simazine	1 + 3/8	14/5	14/6 & 11/8
4. Prometryne	1	14/5	14/6 & 11/8
5. Paraquat + Simazine	¾ + ½	14/5	14/6 & 11/8

Exp. design: 5 x 4 random block

Main weeds: Galium aparine L. Chenopodium album L. Polygonum aviculare L. P. persicaria L. Veronica spp. L. Stellaria media Vill.

1964a Planted 7/4			
Treatments:			
1. Standard cultivations			4/6
2. Control (hand-weeded)			4/6
3. DNBP in oil	2¼	5/5	4/6
4. Diquat + Paraquat	3/8 + 3/8	5/5	4/6
5. Prometryne + Simazine	1½ + 3/8	5/5	4/6
6. Prometryne	1½	5/5	4/6
7. Ametryne	1½	5/5	4/6
8. Linuron	2	5/5	4/6

Exp. design: 8 x 4 random block

Main weeds: Polygonum aviculare Chenopodium album Veronica spp. Vicia spp. Stellaria media. P. persicaria Viola spp Matricaria spp L. Sinapsis arvensis L.

1964b Planted 9/4

Treatments	Row width (in.)	Spacing (in.)	
1.	28	18)	sprayed with prometryne 1½ + simazine 3/8 on 5/5/64
2.	28	9)	
3.	21	18)	
4.	21	9)	
5. 'beds'	14	14)	

The soils were light to medium sandy loams with pH levels between 6 and 7. A typical soil analysis is as follows:- % organic matter 3.2, % coarse sand 37, % fine sand 32, % silt 14, and % clay 14.

Rainfall data are given in Table 2.

Table 2

Early summer rainfall 1963-64 (in inches)

Period		1963	1964
April	1-15	0.66	0.19
	16-30	1.08	1.27
May	1-16	0.49	0.58
	17-31	0.58	1.68
June	1-15	0.78	1.54
	16-30	2.34	0.11

RESULTS.

A. Effect of herbicides on weeds.

The effects of the treatments on the weed populations were compared about one month after the date of spraying. The results are summarised in Table 3.

Table 3

Mean number of annual weeds per yd^2.

1963, assessed 14/6

Treatment	1	2	3	4	5	Mean	Signif.
No. of weeds	2.3	1	7.8	10	17	7.6	N.S.

(b) 1964, assessed 4/6

Treatment	1	2	3	4	5	6	7	8	Mean	Signif.
No. of weeds	19	1	4.3	19.8	5.3	4.8	4	1.7	7.4	L.S.D. = 6.02 P = 0.05

In both years all treatments gave good control of annual weeds compared with mean totals per yd^2. in adjacent unsprayed areas of 225 in 1963, and 117 in 1964. In 1963 Galium aparine was resistant to all herbicides and by August covered 10-20% of the ground in sprayed plots compared with 5% after standard cultivations. In 1964 control of annual weeds by all herbicides was virtually complete, but by August some Chenopodium album and Sinapsis arvensis were evident after standard cultivations.

B. Effect of herbicides on potatoes.

(i) Development In both years slight scorch and marginal necrosis of leaves was observed after emergence, but the symptoms quickly disappeared. In 1964 after a period of heavy rain in early June occasional leaf discolouration occurred in areas treated with linuron, ametryne, prometryne and simazine, as white patches along or between veins. In 1964 mid-season sampling showed no evidence of any reduction in tuber weight or number after spraying as shown in Table 4.

Table 4.

Weight of tubers in oz. and number, assessed 2/7 (mean totals for 8 plants)

	Treatment								
	1	2	3	4	5	6	7	8	Mean	Signif.
(a) Weight of tubers	120	144	132	141	132	126	166	143	138	N.S.
(b) Number of tubers	114	133	132	144	115	120	152	135	131	N.S.

Prior to harvest the haulm was burnt off with sulphuric acid and the number of ware sized 'green' potatoes recorded. Results are summarised in Table 5.

Table 5.

Mean number of ware sized 'green' potatoes in 31.1 yd^2.

Treatments.

	1	2	3	4	5	Mean	Signif.
1963	17.0	17.8	58.0	38.0	44	36	L.S.D. = 18.4 P. = 0.05

	1	2	3	4	5	6	7	8	Mean	Signif.
1964	25.7	62.2	31.2	43.2	28.5	39.7	32.2	28.2	36.4	L.S.D. = 16.7 P. = 0.05

(ii) Yield.

Data for total, and ware yields of Majestics in 1963 are summarised in Table 6. Differences between treatments were not significant.

Table 6

Mean total, and ware yields of Majestic in 1963 (tons per ac.)

Treatments.

	1	2	3	4	5	Mean	Signif.
(a) Total yield.	14.2	15.5	13.4	13.5	13.3	14.0	N.S.
(b) Ware yield. (> 2 in.)	8.6	10.4	8.4	8.5	8.5	8.9	N.S.

In 1964 sampling in mid-July indicated that over a range of population from 10,000 to 24,000 plants per ac., total yields were similar at 10 to 12 tons per ac., although larger tubers were associated with lower populations. Under favourable growing and high fertility conditions the effect of varying plant population and yield within these limits appeared to be small.

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WEED CONTROL BY HERBICIDES IN POTATOES

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Summary Experiments at Rothamsted and Woburn showed that weed numbers can be reduced by herbicides as satisfactorily as by mechanical cultivations, but some of the weeds surviving the herbicide can grow vigorously and cover the ground while mechanical cultivations prevent this. Simazine reduced the crop yield, and the reduction was made bigger by irrigation. Its effect on weeds was reduced by dry weather and light soil. Where weeds are controlled by herbicides the yield of potatoes can be as big as where controlled by mechanical cultivations. Mechanical cultivations can, under some conditions, reduce the yield and size of the tubers.

INTRODUCTION

In 1959-63 a series of annual experiments was done at Rothamsted and Woburn to see if herbicides could be used to control weeds in the potato crop, and to compare the resulting crop yields with those where weeds were controlled by mechanical cultivations. All spray treatments were applied on ridges which had been rolled after planting with a serrated ridge roller

1959 Experiments

Simazine and atrazine were applied as a post-planting spray at Rothamsted and Woburn. At Rothamsted the variety was Ulster Supreme, at Woburn King Edward.

Treatments: lb a.i. per ac

O	=	No weed control
S	=	Simazine
A	=	Atrazine
1	=	½ lb
2	=	1 lb
3	=	1½ lb

Table 1
Potatoes - Rothamsted 1959 - mean weed numbers per yd^2

	0	S_1	S_2	S_3	A_2
Chenopodium album	4.4	0.8	1.2	-	-
Poa annua	12.0	0.4	-	-	-
Polygonum persicaria	22.8	1.6	2.0	3.2	-
Stellaria media	38.0	1.2	-	-	-
Polygonum convolvulus	6.0	1.6	0.8	0.4	0.4
Galium aparine	13.2	2.8	9.2	5.6	1.6
Other	9.6	4.4	2.8	1.2	2.0
Total	106.0	12.8	16.0	10.4	4.0
Wild Oats*	1.8	0.7	0.4	0.6	0.3

* Counted on whole plots in July
\- None present

Table 2
Potatoes 1959 - mean yield tons/ac

	0	S_1	S_2	S_3	Mean	A_2*	Mechanical* Weed Control
Rothamsted: (±0.941)	4.55	11.91	11.81	11.16	9.86	12.40	13.66
Woburn: (±0.721)	3.16	3.96	4.57	3.60	3.82	3.64	9.59

* Yields from treated strips outside experimental area

1960 Experiments

Simazine was used on 2 potato experiments in 1960, at Rothamsted on a heavy loam and at Woburn on a sandy loam; the variety was Ulster Supreme. In addition to post-planting spraying and mechanical cultivation, two combinations of sprays and cultivations were used. In one grubbing and ridging was done on 17 and 20 June after an early application of spray, and in the other early mechanical cultivations were followed by a spray on 27 May just before the potatoes emerged.

Treatments: lb a.i. per ac

- 0 = No weed control
- M = Mechanical cultivation only
- S_1 = Simazine ½ lb
- S_2 = Simazine 1 lb
- S_2E = Simazine 1 lb followed by mechanical cultivation
- S_2L = Mechanical cultivation followed by simazine 1 lb

At Rothamsted weeds were counted and their dry weights determined. At Woburn weeds were few and were not counted.

Table 3
Potatoes - Rothamsted 1960 - mean dry weight and number of weeds per yd^2

	O	M	S_1	S_2	S_2E	S_2L
Dry wt. g	88.4	8.2	63.4	31.9	7.1	1.9
Number	98.0	15.0	58.5	31.5	9.0	5.0

Table 4
Potatoes 1960 - mean yield tons/ac

	O	M	S_1	S_2	S_2E	S_2L	Mean
Rothamsted:							
Yield (1)	8.7	14.2	9.9	11.9	11.8	12.1	11.6
% "greened"	8.2	16.2	13.6	13.8	10.9	6.6	12.5
Woburn (2)							
Yield	21.6	24.2	19.6	21.0	22.4	19.2	21.4
% "blighted"	12.7	9.0	19.9	15.6	10.2	9.2	13.3

(1) = Treatments O, S_2E, S_2L (± 0.44)
" M, S_1, S_2 (± 0.31)
(2) = Treatments O, S_2E, S_2L (± 1.51)
" M, S_1, S_2 (± 1.07)

1961 Experiments

In 1961 an experiment was done at Rothamsted, and on heavy soil at Woburn, to compare mechanical cultivation with simazine and prometryne as post-planting sprays. In both experiments the treatments were the same; at Rothamsted soil tilth was poor and the potatoes grew badly, but at Woburn conditions were satisfactory and the crop grew well.

The variety at Rothamsted was Ulster Supreme, and at Woburn King Edward. At Rothamsted spraying was done 7 days after planting and at Woburn 11 days after planting. Six mechanical cultivations were done at Rothamsted and 5 at Woburn.

Treatments: lb a.i. in 40 gal/ac
O = No weed control
M = Mechanical cultivations
S_1, S_2 = Simazine ½, 1 lb
Pr_1, Pr_2 = Prometryne 1¼, 2½ lb

Table 5

Potatoes 1961 - mean weed numbers per yd^2

	O	M	S_1	S_2	Pr_1	Pr_2
Rothamsted	273.6	11.4	98.4	66.6	82.2	48.0
Woburn	200.2	19.1	76.0	68.3	77.8	53.4

Table 6

Potatoes 1961 - mean yield tons/ac

	O	M	S_1	S_2	Pr_1	Pr_2	Mean	
Rothamsted:								
Yield	2.3	8.0	4.1	5.1	4.0	6.1	4.9	± 0.545
* % "greened"	1.9	1.8	3.7	2.9	0.9	4.2	2.6	
⊙ % ware	77.2	96.4	88.1	92.7	91.9	93.0	89.9	
Woburn:								
Yield	6.5	13.7	8.9	8.8	9.1	10.0	9.5	± 0.819
⊙ % ware	90.9	96.7	95.8	94.2	96.0	95.0	94.8	

* Percentage "greened" are tubers with 10% or more of surface showing green marks.

⊙ Percentage ware through 1½ in. riddle

Irrigation Experiments

In 1960, 1961 and 1962 herbicides were used at Woburn on early potatoes in an experiment which included 2 levels of irrigation and 2 levels of nitrogen. In 1960 and 1961 simazine was applied at 1 lb in 40 gal/ac, 8 days after planting in 1960 and 14 days after planting in 1961. All plots had few weeds each year which were not counted. In 1962 trietazine was used as a pre-emergence spray at 1½ lb in 40 gal/ac 4 weeks after planting. The crop grew slowly because of the cold spring and dry June. Trietazine gave poor weed control but weeds were not counted.

Treatments:

O	=	No irrigation	
C	=	2.25 in. of irrigation	1960
		4.0 " " "	1961
		3.0 " " "	1962
N_1	=	0.6 cwt N/ac	
N_2	=	1.2 cwt N/ac	

Table 7
Woburn Irrigation Experiment 1960
Arran Pilot Potatoes - mean yield tons/ac

	ON_1	CN_1	ON_2	CN_2	Mean
Mechanical cultivations	9.1	10.9	10.4	13.1	10.8
Simazine	7.1	8.4	8.6	10.7	8.7
Difference	-2.0	-2.5	-1.8	-2.4	-2.1

Table 8
Woburn Irrigation Experiment 1961
Arran Pilot Potatoes - mean yield tons/ac

	ON_1	CN_1	ON_2	CN_2	Mean
Mechanical cultivations	5.9	13.3	6.2	15.0	10.1
Simazine	4.8	7.2	5.7	10.3	7.0
Difference	-1.1	-6.1	-0.5	-4.7	-3.1

Table 9
Woburn Irrigation Experiment 1962
Arran Pilot Potatoes - mean yield tons/ac

	ON_1	CN1	ON_2	CN_2	Mean
Mechanical cultivations	2.9	5.3	2.8	6.2	4.3
Trietazine	1.9	4.8	1.7	4.8	3.3
Difference	-1.0	-0.5	-1.1	-1.4	-1.0

1962 Experiments

In 1962 a wider range of herbicides was used on King Edward potatoes at Rothamsted and Majestic at Woburn, two post-planting and three pre-emergent.

Treatments: lb a.i. in 40 gal/ac

O	=	No weed control
M	=	Mechanical cultivations
Ds_1, Ds_2	=	Dinoseb 4, 6 lb
Pr_1, Pr_2	=	Prometryne 1¾, 2½ lb
Te	=	Trietazine 1½ lb
TeP	=	Trietazine 1½ lb + paraquat ¾ lb
DB_1, DB_2	=	2,6-DBN 1, 2 lb

At Rothamsted the Pr and DB plots were sprayed 13 days after planting, the other plots 5 weeks after planting. Five mechanical cultivations were given to the M plots. At Woburn the DB, Te and TeP plots were sprayed 10 days after planting, the other plots and a second dose of paraquat (¼ lb/ac) to the TeP plots, were sprayed 5 weeks after planting. Eight cultivations were given to the M plots.

Table 10

Potatoes - Rothamsted 1962 - mean weed numbers per yd^2

	O	M	Ds_1	Ds_2	Pr_1	Pr_2	Te	TeP	DB_1	DB_2
Graminaceous	16.6	1.8	25.9	20.2	22.0	15.1	31.7	2.5	36.0	10.1
Chenopodium album	285.5	-	1.1	2.2	3.2	2.5	12.6	6.1	119.9	51.5
Polygonum convolvulus	24.1	-	1.8	0.4	0.4	-	0.7	1.1	9.4	11.2
Polygonum aviculare	15.8	-	-	1.1	1.1	2.2	5.4	-	5.0	2.5
Stellaria media	9.7	-	-	-	0.7	0.4	1.1	-	4.7	2.5
Other	19.1	-	1.8	0.7	5.0	3.2	7.9	1.1	11.2	2.9
Total	370.8	1.8	30.6	24.6	32.4	23.4	59.4	10.8	186.2	80.7

Table 11

Potatoes - Woburn 1962 - mean weed numbers per yd^2

	O	M	Ds_1	Ds_2	Pr_1	Pr_2	Te	TeP	DB_1	DB_2
Graminaceous	54.7	6.5	56.9	42.9	74.5	58.0	34.2	16.6	43.6	33.5
Polygonum aviculare	87.5	-	22.0	33.5	65.9	42.5	20.5	0.4	23.4	12.2
Stellaria media	37.8	-	0.7	1.8	1.4	0.4	2.5	-	10.1	4.7
Polygonum convolvulus	5.4	-	-	1.1	0.4	0.4	0.7	0.7	6.1	4.0
Other	28.4	0.7	3.2	2.9	2.9	4.0	7.2	0.7	2.5	2.2
Total	213.8	7.2	82.8	82.2	145.1	105.3	65.1	18.4	85.7	56.6

At Woburn five treatments were sampled for weed dry weight on 30 July, 1962.

Table 12

Potatoes - Woburn 1962 - weed dry wt. in g per yd^2

	O	M	TeP	DB_1	DB_2
Weed dry wt.	287.4	3.8	8.9	128.8	85.0

Table 13

Potatoes 1962 - mean yield tons/ac

	O	M	Ds_1	Ds_2	Pr_1	Pr_2	Te	TeP	DB_1	DB_2	Mean
Rothamsted:											
Yield (±0.845)	+	14.66	12.88	14.62	12.34	14.40	12.37	13.77	+	+	13.57
% ware**	+	92.9	92.9	94.7	93.4	94.4	93.3	92.9	+	+	93.5
Woburn:											
Yield (±0.543)	2.21	7.49	6.32	6.50	4.91*	5.71	5.79	8.98	5.75	6.36	6.00

* Pr_1 = $1\frac{1}{4}$ lb/ac at Woburn

** = Percentage ware through $1\frac{3}{4}$ in. riddle

\+ = No yields taken

1963 Experiments

In 1963 at Rothamsted and Woburn three residual herbicides were used each with the addition of paraquat, and paraquat alone, all as pre-emergent sprays. At Rothamsted additional nitrogen was included as a factor so that the effect on weeds could be observed. The variety was King Edward at Rothamsted and Majestic at Woburn. At Rothamsted spraying was later than intended and between 30 and 40% of the plants had emerged when spraying was done.

Five days after the spraying most of the plants which had emerged at spraying appeared stunted, with a high proportion of the leaf area scorched, and with yellow patches on the leaflets. Eleven days after spraying these plants still seemed stunted, but the yellowing had largely disappeared. These ill-effects had disappeared 3 weeks after spraying.

Treatments: lb a.i. in 40 gal/ac

O	=	No weed control (until counts were made)
M	=	Mechanical weed control
P	=	Paraquat $\frac{3}{4}$ lb
PrP	=	Paraquat $\frac{3}{4}$ lb + prometryne 2 lb
TP	=	Paraquat $\frac{3}{4}$ lb + trietazine 1 lb
SP	=	Paraquat $\frac{3}{4}$ lb + simazine $\frac{1}{2}$ lb
-	=	No extra nitrogen
N	=	Extra notrogen 0.6 cwt/ac

At Rothamsted the area was fairly clean and there were relatively few weeds even on the control plots when weed counts were made on 28 June. Six cultivations were done at Rothamsted and 3 at Woburn.

Table 14
Potatoes - Rothamsted 1963 - mean weed numbers per yd^2

	M	P	PrP	TP	SP	O
Graminaceous	-	-	-	-	-	-
Polygonum convolvulus	13.1	14.0	5.0	5.0	7.7	53.1
Stellaria media	11.7	7.7	0.5	1.4	0.5	29.7
Other	4.5	3.6	2.7	0.9	2.7	11.3
Total	29.3	25.3	8.2	7.3	10.9	94.1

On 22 July 1963 weeds were counted on the paraquat treatment and the paraquat + prometryne treatment, to measure the effect of the residual herbicide.

Table 15
Potatoes - Rothamsted 1963 - mean weed numbers per yd^2

	P	PrP
Graminaceous	-	0.5
Polygonum convolvulus	13.5	4.5
Stellaria media	18.5	8.6
Other	10.4	2.7
Total	42.4	16.3

- Table 16
Potatoes - Woburn 1963 - mean weed numbers per yd^2

	M	P	PrP	TP	SP	C
Graminaceous	1.4	11.7	2.7	8.6	7.7	29.9
Polygonum aviculare	0.5	4.1	0.5	3.2	4.5	12.2
Matricaria inodora	-	3.6	1.4	0.9	2.7	18.9
Other	-	3.6	-	0.9	2.7	16.7
Total	1.9	23.0	4.6	13.6	17.6	77.7

Table 17
Potatoes 1963 - mean yield tons/ac

	M	P	PrP	TP	SP	Mean	O
Rothamsted:							
	9.13	10.34	9.59	9.45	9.40	9.58	9.76
N	10.15	10.03	9.12	10.50	8.91	9.74	10.40
Mean (±0.394)	9.64	10.18	9.35	9.97	9.15	9.65	10.08
Diff (±0.590)	+1.02	-0.31	-0.47	+1.05	-0.49	+0.16 (±0.264)	+0.64
Woburn:							
Mean (±0.873)	10.54	11.40	10.54	11.64	9.60	10.74	9.81

Table 18
Potatoes 1963 - % ware (1⅝ in. riddle)

	M	P	PrP	TP	SP	Mean	O
Rothamsted:							
-	90.8	89.8	88.7	90.3	91.0	90.1	90.0
N	91.3	91.0	91.4	92.1	91.6	91.5	91.1
Mean	91.0	90.4	90.1	91.2	91.3	90.7	90.5
Diff	+0.5	+1.2	+2.7	+1.8	+0.6	+1.4	+1.1
Woburn:							
Mean	58.0	66.0	70.2	70.4	65.5	66.0	66.4

DISCUSSION OF RESULTS

1959 Experiments

Table 1 shows that all weeds except Galium aparine were controlled by the herbicides. Simazine at the lowest rate (S_1) dramatically decreased the weed population but the two higher rates (S_2, S_3) had no further effect. Table 2 shows the effect of weed competition on yield. At Woburn neither herbicide was effective and the whole area became very weedy. Their failure can be ascribed to the little rain, only 0.64 in. in the first 4 weeks, and 0.51 in. in the second 4 weeks after spraying. The low yields reflect the effect of intense competition with weeds in the dry, light soil. On the sprayed plots about 50% of the tubers were shrivelled in the ground but on the mechanically cultivated plots only 17% were shrivelled.

Yield of tubers from land adjoining the experimental area on both farms suggest that atrazine at 1 lb/ac behaved like simazine, while mechanical control gave the biggest yield. This superiority of mechanical control at Rothamsted may be due largely to its greater success in controlling cleavers.

By the end of the season this weed had formed an almost complete cover over the simazine and atrazine-treated plots, for though the initial population of cleavers was small, the plants had no competition from other weeds and grew vigorously.

1960 Experiments

Table 3 shows that simazine alone had less effect than mechanical cultivation on the weed population, probably because of the dry spring. In the 4 weeks after spraying at Rothamsted there was only 1.52 inches of rain. Weed control was satisfactory on the M and S_2E treatments, but best on S_2L. The weeds were counted after the S_2E plots had been cultivated which explains why these had fewer weeds than the S_2 plots, though the two had similar yields.

In both experiments (Table 4) the yield of the M treatment was bigger than with any of the simazine treatments, even where simazine was used with mechanical cultivations and weed control was good. The S_2L plots were darker green in late July and August but this was not reflected in the yield. Ridging decreased the percentage of "blighted" tubers at Woburn (treatments M, S_2E, S_2L) but there was no definite trend at Rothamsted in the percentage "greened".

1961 Experiments

In both experiments (Table 5) weedkillers reduced the weeds, but none as effectively as mechanical cultivations. The higher rate of weedkiller application was more effective than the lower in both experiments. The reduced weed population on the sprayed plots grew vigorously and the ground was completely covered with weeds; the plots cultivated mechanically were satisfactorily clean.

The better growing conditions at Woburn are reflected in the bigger overall yield (Table 6). At both farms the plots with mechanical treatment gave the biggest yield, and the untreated plots the lowest yield and the smallest percentage of ware. Both herbicides reduced the yield. The figures for percentage "greened" fluctuate and show no clear trend.

Irrigation Experiments

In all these experiments (Tables 7, 8 and 9) the yield of potatoes was consistently less on the herbicide-treated plots, both with and without irrigation, and at both levels of nitrogen; where simazine was used the difference was made bigger by irrigation.

1962 Experiments

The O treatments at both farms had many weeds, but very few remained after mechanical treatments (Tables 10 and 11). The TeP treatments gave good weed control. At Rothamsted Chenopodium album was so prevalent on the O and DB treatments that they were removed and no yields taken. At Woburn by 30 July, Polygonum aviculare had covered the ground on all except the M and TeP treatments.

Table 13 shows that at Rothamsted the yield of potatoes from some herbicide treatments was almost as good as from the M treatments; at Woburn the TeP treatment gave a bigger yield, suggesting some harmful effect of mechanical cultivations.

1963 Experiments

The extra nitrogen had no effect on the weed population at either count but weeds, especially Stellaria media, had increased by the second count on both the P and PrP treatments (Tables 14 and 15). At Woburn there were few weeds and most of them were graminaceous (Table 16). At both farms paraquat alone was the least effective herbicide.

Table 17 shows that at both farms the yield of potatoes from the herbicide treatments was as big as that from the mechanical treatments. On the light Woburn soil the tubers from the mechanical treatment were smaller than where herbicides were used (Table 18). The yield from 4 plots adjoining the experimental area, treated with linuron, gave a mean yield of 9.10 tons/ac of which 90.5% was ware.

The Long-term Effect of Herbicides

Although herbicides can give satisfactory weed control without apparent loss of yield, in few of the experiments was their residual effect measured, and nothing is known of the long-term effect of herbicides on a rotation of crops.

A four-course rotation experiment was started at Rothamsted in 1961 to measure the immediate and residual effect of herbicides, which may differ from year to year and crop to crop, in wheat, potatoes, barley and beans. If herbicides give adequate weed control in these four crops this could lead to a simplification of conventional field cultivations, so each crop is grown on ground assigned to either mouldboard plough, rotary cultivator or rigid-tine cultivator. Weeds are counted each year on the potato and bean plots, and the breakdown of some of the herbicides in the soil is being followed. The soil will be examined for differences in its physical state brought about by the different primary cultivations. A simpler experiment involving only barley and potatoes was started at Woburn.

The experiments have not been going long enough to warrant the presentation of the results.

Research Summary

THE INFLUENCE OF CHEMICAL WEEDING ON THE GROWTH AND YIELD OF THE POTATO

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Summary An account is given of herbicide trials in potatoes carried out in 1963 and 1964. Dinoseb-in-oil, applied at 2·25 lb a.i. per acre to the ridged drills shortly before the emergence of the crop, provided a successful method of weed control, being superior to the mechanical cultivations normally carried out.

Weight of shoot growth and tuber yield per plant was greater where chemical treatment was used, at spacings of 2½ ft x 2 ft and 1½ ft x 1 ft. It would appear from the work carried out that row and in-the-row spacings can be reduced considerably from those currently used, without detriment to yield.

INTRODUCTION

It has been the practice for very many years to intensively work potatoes in order to obtain good weed control, until such time as the haulm forms a continuous cover. Cultivations have been reported as having beneficial effects in addition to the control of weeds (Aldrich & Campbell 1952; Hawkins 1960) but excessive cultivations can reduce yields (Aldrich et al 1954) and retard maturity.

Furthermore mechanical cultivations on many soils, especially on wet soils, while producing a fine surface tilth also produce sub-surface clods which remain until lifting and cause problems where mechanical harvesters are used (Robertson 1960).

Chemical weeding of potatoes has been successfully used for some years in North America where several States issue recommendations (Aldrich et al 1954), these recommendations being either for residual herbicides to be sprayed at planting time or for contact herbicides to be used just before crop emergence.

More recently chemical weed control methods have been used, to a limited extent, in the U.K. using several herbicides including dinoseb-in-oil which was the material used in these experiments. Dinoseb-in-oil at 2·25 lb a.i. per acre applied just before crop emergence will destroy seedlings and young plants of broad-leaved weeds which have grown since planting, and will give control of weed seedlings germinating subsequently in the surface soil, at least until the haulm forms a continuous cover.

The aim of this investigation was to determine the effect of chemical weeding on vegetative and tuber yield and uniformity of dinoseb weeded crops compared with normal mechanical weeding.

METHOD AND MATERIALS

Weed control work in potatoes, using dinoseb-in-oil, began in 1963 and has been continued during 1964, with a replicated trial of three treatments, viz. dinoseb-in-oil*, mechanical and control.

*Pulvicide-B

The variety used was Dr. McIntosh at spacings of 2½ ft x 2 ft and 1½ ft x 1 ft. The crop was planted on the 20th April and ridged immediately after planting.

Spraying was carried out 4 weeks after planting, i.e., as the first potato shoots were beginning to appear, applying dinoseb-in-oil at 2·25 lb a.i. in 40 gallons of water per acre.

The first mechanical treatment, consisting of harrowing down the ridges, followed by immediate re-ridging, was carried out as the first shoots began to emerge and was repeated when a second braid of weeds started to appear 3 weeks later.

Control plots were planted and ridged in the same manner as other plots, but once ridging had been carried out no subsequent treatment was given.

At the time the spraying and the first harrowing down was carried out there were approximately 30 seedling broad-leaved weeds per ft^2. The main types present were Sinapis arvensis (charlock), Capsella bursa-pastoris (shepherd's purse), Urtica urens (annual nettle), Chenopodium album (fat hen), Tripleurospermum maritimum ssp. inodorum (scentless mayweed), Sonchus oleraceus (annual sowthistle), Senecio vulgaris (groundsel) and Thlaspi arvense (field pennycress).

RESULTS

Weed Control - 1964 Replicated Trial

Weed counts were made 4, 8 and 12 weeks after spraying or first mechanical treatment, the estimate of weed control being made on the basis 0 = no weed control, 10 = complete weed control.

Time of Assessment (weeks)	Dinoseb-in-oil	Harrowed	Control
4	9·5	10·0	0
8	9·5	6·5	0
12	9·5	2·0	0

The dinoseb-in-oil spray was applied to a heavy cover of weeds, as mentioned above, i.e., 30 per ft^2 and gave almost a complete kill. Very few seedlings developed later and these were quickly smothered by the haulm growth.

It should be noted that the complete weed control recorded at 4 weeks on the mechanically treated areas was due to the second harrowing given one week before.

The results of the 1964 trial corresponded very closely to results obtained during 1963.

Yield - 1964 Replicated Trial

Many references can be found to the influence of various chemical and mechanical treatments on tuber yield. (Robertson 1960; Wood, et al 1960; Milford & Pfeiffer 1962; Becker 1962; Watt 1962; Burghausen 1963; Kabiersch 1963; Pätzold 1963).

The object of this investigation was to determine the influence of dinoseb-in-oil and mechanical cultivations on haulm and tuber weight and uniformity.

As the crop had to be harvested before reaching maturity haulm and tuber weights are not given in cwt. per acre but as percentages, taking results obtained from plots receiving normal mechanical cultivations as 100.

(a) Shoots

(i) Spacings 2½ ft x 2 ft

The weight of haulm per plant on the dinoseb treated plots was 38% greater than on the plots harrowed twice. Shoot numbers per plant were similar on both the dinoseb and mechanically treated plots, but the average shoot length was 22% greater with the former treatment. In addition 22% more shoots occurred within a 2 in. variation of the average shoot length, demonstrating the greater haulm uniformity obtained with chemical weeding.

(ii) Spacings 1½ ft x 1 ft

The same pattern was observed with the closer spacings, haulm on the dinoseb treated plots being heavier and more uniform and shoots being longer than on mechanically treated plots.

(b) Tubers

(i) Spacings 2½ ft x 2 ft

Tuber weight per plant was 23% higher in dinoseb treated plots than in those given two harrowings. Potatoes were graded for size into small, medium and large categories. The percentage of potatoes occurring in the medium grade was 150% higher in the dinoseb treated plots compared with areas which were mechanically weeded, indicating greater tuber uniformity.

(ii) Spacings 1½ ft x 1 ft

Tuber yield per plant was 31% higher on dinoseb treated plots and the percentage of medium grade tubers 27% higher than on the harrowed plots.

Haulm & Tuber Yield - 2½ ft x 2 ft Spacing

	Shoots				Tubers	
Treatment	Weight	Uniformity	Numbers	Average Length	Weight	Uniformity
Dinoseb	**138**	**122**	**100**	**122**	**123**	**250**
Harrowed	**100**	**100**	**100**	**100**	**100**	**100**
Control	**34**	**67**	**90**	**84**	**30**	**60**
	Haulm & Tuber Yield - 1½ ft x 1 ft Spacing					
Dinoseb	**114**	**116**	**106**	**118**	**131**	**127**
Harrowed	**100**	**100**	**100**	**100**	**100**	**100**
Control	**56**	**130**	**80**	**108**	**64**	**45**

DISCUSSION

Dinoseb-in-oil gave a better long-term control of weeds than mechanical cultivations, together with increased haulm and tuber growth and haulm and tuber uniformity.

It was interesting to note that both haulm and tuber weights per plant were greater at the closer spacings and this increased weight per plant coupled with increased plant densities could lead to considerable increases in yield per acre.

Measurements of soil moisture content of the ridges were carried out and it was found that the soil of dinoseb treated plots contained an average 4% more moisture than soil from mechanically cultivated plots and this could well be an important factor, especially in dry seasons.

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THE INFLUENCE OF CHEMICAL WEEDING ON THE GROWTH AND YIELD OF THE POTATO

(Supplementary Sheet)

Final Tuber Weights

Treatment	Spacing	No. Plants/Acre	Total Tuber Weight (tons/acre)
Harrowed	$2\frac{1}{2}$ ft x 2 ft	8,708	9·6
Dinoseb	$2\frac{1}{2}$ ft x 2 ft	8,708	11·4
Harrowed	$1\frac{1}{2}$ ft x 1 ft	8,708	9·4
Dinoseb	$1\frac{1}{2}$ ft x 1 ft	8,708	11·8

Where the crop was close planted at $1\frac{1}{2}$ ft x 1 ft (in 3 ft wide beds, consisting of 3 rows each) and chemically weeded with dinoseb, the tuber weight per plant was greater than where similar treatment was given on plants spaced at the more conventional $2\frac{1}{2}$ ft x 2 ft.

Tuber weight per plant was reduced when close planted crops were mechanically weeded, presumably due to the greater damage suffered by the plants, than where the $2\frac{1}{2}$ ft x 2 ft spacing was used.

Final yield figures show a slight falling off in the percentage increase obtained by chemical as against mechanical treatments at both spacings than those shown in the table on page 3. This may have been due to the growth of chemically treated plots being more advanced throughout the season, the haulm dying off some time before that on mechanically treated crops. As the latter were still growing when late summer rains fell, a certain amount of late swelling of the tubers is likely to have occurred.

If it was possible to contemplate solid planting at $1\frac{1}{2}$ ft x 1 ft, rather than growing close planted crops on a bed system, plant numbers per acre could be increased to approximately 30,000, and considerable yield increases would then seem to be possible.

Correction to main text last page line 4 delete........'both haulm and'........

THE COMMERCIAL APPLICATION OF THE "NON CULTIVATION METHOD"* OF GROWING POTATOES USING HERBICIDES INSTEAD OF MECHANICAL WEED CONTROL.

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Summary — Commercial application of the above method hereafter referred to as N.C., over a period from 1956 to 1964 on a total of 2,880 acres has shown that this practice has been accepted by farmers, has become standard on some farms, and will become standard practise on many more.

The success of the method brings increased yield, maintenance of moisture, better shaped tubers, and opportunities to deploy labour elsewhere with reduced production costs.

Success is governed by the following factors:- (a) Soil type; (b) Land preparation; (c) Weed species present; (d) Method of planting; (e) Weather conditions; (f) Herbicides used — ideally a contact and and residual herbicide which will persist at least eight weeks and will control a wide spectrum of weeds including annual grasses without depressing yield is the answer. In the writers experience, monolinuron has shown that it satisfies these conditions.

INTRODUCTION

The following report deals with the experience of a Farming and Chemical Distribution Organisation in connection with the N.C. method of growing potatoes. Information was collated from the Company Farms which cover some 4,500 acres and from the Chemical Organization which supplies farmers, spraying contractors and agricultural merchants in 17 counties with agricultural chemicals. The information gained as a result of visits to farmers and contractors, is particularly valuable as this is obtained by trained advisory personnel and is the result of practical experience.

EXPERIENCES WITH N.C TECHNIQUE FROM 1956–1964.

1956/57

Following initial reports from Scotland on N.C., cultivation was reduced in several plots of potatoes around Evesham, the effect being to produce a weed coverage at emergence of the potatoes. The weed coverage was burnt off with contact herbicides based on cresylic acid and pentachlorphenol, but mechanical cultivation had to be re-introduced to destroy subsequent germination of weed after the potatoes had emerged.

*N.C. Definition. Deep preparation of soil pre-planting, ridging at and just after planting, no further cultivation. Weed control by Residual Herbicide.

1958/9/60
M.C.P.A. was used commercially in order to try to advance the N.C. method, but weed spectrum control was not found to be sufficient, and it was suspected that the chemical treatment depressed the potatoes.

1961
At the instance of N.A.A.S. Worcester, two acres of potatoes were planted on the N.C. method in the centre of a field of potatoes at Charlton, Evesham, where normal cultural methods were being carried out. The two acres were ridged at time of planting and sprayed a fortnight later with 4 lbs. D.N.B.P. amine as a contact and residual herbicide. The whole field was irrigated twice and blight prevention sprays were carried out. No cultivation on the N.C. plot was carried out until lifting.

50 pairs of plants were lifted at random points in the two N.C. acres and 50 pairs from the adjoining cultivated portions of the field.

A weight comparison indicated an increase of 15 cwt. per acre on the non cultivated over the normal method.

1962
As a result of 1961 experience it was decided to plant 32 acres of potatoes on the N.C. method on the Company farms at Charlton, and also to suggest to selected potato growers in 10 counties that the new method showed great promise and that they might care to try a proportion of their potato planting on this method. 500 acres were planted using 4 lbs. per acre of D.N.B.P. amine as the Herbicide.

The following results were recorded:-
65 per cent Growers were very satisfied and said that they would increase their acreage in 1963. They reported apparently increased yield, and a much better sample of ware potatoes. They reported also harvesting made easier by loose soil and absence of clods.

20 per cent reported, fair results with little advantage seen.

15 per cent reported, failure.

Failure and fair results were due to bad soil preparations particularly heavy soil, producing too many clods. Failure to control certain weeds, i.e. cirsium arvense, polygonium species and in particular poa annua.

1963
N.C. acreage on the Company farms in the Vale of Evesham was increased to 90 acres. More farmers were approached to try the method and 650 acres were planted adopting this technique. 4 lbs. of D N.B.P. amine was again used per acre.
In order to form a better ridge to hold the potatoes and avoid greening, it was suggested that re-ridging to a rounded heavy contour be carried out one week after planting. In order to obtain this type of ridge farmers planted on an average at 30" x 10" distance between tubers.

A survey of results gave the following: 70 per cent very satisfied; 20 per cent fair results; 10 per cent failure.

1964
As a result of experimental work carried out in 1963, in the Vale of Evesham and

information from Germany (Hoechst A.G.), it was decided to substitute monolinuron for D.N.B.P. amine.

The objects of the change were to obtain a wider spectrum of weed control including annual grasses, to obtain a longer period of weed control with a more persistent chemical and to bring a less toxic more economical chemical into use

Although the survey is not yet completed, information to date is as follows:-
N.C. acreage on Company farms was 104, and farmers in 17 counties planted 1,700 acres on the N.C. method, these being sprayed with 1 lb. a.i. monolinuron per acre. Some of these have already reported yield increases by adopting N.C. as an alternative to conventional cultivation methods.

In addition, two acres of potatoes were planted on the bed system at 10" x 14" N.C. on the Company Farms at Severn Stoke, Worcester. These potatoes and the adjacent control have suffered from drought and have not yet been lifted but the results show promise of an increased crop over the 30" x 10" N.C. method In this instance D.N.B.P. amine was the Herbicide used.

PRACTICAL OBSERVATIONS

(i) Herbicide efficiency.
Contact and short terms residuals are not suitable for N.C.
The chemical treatment adopted should have a residual effect lasting at least two months (and some initial contact effect). A vigorous haulm during the growth period will aid the chemical weed control
The herbicide used should be effective against a wide weed species spectrum including annual grasses.
Rates of application for weed control should not depress the saleable yield of potatoes.
The writers experience is that monolinuron conforms to these conditions, except that monolinuron is not effective against Gallium aparine and only partly effective against Solanum nigrum.
D.N.B.P. amine which served an excellent purpose in pioneering N.C. has the following disadvantages:- Poor control of annual grasses, low persistency, subject to drought effect.

(ii) Application.
It was noted that weed control is less effective in the tractor wheelings, hence the importance of using a wide boom. Calm weather is of greater importance when applying residual herbicide to potatoes than in other spray applications Cross winds will cause a heavy weed striping along the leeward side of the ridge.

(iii) Crop Aspects.
Crops generally take longer to emerge under N.C. method but haulm once emerged catches up and outgrows the haulm of the normal method potatoes gaining in vigour. In the writers opinion the lack of mechanical damage to fresh shoots is responsible for the rapid aerial growth of the N.C. potatoes. It was noted that where part of a field had been planted N.C. and part on normal cultivation, the aerial growth of the latter potatoes was more susceptible to late Spring frost. The wide heavy ridge has overcome one of the main disadvantages of the method i.e. an excessive proportion of green potatoes.
Absence of clods, and a fine tilth has been reported as making harvesting easier for the farmers.

DISCUSSION

It is considered by the writers that it will be a pity if potato growers become divided into two camps. Cultivation versus N.C. They should rather be divided into those who are able to carry out N.C. and those who are not.

The N.C. technique of potato growing has not proved successful on heavy clay soils largely because of the difficulty of preparing a satisfactory tilth pre-planting. Some growers have overcome this difficulty by forming an over-wintering ridge which, after effective weathering, is split back in preparation for planting. On shallow stony soils, e.g. Cotswold brash, greening of tubers can occur because of lack of soil cover on the ridge after early final ridging. Peat soils, due to their absorbing power, tend to show a lowering of herbicide efficiency.

When adopting the technique it is essential to carry out deep cultivation pre-planting in order to produce a favourable tilth This may necessitate forward planning and timely action when soil conditions are favourable. Care is necessary in carrying out ridging to provide maximum soil coverage to reduce tuber greening. Soil moisture is often a limiting factor governing herbicide efficiency and baulks should not be allowed to dry out excessively during the process of planting.

An efficient wide spectrum persistent herbicide, such as monolinuron, is required for satisfactory control of weeds. Contact or short term residual herbicides, such as D.N.B.P. amine, are seldom able to control late germinating weeds such as Chenopodium album and sometimes Polygonum persicaria and these can often prove troublesome at harvest. Some perennial weeds — Agropyron repens, Cirsium arvense, Rumex obtusifolius, are resistant to the herbicides hitherto tested and the N.C. method is unsuitable where such weeds abound. In any case potatoes should not be planted in fields infested with these weeds.

The N.C. technique, involving great care in land preparation pre-planting, could be adopted to advantage in many potato growing areas. It can lead to economy in labour, ease of harvesting and increased yields of saleable potatoes.

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Research Summary

CHEMICAL WEED CONTROL IN POTATOES

IN THE SEED PRODUCTION AREA, HANOVER, WEST GERMANY

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Landwirtschaftsrat, Uelzen

Fully mechanised harvesting of potatoes is hindered by weeds and heavy weed infestations in potato crops can result in serious yield losses. Early investigations on chemical weed control in potatoes in West Germany emphasised the benefits likely to accrue from reduced or nil cultivations post emergence of the crop and hinted that, nowadays, potatoes should be regarded as a 'spray crop' (Spritzfrucht) rather than a 'hoeing or scuffling' crop. (Hackfrucht). More recently, however, experiments and practical experiences have indicated that this generalisation can only be applied widely to crops grown on light soils and where annual weeds dominate. On the heavier soils and in the presence of rhizomatus weeds post-planting cultivations are still essential to maintain weed free high yielding crops.

Other considerations can also influence the decision of whether to adopt chemical weed control methods in potatoes -:

1. Mechanical cultivation, post emergence of the crop, increases the risk of transmitting Virus X and Y. Experiments in 1959 and 1960 showed a doubling of Virus X incidence and clear evidence of increases of Virus Y following post-emergence cultivations in many potato varieties in common use.

2. The success of nematode resistant varieties relies to a large extent upon vigorous early growth with easy root penetration through the upper soil layers. Cultivations after planting can hinder the development of the feeding roots and retard the crop where haulm is damaged.

3. Acute labour shortage can be overcome by substituting a single spray application thus eliminating the need for cultivation at periods of peak labour demand.

Growth regulating herbicides are seldom used. These will generally leave undesirable side effects and in the case of 2,3,6 - T.B.A. dangerous soil residues. M.C.P.A. alone has little effect on Polygonum and Galeopsis species and often there is incomplete control of Chenopodium album and Cirsium species. Where perennial rhizomatus weeds are troublesome these must be treated either in a previous cereal crop or in autumn stubbles, e.g. Cirsium by growth regulators, Agropyron repens by T.C.A. using 25-40 lb. per acre on cultivated stubbles and Tussilago farfara with repeated treatment of Mecoprop (C.M.P.P.) in the cereal crop or Amitrole after harvest.

Calcium cyanamide, applied at $2\frac{1}{2}$ cwt. per acre along the ridges before crop emergence, is an established method of controlling early weed growth in potatoes as well as providing an additional source of nitrogen for the crop. Pre—crop emergence treatment with Paraquat requires further testing but it appears that its effect is short lived and in many instances heavy infestations of Poa annua have developed following treatment. Aretit (Dinitrophenyl acetate) used since 1961 at rates of $4\frac{1}{2}$ lb per acre, generally, gives better results and is widely used in some localities. This material also has a rather limited effective life of about eight weeks duration and will not control late germinating weeds in main crops. Simazine sprayed at 1 lb. per acre, shortly before crop emergence, has a longer effective life without seriously affecting crop yield. The combination of Simazine and Prometryne has been tested experimentally over two years and whether this mixture will improve on Simazine alone is still doubtful. The efficiency of the Triazines declines sharply following application under dry soil conditions. Experimental evidence, supported by commercial use (about 4,500 acres in 1964), suggest that the most efficient herbicides for weed in potatoes are the urea derivatives and in particular Aresin (monolinuron) applied at 2 - $2\frac{1}{2}$ lb. per acre. It gives good control of the following weeds -: Poa annua, Stellaria media, Sinapis arvensis, Polygonum convulvulus, Polygonum persicaria, Chenopodium album, Senecio vulgaris, Chrysanthemum segetum and Galeopsis arvensis. Centaurea cyanus is, however, rather resistant to treatment with Aresin. Higher rates of this chemical, up to $4\frac{1}{2}$ lb. peracre, are necessary to give satisfactory weed control on peaty soils due to their greater absorptive power and under practical conditions the crop suffers only slight damage at this higher rate of application. In our most recent experiments another urea derivative Fa. C.I.B.A. (C.3126) has given good results equal to that originally claimed from its source the C.I.B.A. Laboratories Limited, Horsham.

Late emerging weeds, such as Galinsoga parviflora and Solanum nigrum, are seldom effectively controlled by the urea derivatives hitherto tested. Simazine applied after crop emergence at 0.6 lb. per acre, when the haulm is about 8 in. high, will give satisfactory control of these weeds but, in many instances, yield depressions of the order of 10 per cent have been recorded. The destruction of these late developing weeds, coupled with potato haulm killing in order to simplify harvesting, can be effected using Diquat at 0.25 to 0.5 lb. per acre, but some consideration of tuber maturity is necessary when using this material. Other chemicals such as D.N.O.C. oil formulations and phenol preparations are scarcely used because of their toxic nature. Arsenic preparations, such as 'Aamorta' are no longer used in agricultural practise and have virtually disappeared off the market.

INVESTIGATIONS ON CHEMICAL WEED CONTROL IN POTATOES IN WEST GERMANY

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Until recently weed control in potato crops in West Germany was attained by post-planting cultivations using multi-purpose toolbars and weeders within the period of vegetation (Rademacher 1957). In some areas, however, late developing weeds, especially Galinsoga parviflora L., have proved troublesome at harvest. Here and there such weeds necessitate the use of herbicides in addition to normal cultivation. (Fröchling 1961, Kabiersch 1961 and Pätzold 1959). The discovery that post crop emergence cultivations tend to spread virus disease from plant to plant has, however, stimulated much more attention on the intensive use of herbicides in potato culture (Becker 1962)

An extensive cooperative series of experiments started in 1959 in various parts of West Germany, is investigating the effect of mechanical versus chemical weed control methods in potatoes. In the first experimental period (1959-61) two problems were investigated namely 1) 'The influence of cultivations, after crop emergence, on weed populations and the development of the potato plant and 2) 'The use of calcium cynamide in place of mechanical cultivation' (Pätzold 1963). In the latter group as good an effect could be obtained with pre-emrgence applied calcium cynamide in controlling seedling weeds as was obtained using weeders afteremergence. The plots not mechanically weeded after emergence gave higher tuber yields and a reduced incidence of virus X compared to the crops.

In the second experimental period since 1962 additionally to calcium cynamide various forms of herbicides have been tested for weed control efficiency. In this series the mechanical hoe is used after emergence, but no weeders. Furthermore some plots remained without cultivation after planting and baulking, other plots after emergence. These investigations are not yet concluded but results to date allow for the following statement:- 'Mechanical cultivation in potatoes can be reduced and even eliminated by the correct timed appliecation of herbicides except where rhizomatous weeds are troublesome or where soil, in the absence of cultivations, tends to cap'.

Among the herbicides used, the urea derivative (Aresin-Hoechst) has become well established in West Germany (Härtel 1962).

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