SOME FACTORS AFFECTING THE GROWTH OF TWO AQUATIC WEED SPECIES OF THE NILE - WATER HYACINTH (EICHHORNIA CRASSIPES SOLMS.) AND WATER LETTUCE (PISTIA STRATIOTES L.)

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Summary A comparative study was made of the growth of Eichhornia crassipes and Pistia stratiotes in water-culture in a factorial experiment in which pH values 4.0, 5.5 and 7.0 were in combination with nitrogen levels 1, 5 and 25 ppm. The response of each species was measured in terms of number of plants produced, total dry-weight and dry-weight per plant. The results are discussed in relation to a number of ecological problems posed by the recent entry of E. crassipes into the Sudanese Nile system.

INTRODUCTION

Water hyacinth (Eichhornia crassipes Solms.) has been estimated to have first entered the Sudanese Nile early in 1957 (Gay 1960) by some method unknown. The explosive spread of the species in this region has been well documented (Gay 1958a, 1960) and some of the catastrophic effects of this spread described (Gay and Berry 1959, Davies 1959). But little information is available on the more fundamental biological behaviour of the species in this new environment. This information is pertinent, however, to some of the interesting ecological questions posed by the entrance and successful maintenance of the water hyacinth in the Nile and thus such information is urgently required.

Eichhornia crassipes was not unknown in the Nile prior to 1957; it has been present in the Delta for many years (Tackholm and Drar 1950) but has never reached the 'plague' proportions exhibited in the Sudan. In the Bahr el Ghazal, a tributary of the White Nile, the species is similarly much less prolific. Possibly these two facts may be explicable in terms of water characterstics of both situations (Talling 1957, Gronblad, Prowse and Scott 1958) but little is known of the ecological requirements of E. crassipes for optimum growth.

Of equal interest is the effect that Eichhornia crassipes has had upon other elements of the riverain flora, in particular the aquatic, water lettuce, (Pistia stratiotes L.). Gay (1958b) noted that this species, previously abundant in the White Nile, had virtually been eliminated by water hyacinth in some regions and an 'antagonism' between the two species had also been observed (Anon. 1957). This may be due to the modification by E. crassipes of its substrate (Bishai 1960, Chadwick 1961), thus rendering it less suitable for the continued success of P. stratiotes; or it may be that water hyacinth is better suited to the original habitat than water lettuce; or both factors may be operating. Whatever the case, it only serves to underline the necessity of obtaining accurate experimental data of the ecological preferences of E. crassipes and some of the associated species such as P. stratiotes. Indeed, at a recent Symposium on E. crassipes (Anon. 1957) it was noted that little is known of either the upper pH or mineralization limits of the substrate of the species and it was recommended that results for such river basins as the Nile should be obtained.

The results to be presented here are part of a comparative study of the biology and ecology of Eichhornia crassipes and Pistia stratiotes undertaken at the University of Khartoum (see Chadwick 1961, Obeid 1963). Only results bearing on the degree of mineralization and the pH of the substrate will be considered here.

MATERIALS AND METHODS

Clonal material of Eichhornia crassipes and Pistia stratiotes, obtained originally from the White Nile, were grown in water-culture. After preliminary experiments it was ascertained that a culture solution of one-fifth the concentration of the Long Ashton solution (Hewitt 1952) was suitable. The containers used were 7 lb tinned-cans, painted black and lined with polythene bags. Air was bubbled through the solution. Each can contained initially two plants. In one experiment the growth of the two species at pH 3.0, 4.3, 5.6, 6.9 and 8.2 was compared, in culture solution and in tap water. In another experiment growth at pH 4.0, 5.5 and 7.0 at nitrogen levels of 1, 5 or 25 ppm was compared. Results from the two experiments did not conflict and only the second experiment will be described here. Treatments were randomised in each of four replicates. pH and nitrogen levels were maintained as previously described (Bradshaw et al. 1960, Chadwick and Obeid 1963). The experiment proceeded for four weeks after which time the number of plants, total dry-weight, dry-weight per plant, percentage dry-weight and shoot: root ratio were determined. The last two characters will not be discussed here.

RESULTS

Table 1 shows the mean number of plants harvested, the mean total dry-weight and the mean dry-weight per plant at each treatment for both species, in their transformed form. It was found necessary to transform the data for the analyses of variance.

It will be seen from the Table that an increase in nitrogen concentration increased both the number of plants and total dry-weight produced by each species but did not cause a similar increase in dry-weight per plant. It will also be seen that the pH optima of the two species were disimilar, being pH 7.0 for Eichhornia crassipes and pH 4.0 for Pistia stratiotes. In the former species at the two highest nitrogen levels, more plants were produced (although not significantly so), the total dry-weight was greater and individual plants weighed more at the optimum pH level. In P. stratiotes at these two nitrogen levels, however, although the species resembled E. crassipes in producing more plants and a greater dry-weight of plant material at the optimum pH level, individual plants weighed least at this level.

Table 1. The effect of pH and nitrogen level on Eichhornia crassipes and Pistia stratiotes as measured by i) mean number of plants harvested (as $\sqrt{\ }$); ii) mean total dry-weight (log decigrams); iii) mean dry-weight per plant (log centigrams).

			Nitrogen level (ppm)		
	pH		1	5	25
Eichhornia crassipes	4.0	i)	1.494	1.573	1.720
		ii)	1.1411	1.1983	1.2311
		iii)	1.7961	1.8093	1.7668
	5.5	i)	1.470	1.549	1.720
		ii)	1.1342	1.1392	1.2490
		iii)	1.8204	1.5312	1.7846
	7.0	i)	1.573	1.720	1.933
		ii)	1.1857	1.3903	1.5275
		iii)	1.7967	1.9255	1.9561
Pistia stratiotes	4.0	i)	2.738	3.107	3.564
		ii)	0.9226	0.9613	1.0797
		iii)	1.0627	0.9813	1.0131
	5.5	i)	2.110	2.494	2.780
		ii)	0.5127	0.8477	0.9372
		iii)	0.8692	1.0560	1.0504
	7.0	i)	2.284	2.441	2.574
		ii)	0.8082	0.8330	0.9265
		iii)	1.0939	1.0608	1.1127

l.s.d. ($P = 0.05$) i) = 0.552
ii) = 0.0799
iii) = 0.2783

DISCUSSION

From these results emerge not only data on the response of Eichhornia crassipes and Pistia stratiotes to variations in pH and nitrogen concentration of the substrate; there is also an indication of some of the reasons for the success of E. crassipes, relative to P. stratiotes, in the Sudanese Nile.

In most stretches of the White Nile, where E. crassipes is most abundant, the pH is usually 7.0 or above. Water hyacinth, with its higher pH optimum, seems better suited to growth in this substrate than water lettuce. Furthermore, in the Bahr el Ghazal, where the pH of the river water does fall well below 7.0, the water hyacinth is notably less prolific than in the White Nile itself.

Other studies (Parija 1934) have also shown that E. crassipes has a pH optimum near neutral. Parija (1934) found that growth of the species, measured by immersion of the plant material and recording displacement, was over three-times as great in a solution of pH 7.0 - 7.5 as in a solution of pH 4.0 - 5.0. Minshall and Scarth (1952) record an adverse effect of high concentrations of hydrogen ions on the root cells of water hyacinth.

The present studies have also indicated a considerable difference in the behaviour of Eichhornia crassipes and Pistia stratiotes when growing under their respective optimum conditions. E. crassipes responds by producing both more and larger plants under such conditions. P. stratiotes also produces a greater weight of plant material under optimum conditions but this is achieved by producing a large number of smaller plants. This difference in reaction can be interpreted in two ways. Either this is a general response on the part of P. stratiotes which would occurr under natural conditions or, as is more likely, it is an indication that conditions of "crowding", as experienced in the pot, have a severer effect on individual plant size in P. stratiotes than in E. crassipes. If this is so it would suggest that P. stratiotes is more sensitive to interference effects than E. crassipes. It is interesting in this connection that Parija (1934) states, "When Pistia is allowed to grow separately it spreads more quickly than water-hyacinth; but in nature water-hyacinth kills the Pistia by its luxuriant vegetable growth". In terms of the results presented above these two observations are not so conflicting as, at first, they may appear. Apparently P. stratiotes spreads quickly, often by the production of many small plants but these are neither large enough or vigorous enough to compete successfully with the plants produced by E. crassipes.

References

ANONYMOUS (1957) Eichhornia crassipes. Scientific Council for Africa South of the Sahara, publication no. 27.

BISHAI, H.M. (1960) Effect of Eichhornia crassipes on the hydrobiology of the Nile water. Annual Report of the Hydrobiological Research Unit, University of Khartoum, 1959-60, 2-3.

BRADSHAW, A.D., LODGE, R.W., JOWETT, D.& CHADWICK, M.J. (1960) Experimental investigations into the mineral nutrition of several grass species. II pH and calcium level. J. Ecol. 48, 143-50.

CHADWICK, M.J. (1961) Some observations on the ecology of Eichhornia crassipes Solms. Annual Report of the Hydrobiological Research Unit, University of Khartoum, 1960-61, 23-8.

CHADWICK, M.J. & OBEID, MOHAMMED (1963) The response to variations in nitrogen level of some weed species of the Sudan. Weed Res. 3, 230-41.

DAVIES, H.R.J. (1959) Effects of the water hyacinth (Eichhornia crassipes) in the Nile valley. Nature, Lond. 184, 1085-6.

GAY, P.A. (1958a) Eichhornia crassipes in the Nile of the Sudan. Nature, Lond. 182, 538.

GAY, P.A. (1958b) The riverain flora of the Nile. Annual Report of the Hydrobiological Research Unit, University of Khartoum, 1957-58, 7-15.

GAY, P.A. (1960) Ecological studies of Eichhornia crassipes Solms, in the Sudan. J. Ecol. 48, 183-91.

GAY, P.A. & BERRY, L. (1959) The water hyacinth: a new problem on the Nile. Geogr. J. 125, 89.

GRONBLAD, R., PROWSE, G.A. & SCOTT, A.M. (1958) Sudanese desmids. Acta bot. fenn. 58, 1-82.

HEWITT, E.J. (1952) Sand and Water Culture Methods Used in the Study of Plant Nutrition. Commonwealth Agricultural Bureau, Reading.

MINSHALL, W.H. & SCARTH, G.W. (1952) Effect of growth in acid media on the morphology, hydrogen-ion concentration, viscosity and permeability of water hyacinth and frogbit root cells. Can. J. Bot. 32, 188-208.

OBEID, MOHAMMED (1962) An Investigation into the Mineral Nutrition of Some Common Weed Species in the Sudan. M.Sc. thesis, Univ. of Khartoum.

PARIJA, P. (1934) Physiological investigations on water-hyacinth (Eichhornia crassipes) in Orissa with notes on some other aquatic weeds. Indian J. agric. Sci. 4, 399-429.

TACKHOLM, V. & DRAR, MOHAMMED (1950) Flora of Egypt, Vol. II. Fouad I University Press, Cairo.

TALLING, J.F. (1957) The longitudinal succession of water characterstics in the White Nile. Hydrobiologia 11, 73-89.

THE BIOLOGY OF CIRSIUM ARVENSE (L.) SCOP.

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Summary Some aspects of the biology of Cirsium arvense (creeping thistle) are reviewed. Regeneration of the subterranean system and the annual growth cycle are described.

INTRODUCTION

Perennial plants provide the most intractable of weeds both to cultural and chemical control. The ability of many to regenerate from fragments makes them tolerant of, or even dependant upon cultivation; their response to herbicides is highly erratic. A knowledge of the biology of a weed is often a necessary preliminary to success in its control and it is therefore surprising to find that extremely little attention has been paid to the biology of creeping thistle by British workers. An outstanding contribution to our knowledge of this species has been made by Professor Bakker (1960) as a result of studies in the newly reclaimed polders of the Netherlands but this work does not appear to be well known in Britain.

Brenchley (1920) discussing the association of weeds and arable soils states "It occurred on 73% of the fields examined and in 125 of these i.e. 11% it was the chief and dominant weed holding the worst record of all weeds in this respect". Such was its record in arable land where perhaps it has declined since Miss Brenchley's survey. Weeds which show this degree of success in arable land might reasonably be expected to be less well adapted to grasslands. C. arvense appears to be a singular exception for its success as a weed of grassland needs no emphasis. It is therefore pertinent to try to understand the qualities of this perennial plant which give it such potential versatility as a weed.

The seeds and seedlings

There is disagreement on the importance of seed in establishing stands of C. arvense. The initial invasion of the Zuider Zee by the weed appears to have been exclusively by seed (Bakker 1960) and seedlings are easy to raise. Despite these observations there is a general belief that the establishment of an infestation by seed invasion is rare (Salisbury 1961). Sterile capitula are frequently observed, perhaps in part because the plants are either functionally male or female and whole isolated clones derived from one seed will be unable to set seed. Examination of thistle down in transit leads to the belief that the species is entirely sterile, because the pappus normally leaves the achene in the capitulum and blows away by itself. Viable seed is, however, commonly produced although there is evidence that suggests that the distance over which the seed is spread by wind is restricted because of the characteristic loss of the pappus.

Bakker (1960) reviewed some of the literature on the dormancy characteristics of the seed and found it contradictory. Niethammer (1943) and Buchli (1936) claimed that the seed of C. arvense had a dormancy period whereas Hayden (1934) and Kolk (1947) reported either no dormancy or very little.

Bakker himself found that between 7 and 20% of the seed was capable of germinating immediately after harvest but that three to six months of storage were necessary before all the viable seed was capable of immediate germination. Similar disagreement is found when the viability and longevity of the seed is considered. Hayden (1943) recorded a range of viability between 10 and 95% for different samples and Bakker (1960) reported maximum viabilities just below 50%. Under air dry conditions and in the top centimetre of soil, seed had lost its viability within 30 months (Bakker 1960). Bruns and Rasmussen (1953 and 1957) showed that seed stored under running water remained viable for 22 months but not for 54. Bakker's results under similar conditions showed that viability was fully maintained for at least 30 months as it was when the seed was stored 40 cm deep in soil. It is perhaps strange that Toole and Brown (1946) found 5% viability after 21 years of storage for the evidence of Chippindale and Milton (1934) would suggest that viability is not retained for very long under grassland conditions when the seed is buried.

Under the condition of Bakker's experiment those seeds which germinated in the autumn of the year of their production produced seedlings which failed to survive the following winter; but the majority of the seeds which were initially dormant germinated in the following April and May and produced an organ of vegetative reproduction before the onset of winter. Seeds are therefore probably a significant means of local multiplication; but the species would seem to rely on a means of transportation other than wind for long distance dispersal.

Vegetative development and reproduction

Bakker (1960) described the development of the seedling plant and showed that under favourable conditions horizontal roots and aerial shoots grew out from the primary root within six to eight weeks of germination. Thus seedling thistles could readily be expected to produce a potentially perennial system within the life of a spring sown annual crop as well as in a more permanent agricultural system.

The underground system of C. arvense is complex. Three types of organs are readily distinguished:

(a) roots - root-like structures 1-3 mm diam. with typical endarch vascular arrangement.

(b) roots - non-typical thickened structures 0.5 - 1.5 cm diam. which on morphological and anatomical evidence could not be identified as roots or shoots and whose origin was subsequently confirmed only by following their production and development.

(c) subterranean shoots bearing stem apices at or below ground level and readily identified by the possession of scale leaves and typical stem anatomy.

Samples of organs (b) and (c) were taken from a field at Aber, N. Wales in November 1962. No apices were present on the thickened roots at this time - each piece terminating in a rotting zone. The regeneration potential of the thickened roots and of the subterranean shoots was studied in the laboratory, the most successful regeneration being obtained by placing units of five to six cm length in petri-dishes lined both above and below by filter paper. Very little regeneration occured from the November sample. The experiment was repeated in December and a variety of chemical treatments were applied. Table 1 records the results of this experiment.

Table 1

Total number of shoots produced per 3×6 cm segments

Chemical Supplied	Test Material	Days after 'planting' 5	7	9	11	17	25	35
WATER	Stem (c)	0	0	0	0	1	1	1
	Root (b)	0	1	1	1	2	2	3
GA 10^{-3}M	Stem (c)	1	2	3	5	5	6	7
	Root (b)	1	1	1	1	1	2	3
GA 10^{-4}M	Stem (c)	2	3	3	6	6	7	9
	Root (b)	3	6	6	7	7	7	8
Sucrose 1%	Stem (c)	1	1	2	2	4	4	6
	Root (b)	5	5	7	8	8	10	12
KNO_3	Stem (c)	3	4	6	7	8	9	11
	Root (b)	3	3	3	3	4	5	5

All the applied chemicals stimulated the growth of shoots from the fragments. New shoots arose from shoot fragments in the axils of the scale leaves, but on the swollen roots, there was no apparent order or arrangement of the adventitious shoots. The speed with which some of the buds appeared (within 5 days) suggests that they had been initiated before the segments were taken from the field and that laboratory conditions had simply hastened their growth.

It is not without agronomic significance that Prentiss (1889) found that five out of 36 fragments of roots 0.3–0.6 cm in diameter and 0.6 cm long produced aerial shoots and that all 24 segments of similar roots but 2.5 cm long produced shoots. Hodgson (1964) recorded ecotypic differences in the rate at which root segments of C. arvense produced emerged shoots.

In the present study, C. arvense was grown from seed and from regenerating fragments, and an attempt made to follow the development of the subterranean system in situ. Two methods were used. In the first, seedlings and regenerating root fragments were transplanted into glass sided boxes from which light was normally excluded and the development of the subterranean systems against the glass was observed. The second method consisted of growing seedlings or regenerating fragments in water culture.

Using the first of these techniques, it was clear that the development of the seedling was similar to that described by Bakker (1960); within ten weeks the seedlings had, in most cases, produced a deep tap root with many short laterals. The first adventitious shoot buds arose from the main root ca. 8 cm below the soil surface and subsequently the thickened roots were produced.

Fig. 1 shows the development from a 20 cm long root segment sampled from the field in December and grown for 12 weeks in John Innes no. 1 compost. Two new shoots arose from the root segment and these produced aerial shoots and new roots. These roots which were initially of type (a) showed positive geotropism to varying degrees, but grew generally downward.

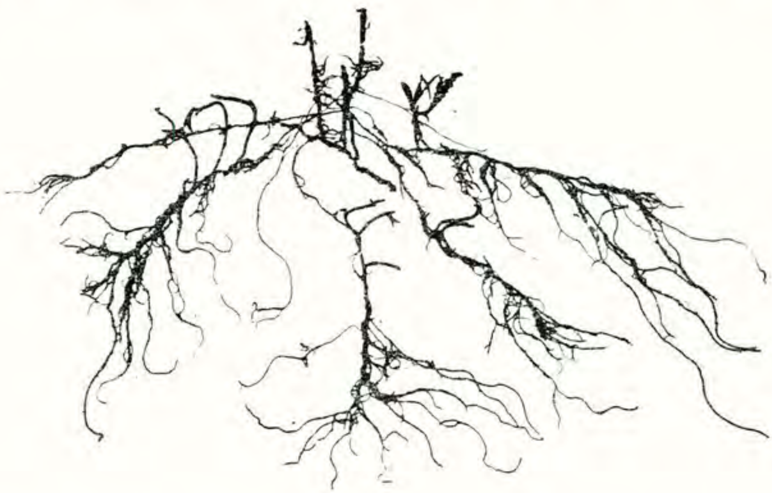

Fig. 1.

A photograph of the subterranean system produced by a segment of swollen root 12 weeks after the segment was planted in the soil. Note the new shoots which arose on the roots and the thickening of those parts of the root which produced the shoots.

After seven weeks, shoots began to form along certain regions of some of these secondary roots. The depth at which this vegetative reproduction took place was variable, but whenever it occurred the whole character of the root changed. Close inspection of Fig. 1. shows that the roots leaving the new shoot are thin, but from the point where the first new shoot arose, the root is obviously thickened, and along this thickened region, further regeneration occurred.

The glass sided boxes had their limitations since many of the roots did not grow against the glass face. Accordingly ten week old seedlings of thistle were transferred to glass containers filled with tap water.

A consequence of the transfer was the loss of all root tips and new laterals were developed at intervals along the length of the main root. In the outer angle of a number of these new lateral roots a shoot arose (Fig. 2). New shoots did not form in any other morphological position on the main root. This pattern of distribution of adventitious shoots was not found on roots growing from regenerating fragments. The restriction of shoots to the axils of roots is reminiscent of the behaviour of the potato reported by Booth (1963) where stolons were produced only after a root had appeared on the stem.

Fig. 2. Shoot production by a root system

The seedling was transferred to water culture and following the death of root apices new roots arose followed by shoots (arrowed) in their obtuse angles.

The development of Cirsium arvense and its growth cycle

The record of the growth cycle which follows is based on a series of excavations made during 1962 and 1963 on a population of C. arvense established in an undisturbed open community at Treborth, Bangor, N. Wales.

After germination a pair of cotyledons are produced on an axis about one cm above the soil surface and the primary root grows vertically downward.

Some weeks later, adventitious buds arise on the main root and these shoots grow to the surface from depths in the soil between one and 60 cm. In the same season, some parts of some of the roots become thickened and from these regions arise new shoots which grow to the surface and after a period of apparent dependence upon the parent, they become self supporting. The thickening of the roots is due to the production of a quantity of storage parenchyma within the stele, and by the end of the season, they may be up to 1.5 cm in diameter. In late summer, flowering occurs, and the products of assimilation pass downwards into the parenchyma tissues of the underground roots (See Fig 3).

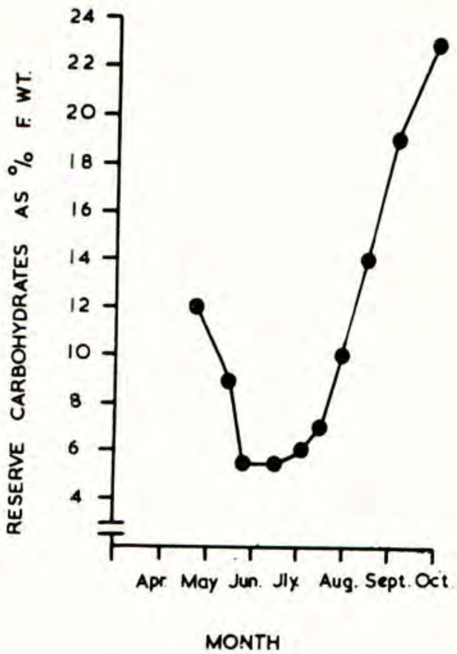

Fig. 3

The changes from April to October in the level of reserve carbohydrates in the subterranean organs of C. arvense (from Bakker, 1960 by permission of Blackwell Scientific Publications Ltd.)

Following this, some of the organs below ground rot and disappear. This loss of material results in the complete independence of progeny which together had constituted an interlinked unit. Accordingly, the thistle examined in autumn and early winter is represented by those organs which are resistant to breakdown in the soil, these being the swollen roots, together

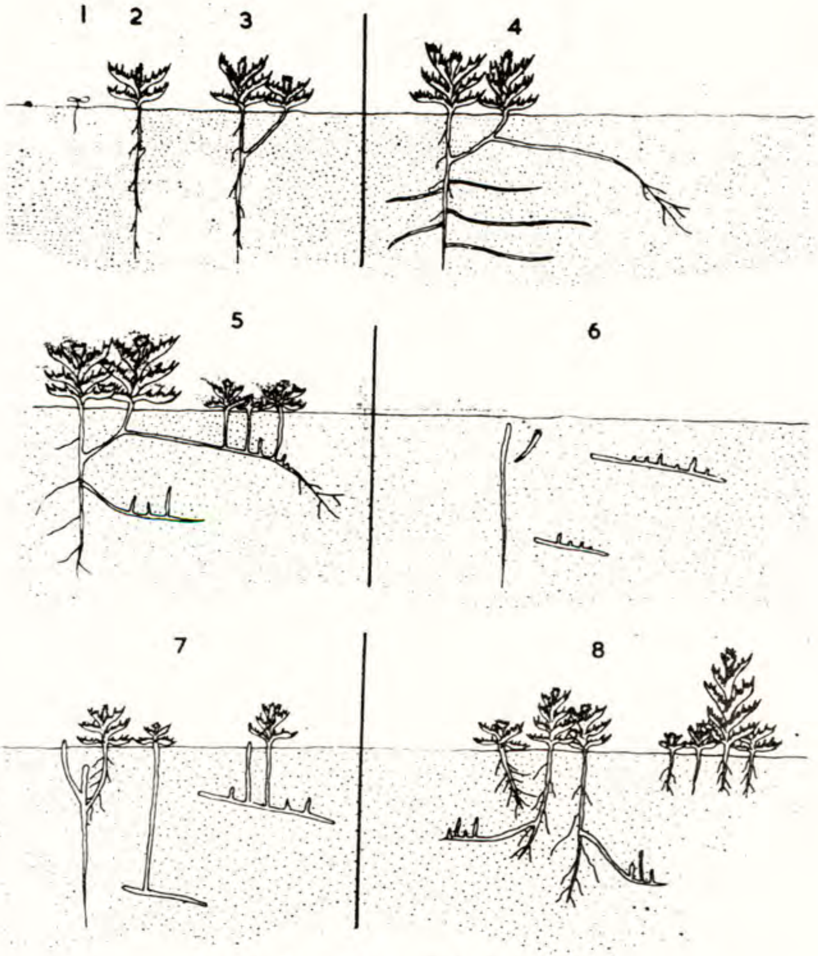

Fig. 4 The Development of C. arvense.

1. Seedling; 2. Tap root produced; 3. New aerial shoot arises from tap root; 4. ± horizontal roots produced from both the old tap root and from the stem of the new shoot; 5. New shoots arise from the horizontal roots; 6. The overwintering condition of plant 5, no aerial parts. Note the decay of old roots and shoots; 7. Spring regrowth from situation 6; 8. Late summer condition of stage 7 (the new horizontal roots have been omitted for clarity)

with a small number of stems, which have arisen from them. In spring the shoots produced by the storage roots in the previous autumn grow to the surface of the soil and establish the new aerial system. New adventitious roots then arise from these stems and parts of these swell and form perennating organs for the following year. The storage roots appear to persist for a little over 12 months, and having produced a flush of new shoots, they disappear. Fig. 4 illustrates this growth cycle diagramatically.

DISCUSSION

Like the majority of perennial plants with ramifying subterranean systems, the control of Cirsium arvense, both by cultural and chemical means, has been unreliable. Regeneration is possible from fragments both of underground stem tissue and from the 'swollen' roots. In consequence, a ploughing or other cultivation treatment which results in the break up of the subterranean system is likely to be followed by regeneration. Pavlychenko et al (1940) record rooting to a depth of 2.5 m and Salisbury (1961) quotes a maximum rooting depth of almost 5.5 m. Although the regenerative organs may not reach these depths it is clear that they do frequently lie below the depth of cultivation. This feature allied to the extent of radial spread - figures of 6 to 12 m are quoted by Salisbury (1961) - helps to make the plant a classic perennial weed.

It must be remembered that most of the subterranean system is root and how far the hypotheses which have been developed to account for the translocation of herbicides in rhizomatous systems may be extrapolated to a system which is root is perhaps an open question.

Both in cultural and chemical control, there is strong evidence (Woodford and Evans 1963) that the plant is most vulnerable at or just before the buds of the capitula become coloured. This is difficult to interpret, for it seems a general rule that translocated growth substances applied to the upper leaves of a plant at flowering, move predominantly towards the flowers. Bakker (1960) has shown that the storage reserves of the thistle are minimal between the beginning of May and the middle of July; but subsequently the underground carbohydrate stores increase extremely rapidly (Fig. 3). Since C. arvense flowers during July, August and September the inference is that flowering and the accumulation of reserves may be synchronous, although Arny (1932) showed that the time of minimum carbohydrate reserves actually co-incided with flowering. Nevertheless it may be argued that whereas cultural control measures might be expected to be most successful when food reserves are minimal (e.g. the time of bud colouring), this is not necessarily the time for optimal downward translocation of a herbicide. Herbicides used at the wrong time on a perennial weed may well have an effect like a scythe, stimulating rather than weakening regeneration. Post-flowering application may prove successful. These questions now need answering - for the life cycle of this plant as now exposed would seem to possess critical Achilles heels. In particular (and in marked contrast with bracken) the perennating organs are relatively short lived and if herbicide application can be accurately timed to coincide with the mass downward flow of assimilates - good control may well be possible.

Acknowledgments

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References

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

BAKKER, D. (1960) A comparative life-history of *Cirsium arvense* (L.) and *Tussilago farfara* L., the most troublesome weeds of the newly reclaimed polders of the former Zuiderzee. In J.L. Harper (ed.) "The Biology of Weeds" Oxford, 205-202.

BOOTH, A. (1963) The role of growth substances in the development of stolons. In Ivins and Milthorpe (eds.) "The Growth of the Potato", London, 99-113.

BRENCHLEY, W.E. (1920) "Weeds of Farmland", London.

BRUNS, V.F. and RASMUSSEN, L.W. (1953) The effects of fresh water storage on the germination of certain weed seeds. I. White top, Russian knapweed, Canada thistle, morning glory and poverty weed. Weeds 2, 138-147.

BRUNS, V.F. and RASMUSSEN, L.W. (1957) The effects of fresh water storage on the germination of certain weed seeds. II White top, Russian knapweed, Canada thistle, morning glory and poverty weed. Weeds 5, 20-24.

BUCHLI, M. (1936) "Ökologie der Ackerunkräuter der Nordostschweiz". Berne

CHIPPINDALE, H.G. and MILTON, W.E.J. (1934) On the viable seeds present in the soil beneath pastures. J. Ecol. 22, 508-531.

HAYDEN, A. (1934) Distribution and reproduction of Canada thistle in Iowa. Amer. J. Bot. 21, 355-373.

HODGSON, J.M. (1964) Variations in ecotypes in Canada thistle. Weeds, 12, 167-171.

KOLK, H. (1947) Groningsbiologiska studier på ogräsarter. Vaxtodling, 2, 108-167.

NIETHAMMER, A. (1934) Licht, dunkelheit und strahlung als factoren bei der samenkeimung. Tab. Biol. 4, 40-61.

PAVLYCHENKO, T.K., KIRK, L.E., and KOSSAR, W. (1940) Eradication of perennial weeds by the shallow cultivation method. Univ. Saskatchewan Col. Agr., Agr. Ext. Bull. 100, 1-8

PRENTISS, A.N. (1889) On root-propagation of Canada thistle. Cornell Univ. Agr. Expt. Sta. Bull. 15, 190-192.

ROGERS, C. (1928) Canada thistle and Russian knapweed and their control. Colorado Agr. Coll. Exp. Sta. Bull. 348.

SALISBURY, E.J. (1961) "Weeds and aliens", London.

TOOLE, E.H. and BROWN, E. (1946) Final results of the Duvel buried seed experiments. J. Agric. Res. 72, 201-210.

WOODFORD, E.K. and EVANS, S.A. (Eds.) (1963) "Weed Control Handbook" (Ed. 3); Oxford.

CHONDRILLA JUNCEA L. (SKELETON WEED) IN AUSTRALIA

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Summary The distributions of *Chondrilla juncea* in Europe and Australia are described. Aspects of its biology are discussed with particular reference to the capacity of roots to regenerate after cutting. Reference is made to experiments in which the short term inhibition of growth by herbicides of the chlorinated phenoxyacetic acid type has been used to alleviate the effects of the weed in cereal crops. A field experiment is described comparing a grass and a clover in reducing Chondrilla numbers.

INTRODUCTION

Chondrilla juncea L., a composite, was introduced accidently into Australia in 1914 at Marrar on the Southwestern Slopes of New South Wales. By 1930 it was a serious threat to wheat growing in the southern and central wheat growing areas of that state.

The first records of Chondrilla in Victoria and South Australia were in 1946, and since then it has been found in all mainland States, the latest record being from Western Australia where a small patch was found south of Geraldton in 1963.

Assuming that the Australian population has arisen from a single introduction, then the plant has spread 800 miles in the forty years to 1954, and an equal distance in the last ten. The weed is now well established on all but the heaviest textured clay soils of the wheat growing areas of New South Wales, Victoria and South Australia.

DISTRIBUTION

In Australia Chondrilla is found on soils ranging from pH 4.5 to 8.0, but in Europe it appears to be confined largely to those with calcareous parent materials. The greatest densities in Australia are found on light textured soils.

Chondrilla appears to be adapted to a wide range of climates but optimally to semi-arid and Mediterranean types. In Australia it occurs in localities with annual rainfalls from nine to sixty inches. McVean (1964) found that the limits of distribution in south-eastern Australia are within the isotherm for a mean minimum of 40°F from April to July. This is seemingly in agreement with the findings of Ballard (1956) and Cuthbertson (1963) that Chondrilla requires a period at low temperatures for flower induction. There is also a low temperature-long day interaction which as yet has not been fully resolved.

The centre of distribution of Chondrilla juncea in Europe appears to be the Balkans, but it has been collected as far north as the Netherlands. The latitudinal spread in Europe is between 25 and 53°N and in Australia from 27 to 37°S.

VARIABILITY

Russian workers have described Chondrilla juncea as an obligate apomict and McVean (1964) has confirmed that Australian plants will set viable seed even in the absence of the stimulus of pollination. Morphological variability within the Australian population is slight, and seemingly the present distribution is from a single introduction.

Plants grown in Australia from seed collected in Europe and in the United States show a considerable degree of morphological variability. Differences in seedling establishment and growth rate have been found between material of local and Cyprus provenance suggesting that there are also physiological differences among populations. Both morphological and physiological variability of Australian and European plants are being studied under controlled conditions at Canberra.

GERMINATION AND ESTABLISHMENT

Chondrilla juncea has a fluted non-endospermous seed attached to a pappus. Cuthbertson (1963) and Ballard (1964) found that morphologically mature seeds have no dormancy and germinate rapidly at temperatures from 10 to 37°C. Storage tests indicate that viability may be lost within three to four years.

McVean (1964) found that the maximum depth from which seedlings could emerge in a medium textured soil was one inch, and Cuthbertson (1963) obtained no emergence below three-quarters of an inch in heavy textured clays.

The radicle extends rapidly and in cultivated soils may penetrate to three or four inches while the seedling is still in the cotyledon stage. In a study of the mineral requirements of seedlings, McVean found that the growth rate and establishment were poor on Mallee dune sands. There was, however, a marked response to phosphorus suggesting that the heavy infestation in the Mallee may be due in part to the use of superphosphate in wheat growing.

GROWTH CYCLE

Chondrilla commences growth in early autumn by forming a rosette of leaves on the soil surface. The leaves increase in size and number during the winter and early spring and a single flower stalk is produced in early October at latitude 35°S. The almost leafless flower stalks branch in early summer and flowering begins in December continuing throughout the summer.

As seeds mature the basal rosette of leaves senesces, but flower stalks remain green until autumn. New rosettes are formed in response to cultivation at any time of the year.

The plant is well adapted to wheat-fallow-wheat farming and plant densities are greatest on cultivated land, road sides and other places subject to repeated disturbance. Once established Chondrilla has early access to nitrogen mineralised in the soil during late summer and early autumn. The significance of competition between Chondrilla and wheat seedlings for nitrogen and its effects on wheat yields have been indicated by Greenham (1943) and Myers et al (1958).

Continual cultivation of fields containing patches of Chondrilla will result eventually in a complete infestation. In Australia paddocks may have 7 rosettes per $ft.^2$ distributed more or less regularly over 2-300 acres.

In countries in which it is native Chondrilla is not regarded as a weed of any significance. According to McVean the plant is generally a ruderal in Europe and only in Greece did he find it in crop stubbles.

In European floras Chondrilla juncea is described as biennial. In Australia it is deep rooted and there seems little doubt of its perenniality under conditions of disturbance. However, little is known of its biology in the absence of any form of disturbance.

ROOT SYSTEM

The root system is generally a simple tap root, but in Mallee sand it may also form horizontal roots. Excavated roots cut three feet below the soil surface have produced stems which have grown through to the surface after replacement of the soil. The capacity of Chondrilla roots to generate stem buds and ways in which bud formation may be inhibited are under study at Canberra. Preliminary experiments of Kefford (1964) showed that 36 days from germination excised roots averaging 18cm in length regenerated and produced an average of 5.8 buds per root after 21 days at 25°C in darkness. Under the same conditions 17 day old rootlets averaging 16cm in length failed to produce stem buds when excised. Distance from the root apex had no effect on the regeneration of 4cm sections excised from 50 day old roots. All sections regenerated and produced approximately 3 buds per section. Root segments as small as 2cm produced 3 buds. Buds were always formed at the end away from the root apex.

It has been found that bud formation is inhibited by increasing the auxin status. The most effective chemical used has been 24-D which at a concentration of 10^{-5}M completely prevented bud formation on 4cm root sections.

CHEMICAL CONTROL

Several phenoxyacetic acid compounds applied at a number of concentrations and growth stages were without permanent effects on densities of Chondrilla populations more than six months old.

Time of spraying had a small but significant effect only in the year following treatment. Spraying at or just before flower stem initiation reduced densities for longer periods than treatment with similar compounds at any other stage of growth. The effects of chemical treatments on densities seldom persisted for more than twelve months.

The effects on yields of spraying cereal crops in spring have been variable. Sometimes yields of sprayed have been greater than unsprayed plots but on other occasions the effects of spraying have been most evident in crops sown the following year. These latter results have been attributed to reductions in the numbers of Chondrilla rosettes among wheat seedlings in autumn as consequences of sprays in the preceding springs. Myers et al (1958) similarly reduced weed numbers in newly established wheat and obtained increases in grain yields by spraying Chondrilla in the fallow several weeks before sowing.

Dosages of phenoxyacetic acid compounds as low as 2oz/ac a.e. applied in spring at flower stalk emergence have prevented interference to harvesting by the tough latex-bearing flower stems of Chondrilla.

Parsons (1963) found that there was no regeneration of Chondrilla three years after treatment with 24lb/ac TBA. At 12lb/ac there was a 6% regeneration.

CONTROL BY COMPETITION

Because of its growth habit Chondrilla is vulnerable to shading by cool season annuals and this probably accounts for its occurrence on frequently cropped and other habitats low in soil nitrogen. Cool season legumes seemingly offered possibilities for altering such favourable environments because of their independence of nitrogen already in the soil. Field experiments have shown that Trifolium subterraneum L. in some localities is an effective competitor with Chondrilla.

In an experiment at Cowra, New South Wales, changes in Chondrilla populations oversown with a grass and a clover singly and in combination were followed by counting numbers of rosettes on each plot in the spring when rosette densities are at a maximum. A few of the data are shown in Table 1.

Table 1.

Effects on grass and clover singly and in combination on densities of Chondrilla juncea L. Means of six replicates

Treatments	Rosette densities % of unsown After 1 yr	2 yr	3 yr
Lolium rigidum	111	94	84
Trifolium subterraneum	78	36	39
Lolium and Trifolium	85	47	49
Unsown No/lk$_2$	7.6	8.5	7.6

Trifolium was the more effective competitor and in four years reduced the dry weight of aboveground parts of Chondrilla by 80% relative to the unsown control. The corresponding reductions by Lolium and Lolium-Trifolium were 3 and 43% respectively.

The final outcome of repeated clover-cultivation-wheat cycles could not be shown experimentally but there is evidence from farms using the ley system that Chondrilla is eradicated after two or three cycles.

More detailed experimental analyses of Trifolium-Chondrilla competition are in progress at C.S.I.R.O. in Canberra.

CONCLUSION

An effective way of reducing the effects of Chondrilla in cereal farming is by oversowing with cool season legumes such as Trifolium subterraneum. In environments to which it is suited clover reduces Chondrilla numbers and increases levels of nitrogen available to succeeding crops. In the Cowra experiment quoted the levels of nitrate-nitrogen in the top four inches of soil averaged 22 ppm on the unsown controls and 48 ppm on plots with clover. Increasing soil nitrogen modifies one, and perhaps the most important, factor in competition between Chondrilla and cereals.

The growth of legumes presently available in Australia is too poor to provide effective competition against Chondrilla in many of the places in which it is a weed problem. There is still a need for non-residual chemicals particularly for new outbreak areas such as in Western Australia. The failure of phenoxyacetic acid compounds to translocate sufficiently to prevent regeneration from roots has initiated a new approach by C.S.I.R.O. at Canberra where the processes of bud formation are being studied with a view to their control by otherwise non toxic chemicals.

References

BALLARD, L.A.T. (1956) Flowering of Skeleton Weed. J. Aust. Instit. Agric. Sci. 22, 57-61.

CUTHBERTSON, E.G. (1963) Private communication

GREENHAM, C.G. (1943) The Effect of Skeleton Weed on Wheat. J. Coun. Sci. Ind. Res. 16, 142-148.

KEFFORD, N.P. (1964) Private communication

McVEAN, D.N. (1964) Private communication

MOORE, R.M. and ROBERTSON, J.A. (1961) Studies on Skeleton Weed. Chemical Control. Field Sta. Rec. 1.

MOORE, R.M. and ROBERTSON, J.A. (1963) Studies on Skeleton Weed. Control by Competition. Field Sta. Rec. 3.

PARSONS, W.T. (1963) Private communication

A COMPETITION STUDY OF CARDARIA spp. AND CENTAUREA REPENS[1]

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Summary A 7-year ecological study of natural infestations of *Cardaria pubescens*, *C. chalapensis*, and Russian knapweed (*Centaurea repens*) was conducted under conditions of irrigation and dry land farming in southern Saskatchewan. Density and area measurements were compared annually in competition with grasses, forbs and shrubs in several environments. The *Cardarias* were well adapted to moist situations but were not to dry, semi-arid environments. *C. pubescens* was better able to survive drought than *C. chalapensis*. *Centaurea repens* was most vigorous in semi-arid as opposed to moist environments. Shrubs were the most effective native competitors of the weeds. Alfalfa, bromegrass, and crested wheatgrass were also effective. Control by cultural and chemical means is shown to be feasible.

INTRODUCTION

Certain perennial weeds introduced from Europe, for example, *Euphorbia esula*, *Linaria vulgaris*, the hoary cresses (*Cardaria* spp.), and *Centaurea repens* are so tenacious in western Canada that they are referred to as "persistent perennials". Infestations in western Canada are believed to approximate 220,000 acres.

Heart-podded hoary cress was introduced to western Canada from Europe, whereas the lens- and globe-podded species and Russian knapweed (*Centaurea repens* L.) were introduced from the Turkestan area of western Asia (Groh, 1940 a,b).

It was the purpose of this study to assess the vigour and competitive ability of the hoary cresses (*C. chalapensis* (L.) Hand.-Mzt.) and *C. pubescens* (Meyer) (Jarmolenko) (Mulligan, *et al*., 1962) and Russian knapweed under conditions of irrigation and dryland farming in competition with various plant species.

METHODS AND DESCRIPTION OF THE AREA

Reported to have been introduced to southern Saskatchewan in Turkestan alfalfa at Glen Kerr and as a contaminant of horse-feed at Leader in the early 1900's, *Cardaria* spp. and Russian knapweed were abundant in brome and alfalfa fields, and present in other areas of disturbance e.g. gardens, feed lots, water courses and irrigation ditches. In both study areas, native vegetation was dominated by the perennial western wheatgrass

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(*Agropyron smithii*) on flood plains, and at Glen Kerr was interspersed with the shrubs *Artemisia cana*, *Sarcobatus vermiculatus* and the half-shrub, *Atriplex nuttallii*.

The same species of grass were present at Leader, but the shrubs were predominantly *Rosa* spp. and *Symphoricarpos occidentalis*. Occasionally natural precipitation was augmented by flooding (about once in 10 years), when the South Saskatchewan River overflowed its banks. The mean annual precipitation was approximately 13 in. at Glen Kerr and 12 in. at Leader since 1925. During 1951-1956, better-than-average moisture conditions prevailed. During the last 3 years of the study, however, precipitation was 15% below average.

Fifteen study sites were established, at the locations Leader and Glen Kerr, in various habitats representing irrigation and dry land farming. A description of the sites is presented in Table 1. Posts spaced at 5 m intervals provided the basis for a grid system of plots, each plot being 5 m square.

Table 1

Site description of Russian knapweed and Cardaria spp.infestations

Study Area Number	Location	Size of exclosure (m)	*Cardaria* species	Past land use	Number of m^2 Quadrats
1	Leader	4x4	-	Abandoned, reseeded	4
2A	Leader)	100x100	*C. pubescens*	Abandoned, regrassed	6
2B	Leader)		*C. pubescens*	Abandoned	5
3	Leader*	75x100	*C. chalapensis*	Abandoned, reseeded	13
4	Leader (line transect)		*C. pubescens*	Abandoned, reseeded	0
5	Leader	10x15	-	Abandoned, reseeded	8
1A	Glen Kerr)	100x100	*C. pubescens*	Native grassland	10
1B	Glen Kerr)		*C. pubescens*	Abandoned, reseeded	4
2	Glen Kerr	10x15	-	Native grassland	10
3A	Glen Kerr)	50x50	*C. pubescens*	Abandoned, reseeded	4
3B	Glen Kerr)		*C. pubescens*	Abandoned, reseeded, (mowed annually)	4
4	Glen Kerr	15x30	-	Native grassland	16
5	Glen Kerr (line transect)		*C. pubescens* *C. chalapensis*	Native grassland	0

*Study area not infested with Russian knapweed

The perimeters of cress patches were charted in the plots and comparisons made annually (involving a total of approximately 2,000 measurements) to determine any changes in the infested area. The annual change in area infested was also measured at two locations with line transects.

Densities of Cardaria and competing species were recorded in a total of 670 permanent quadrats, each 1 m^2. The numbers of forbs and shrubs were counted, and the point transect method (200 points) was used to determine the % basal cover of grasses in each quadrat.

Germination studies, using petri-plates, vermiculite and filter paper, were conducted in the laboratory to determine the effects of temp. on germination and to test longevity of the seed stored at room temp. Five samples of 500 seeds (two years old) were germinated at three temp. levels; 10°, 24° and 32°C and various combinations of them during an incubation period of 13 days. The % germination of seed of various ages was also tested.

The response of lens-podded cress was observed on sandy-loam soil near Saskatoon when subjected to a control program of 1) alternate summerfallow and cropping, 2) competition from a mixture of alfalfa and crested wheatgrass, and 3) repeated applications of 2,4-dichlorophenoxyacetic acid (2,4-D).

RESULTS

Distribution

River erosion was extensive where infestations of hoary cresses and Russian knapweed were present, and in 1953 the South Saskatchewan River eroded into its bank by more than 100 ft. Whole plants of globe-podded cress and knapweed were observed being transported by the current of the river. Patches of knapweed were situated downstream from this main infestation, on a periodically-flooded sandy shore in isolated clones or among Salix spp.

The erosion of the river bank also provided an unusual opportunity for examination of the root systems. The roots of globe-podded cress were traced vertically to a depth of 18.5 ft, and knapweed at 19.5 ft, at which depths the rootlets became too delicate to follow. Since the water level of the river was at 21.5 ft, it is likely that the rootlets extended to the water table.

Germination

Germination of Russian knapweed occurred at a temp. range from 0.5°C to 35°C with the optimum being between 20°C and 30°C (Brown, et al., 1942). In the present study, the % germination of Russian knapweed seed peaked using 32°-24°-32°C combination.

Treatment *	A	B	C	AB	BC	CB	ABC	BCB	CBC
% germination	0	1.6	0.6	5	24.2	50.8	13.0	27.4	53.6

*A = 10°C, B = 24°C, C = 32°C

This combination was used to study germination of seed which had been stored at room temp. prior to the test (see below).

Age of Seed (years):	1	2	5	7	8	9
% germination:	60	34	50	5	69	42

Seed 8-years old germinated most completely (69%). Overwintering in the field did not appear to have a significant effect on germination of the seed.

Germination of Russian knapweed rarely occurred in the field, having been observed only once (1952) in the present study. Three seedlings which germinated from a closed head after water had flooded and receded from the area failed to survive the competition provided by other species.

<u>Rate of Spread</u>

Patches of globe-podded cress increased an average of 2.5 ft in radius at Glen Kerr during 1953-1956 and an additional 1 ft during 1956-1959. The same species increased an average of 5.7 ft in radius at Leader during 1953-1956, representing an increase in area of 91%. During 1956-1959, however, the perimeter receded 1.6 ft. Lens-podded hoary cress was less vigorous, receding 1.8 ft at Leader during 1953-1956. Recession continued until in 1959 only 2 shoots remained of the original infestation which occupied approximately 65m^2. Hoary cress plants were not visible during a thorough inspection of the area in 1960.

Russian knapweed spread consistently at all sites during 1953 to 1956, ranging from 2.3 to 10.7 ft. On the other hand, only slight perimeter increases occurred at 3 locations during 1956 to 1959 (Table 2). At 3 other locations, decreases in perimeter occurred.

Table 2

<u>The increase or decrease in radius of knapweed patches at various locations during 1953-1956 and 1956-1959</u>

Site	No	Period	
		1953-1956	1956-1959
Log Valley	1	+ 5.82	+ 1.30
" "	2	+ 4.30	- 0.03
" "	4	+ 4.49	+ 0.52
Leader	1	+ 2.33	+ 1.23
"	2	+ 10.70	- 4.00
"	4	+ 4.97	-
"	5	+ 2.30	- 0.37

Lens-podded cress receded in the entire area at Leader regardless of competing species, and globe-podded cress spread only slightly in competition with bromegrass and western wheatgrass. Extensions were less frequent, and in some cases, recessions occurred in competition with bromegrass (*Bromus inermis*) and Russian knapweed. The shrubs *Rhus*, *Rosa* and *Symphoricarpos* were most effective in containing the weed species in semi-arid environments. Crested wheatgrass (*Agropyron cristatum*) contained Russian knapweed most efficiently on sandy soil. Under irrigation, western wheatgrass was a vigorous competitor and was inferior only to alfalfa in competitive ability.

Density Relationships

Infestations of hoary cresses and Russian knapweed were characterized by scattered, dense patches with densities rarely exceeding 100 shoots per m^2. Russian knapweed increased in density (a mean of 42% at Leader) at dry locations and decreased in density (a mean of 24% at Glen Kerr) at moist locations. On the other hand, the density of hoary cress increased at moist locations (Glen Kerr) and decreased at dry locations (Table 3).

The density of knapweed increased between 14% and 60% at the 5 Leader locations, accompanied by increases of similar magnitude in the density of shrubs, represented by *Rosa* and *Symphoricarpos*. This was accompanied by a 95% decrease in density of hoary cress.

Lens-podded hoary cress decreased in density after 1956 until quadrats were devoid of the weed by 1959 (Table 3). This site was dominated by shrubs, as bromegrass decreased significantly in density also.

At Glen Kerr, knapweed densities decreased on irrigated lands and increased on those not irrigated. In irrigated native grassland, knapweed decreased in density by 37% in competition with western wheatgrass and bromegrass, and 27% in competition with bromegrass (Table 3). Annual mowing further decreased knapweed density, for a maximum of 53%. Mowing had a similar effect upon hoary cress. Under dryland farming at Glen Kerr, the density of knapweed increased 15% at one location but decreased 18% at another, the latter being densely populated by the shrub skunk bush (*Rhus trilobata*).

The stand of hoary cress at Glen Kerr was initially sparser in mowed plots, compared with unmowed plots and the relationship was maintained throughout the study. The stunted and spindly nature of surviving cress plants in mowed plots reflected intense competition from the alfalfa (sown in 1956). However, an increase in density of hoary cress and bromegrass occurred in 1959 following extensive "winter-killing" of alfalfa during the winter of 1958-1959.

Established stands of lens-podded hoary cress were eradicated on sandy-loam soil after 6 years of alternate summer-fallow and cropping, and also competition from a mixture of alfalfa and bromegrass. Patches of the weed survived only in moist depressions. In these depressions, three applications annually of the butyl ester of 2,4-D at a rate of 2 lb/ac for 3 years (in competition with perennial grasses) killed established plants. The first treatment was made at the early blossom stage and subsequent applications when regrowth was 2 to 3 in. tall. In some cases, treatments were not required after the second year.

Table 3.

The average number of shoots of Cardaria spp. and Centaurea repens per m^2 during 1952-1959

Location	year 1952	1953	1954	1955	1956	1957	1958	1959	% chge 1952-59
Ldr 2A									
C. p.	22	25	19	17	7	2	7	4	- 80
Ce.r.	24	45	77	76	85	63	40	35	+ 45
Ldr 2B									
C. p.	85	108	37	50	6	14	14	9	- 96
Ce.r.	24	45	77	76	85	63	40	35	+ 45
Ldr 3									
C.ch.	13	59	17	15	19	-	10	0	- 100
Ldr 4A									
Ce.r.	13	8	18	12	19	-	-	-	+ 50*
Ldr 4B									
Ce.r.	26	23	41	42	29	-	-	-	+ 14*
Ldr 5									
Ce.r.	8	8	8	9	8	-	7	11	+ 40
Gl.Kerr A									
C. p.	8	23	15	25	15	24	8	16	+ 100
Ce.r.	39	58	35	41	33	32	22	24	- 37
Gl.Kerr 1B									
C. p.	6	5	12	9	14	22	20	18	+ 192
Ce.r.	37	43	26	30	25	24	19	15	- 59
Gl.Kerr 2									
Ce.r.	15	15	13	12	12	-	12	-	- 18
Gl.Kerr 3A									
C. p.	30	26	31	11	18	-	39	32	+ 6
Ce.r.	22	29	23	24	29	-	20	16	- 27
Gl.Kerr 3B									
C. p.	3	13	12	9	11	-	2	9	+ 260
Ce.r.	19	35	22	32	14	-	33	9	- 52
Gl.Kerr 4									
Ce.r.	31	39	30	51	45	-	35	-	+ 15

C. p. = *Cardaria pubescens*
Ce.r. = *Centaurea repens*
C.ch. = *Cardaria chalapensis*

*% change during 1952-56

DISCUSSION

The seed of Russian knapweed had an initial dormancy period which was broken by alternating temperatures.

That globe- and lens-podded hoary cresses are well adapted to moist situations is indicated by their prevalence in this environment and their capacity for vegetative reproduction under irrigation. Under these conditions, the competition provided by hoary cress was a serious hazard to crop production.

Although knapweed infestations increased in area under irrigation, this species decreased in density and was generally less hardy in a moist environment. This can be attributed to vigorous competition from perennial grasses.

Prolonged dry conditions resulted in reduced vigour, decreased densities, inflorescence inhibition, suppressed growth, and recession of the infested area of the hoary cresses. These trends were particularly marked during the last three years of the study when precipitation was 15% below average for the area. The rate of spread of knapweed was reduced also during this period. At some locations the density of knapweed followed a similar trend (Table 3), increasing during years of higher-than-average precipitation (1952-1956) and decreasing thereafter. However, the average density was greater in drier habitats.

Globe-podded cress was hardier than the lens-podded species under conditions of drought.

Shrubs were the most effective competitors under dry conditions, presumably because the more extensive root systems of *Rosa* and *Symphoricarpos* permitted fuller utilization of subsoil moisture.

Hoary cress can be eradicated by cultural means under dry land farming conditions, especially in years of lower-than-average precipitation.

Where moisture is plentiful, however, hoary cress will continue to spread vegetatively. Alfalfa is a more effective competitor than perennial grasses where moisture is abundant. Hoary cress can be virtually eradicated and knapweed stands significantly reduced under irrigation in a dense stand of alfalfa which is mowed 2 or 3 times annually for a period of 5 years. Winterkilling of alfalfa which sometimes occurs in western Canada, would extend the time required for eradication.

Preliminary studies indicated that repeated, timely applications of 2,4-D at a rate of 2 lb/ac for 2 or 3 years (in competition with perennial grasses) kills established plants. This method was effective also in controlling the "persistent perennial", leafy spurge (*Euphorbia esula*) (Selleck, 1956)

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References

BROWN, E.O. and R.H. PORTER. (1942) The viability and germination of seeds of Convolvulus arvensis L. and other perennial weeds. Iowa State Coll. Expt. Sta.Bul. 294, 475-504.

GROH, H. (1940 a.) Hoary cresses in Canada. Sci. Agr. 20, 750-756.

__________ (1940 b.) Turkestan alfalfa as a medium of weed introduction. Sci. Agr. 21, 36-43.

MULLIGAN, G.A. and C. FRANKTON. (1962) Taxonomy of the genus Cardaria with particular reference to the species introduced into North America. Can. J.Bot. 40, 1411-1425.

SELLECK, G.W. (1959) Leafy spurge control with 2,4-D. Proc.NCWCC. Winnipeg, Manitoba. p.70.

Research Summary

HEMIPARASITIC WEEDS

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Summary Data are presented to show the effect of a host plant on the vigour of the hemiparasite Odontites verna. Results are given of autoradiographic and quantitative experiments, showing the passage of assimilated ^{14}C-containing compounds from a host to O. verna.

INTRODUCTION

Hemiparasites are plants which have functional photosynthetic tissues but which form root contacts or haustoria with other, autotrophic, plants.

By far the largest group of hemiparasitic species are those contained within the sub-family Rhinanthoideae of the family Scrophulariaceae. These species form an interesting series exhibiting increasing dependence upon a host plant and increasing specificity for host species; the pattern of increasing parasitic specialisation can be extended to include the non-photosynthetic, totally parasitic, species of the Orobanchaceae.

The most serious hemiparasitic weeds in the world are species of Striga (Witchweed) found in crops of maize and sorghum in Africa and the Southern United States. Some of the British species can be regarded as serious weeds, especially Orobanche minor (Lesser Broomrape), a weed of clover crops and clover in temporary leys, and Rhinanthus spp. (Yellow Rattle) which can become a serious weed of damp meadows and pastures. Other hemiparasites occurring as grassland weeds are Euphrasia spp. (Eyebright), Melampyrum arvense (Field Cow-wheat) and Parentucellia viscosa (Yellow Bartsia).

This report deal with the species Odontites verna (Red Bartsia) which occurs as a weed of both grassland and arable crops. O. verna is the least specialised parasite in the Rhinanthoideae, forming root connections with a very wide range of species. Moreover, this hemiparasite will complete its life cycle in the complete absence of a host plant, though it is then very much less vigorous.

The effect of a host plant on the growth and development of Odontites verna

Plants of Odontites verna were grown in the presence of a host (Perennial Ryegrass) and these were compared with plants grown under similar conditions in the absence of a host.

The plants were grown in John Innes no. 1 compost in flats 42 cm × 31 cm × 9 cm which were arranged as in Fig. 1 in a heated greenhouse.

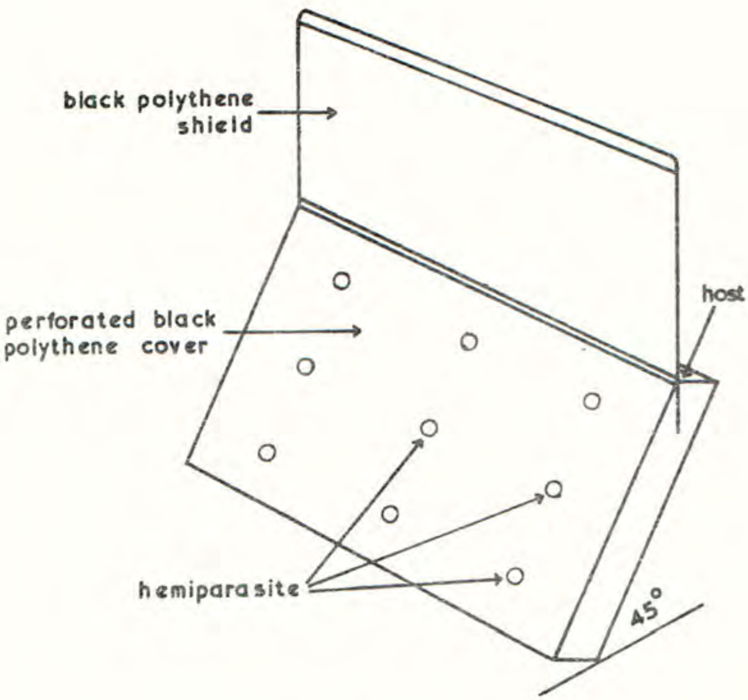

Figure 1
Diagram of the "Slope-box" system

Seedlings of Odontites verna were collected from the field and transplanted into the boxes through holes out in black polythene sheeting. In order to eliminate any above-ground interference between the two species, a vertical black polythene shield was erected to separate the above-ground parts of host and parasite. This "slope-box" system is designed to ensure maximal contact between the roots of the two species.

Eighteen boxes were set up in a randomized block design, and the seeds of perennial ryegrass were sown in nine of these on December 7th, 1962. These seeds were sown in a single row along the uppermost side of the box. No host was sown in the remaining nine boxes. Nine seedlings of Odontites verna were transplanted into each box on May 24th, 1963.

The Odontites plants were harvested on September, 2nd, 1963. The perennial ryegrass plants were 'managed' by a cutting regime, being cut to one inch whenever they reached six inches in height.

The effect of the presence of a host on the growth and development of Odontites is shown in several parameters of growth (see Table 1).

Table 1

The effect of a host plant on the growth of Odontites verna

(Harvested after 15 weeks Means of 81 plants)

	With host	Without host	Fiducial limits $P = 0.05$
Plant height (cm):	22.18	13.78	2.35
No of flowering branches:	4.67	0.75	1.54
Mean length per fl. branch (cm):	5.12	1.00	0.96
Capsule number per plant:	84.70	17.14	19.39

The results given in Table 1 demonstrate the profound increase in vigour of the Odontites plants when they are able to exploit a host plant. Other workers have shown similar indications of increased vigour by other hemiparasites of the Rhinanthoideae. Heckard (1962) working with the species Castilleja showed that this hemiparasite grown without a host was reduced in size and in branching. Wilkins (1963) has shown that establishment of Euphrasia spp. on a host has the effect of increasing the mean number of branching nodes per plant and the mean dry weight. Yeo (1963), also working with Euphrasia spp. has shown that plants grown without a host have considerably reduced total stem and branch lengths.

Radioactive tracer studies.

i. Autoradiographic methods.

Odontites verna was grown in pot culture with white clover (Trifolium repens) and "Dea" barley plants as hosts.

Individual leaves of the clover and single tillers of the barley were exposed to $^{14}CO_2$, in the light, for 24 hours, using the apparatus and technique described by Quinlan and Sagar (1962). The pairs of plants were then harvested, freeze-dried, mounted and exposed to X-ray plates.

Figure 2 is an example of the resulting autoradiographs showing the presence, in the hemiparasite, of carbon-containing compounds from a clover host plant. Similar ^{14}C transfer to the hemiparasite occurred from barley as a host.

No transfer occurred when hemiparasite and host, although growing together, had failed to form haustorial union.

Koch (1889), Ewart (1895), Kostytschew (1923) and Heinricher (1924), early workers on the nutrition of the hemiparasites, maintained that the hemiparasites obtain only water and mineral nutrients from a host plant. This application of ^{14}C as a tracer has shown that the hemiparasite does receive assimilated carbon-containing compounds from a host plant.

Figure 2

Photographs of (a), a plant of Odontites verna parasitising a plant of white clover. The arrow indicated the leaf of the clover fed with $^{14}CO_2$, and (b) the autoradiograph of the plants shown in (a). An image on the autoradiograph indicates the presence of ^{14}C in that part of the system.

Rogers and Nelson (1962), using similar radioactive tracer techniques, have shown the passage of carbon-containing compounds from maize (Zea mays) hosts to mature plants of the hemiparasite Striga asiatica.

This demonstration that both Odontites and Striga (the least and the most specialised hemiparasites in the Rhinanthoideae) receive assimilates from a host plant may indicate that this is a general feature of this group of parasites.

ii. Quantitative methods.

White clover plants parasitised by individual plants of Odontites verna were grown in pot culture as in the previous experiment.

All the above-ground parts of the clover host were enclosed in a polythene bag which was sealed onto a glass CO_2 feeding chamber. The clover plants were then exposed to $^{14}CO_2$, in the light, for 24 hours. The pairs of plants were then harvested, the Odontites plants were divided into shoot and root fractions, and then host and hemiparasite were dried for 48 hours at $60^{o}C$. The dried material of the host and the shoot and root fractions of the hemiparasite were then ground to a powder.

The activity of samples of these powders was then determined using an end-window Geiger-Muller tube. The samples were weighed and the radioactivity present was expressed as count / min per mg of oven dry weight and as count / min per plant.

As a control, to detect any escape of $^{14}CO_2$ from the feeding chambers, pots containing host and hemiparasite were placed alongside those being treated.

The counts obtained are shown in Table 2.

Table 2

Radioactivity detected in Odontites and host plants after exposure of the host plants to radioactive carbon dioxide

	Count/min per mg⁺			14C per mg of parasite as % of total present per mg
	Clover	Odontites		
	Whole plant	Shoot	Root	
Host exposed*:	139.34	3.29	4.31	2.91
Control:	0.04	0.06	0.26	-

	Count/min per plant⁺ $(x10^{-3})$		^{14}C in the parasite as a % of total in system
	Clover	Odontites	
Host exposed*:	372.2	12.3	3.19

⁺ after subtraction of background count.

* activity of $^{14}CO_2$ applied = 50 μc.

The values given in Table 2 give some indication of the amount of assimilated carbon passing from a clover host to the hemiparasite within the relatively short period of 24 hours. In their work on <u>Striga</u> Rogers and Nelson (1962) have shown ^{14}C transfer from host to parasite of 1.82 per cent after 48 hours and 12.7 per cent after 72 hours.

These experiments have shown that, contrary to previous theories, the hemiparasites make demands on a host not only for a supply of water and mineral nutrients but also for organic substances. Hemiparasites occuring as weeds of crop plants must therefore be regarded as much more serious than they have been up to the present.

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References

EWART, A.J. (1895) On assimilatory inhibition in plants. J. Linn Soc. (Bot.), 31, 364-461.

HECKARD, L.R. (1962) Root parasitism in Castilleja. Bot. Gaz., 124, 21.29.

HEINRICHER, E. (1924) Zum Parasitismus der Rhinantheen. Ber. dtsch. bot. Ges., 42, 243-250.

KOCH, L. (1889) Zur Entwicklungsgeschichte der Rhinantheen. Jb. wiss. Bot., 20, 33.

KOSTYTSCHEW, S. (1923) Untersuchungen uber die Ernahrung der grunen Halbschmarotzer. Beih. bot. Zbl., 40, 351-373.

QUINLAN, J.D. and SAGAR, G.R. (1962) An autoradiographic study of movement of ^{14}C-labelled assimilates in the developing wheat plant. Weed, 2, 264-273.

ROGERS, W.E. and NELSON, R.R. (1962) Penetration and nutrition of Striga asiatica. Phytopathology, 52, 1064-1070.

WILKINS, D.A. (1963) Plasticity and establishment in Euphrasia. Ann. Bot. (Lond)., 27, 533-552.

YEO, P.F. (1964) The growth of Euphrasia in cultivation. Watsonia, 6, 1-24.

THE INCIDENCE AND SIGNIFICANCE OF INJURIOUS WEED SEEDS IN CROP SEED

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Summary The incidence of seed of the five weeds classified as injurious under the Seeds Regulations 1961 in samples tested at the Official Seed Testing Station in 1963/64 is discussed and compared with figures recorded in previous surveys. The frequency with which they occur is influenced by the ecological and morphological relationships between the weed and crop species both in the plant and seed stages, and varies according to the kind and geographical origin of the crop seed; differences in frequency may result from differences in the general pattern of agricultural production, from seasonal factors, from technical developments in cultural practices and seed cleaning, and from seed control legislation and the increased use of voluntary certification schemes.

INTRODUCTION

Factors determining the weed seed population of the soil at the time a crop is sown include the seed production of weeds in previous crops, cultural practices, introduction by various natural and agricultural agencies, and introduction with the crop seed sown (Horne, 1953). Weed seed sown with the crop is favourably placed in a prepared seed bed, and escapes the pre-sowing cultivations designed to reduce weed interference. While its placement in the row by seed drills may intensify interference by the establishing seedlings of the crop, compared with seeds germinating between the rows, its position reduces the risk of elimination by subsequent inter-row cultivations, though not by herbicide treatment.

Salisbury (1961) believes that the weed seeds sown with the crop have been the most important single agency for the introduction of alien species. But early legislation in the United Kingdom was designed to prevent the sowing of excessive quantities of weed seeds, rather than to avoid the introduction of foreign species or the contamination of clean land by native species. Thus regulations made under the Seeds Act in 1922 prohibited the sale or sowing of seeds containing more than 5% by weight of the following injurious weeds:

Docks and sorrels	(*Rumex* spp.)
Cranesbill	(*Geranium* spp.)
Wild carrot	(*Daucus carota* L.)
Yorkshire fog	(*Holcus lanatus* L.)
Soft brome grass	(*Bromus mollis* L. et spp.)

However a declaration of the number of seeds of dodder (*Cuscuta* spp.) in a specified weight was required on the sale of clover seed. Wellington (1960) has contrasted the success of the latter provision in virtually eliminating dodder in home-produced red clover seed with the failure of the former to achieve any reduction in the frequency of occurrence of *Rumex* spp. in samples of herbage seed.

In the light of this experience the Committee on Transactions in Seeds (Anon., 1957) recommended that the purchaser of seed should receive a declaration of the percentage by weight of all weed seeds present, and also the number of seeds of any species represented on a revised list of injurious weeds in a sample of prescribed size; this would provide an indication to the grower of potential field contamination per unit area, and would give warning of the danger of contaminating clean land with harmful species. The injurious weeds were to be the following:

Wild oat	(Avena fatua L. and A. ludoviciana L.)
Dodder	(Cuscuta spp.)
Docks and sorrels	(Rumex spp.)
Black grass	(Alopecurus myosuroides Huds.)
Couch grass	(Agropyron repens (L.) Beauv.)

These recommendations were embodied in new Seeds Regulations (Anon., 1961), which came into effect for cereal seed on the 1st Aug. 1961, and for herbage seed on the 1st Aug. 1962.

Surveys of the occurrence of weed seeds in samples of crop seed tested by the Official Seed Testing Station, Cambridge, such as those of Broad (1962) and Gooch (1963), provide valuable information on the frequency of individual weed species and the characteristic populations associated with crop seed of particular species and geographical origin.

This paper will review the findings of previous surveys for the five weeds now designated as injurious under seeds legislation, and compare these with figures from subsequent seasons.

WILD OATS

Since the last war, when severe infestations developed under heavy cereal cropping, wild oats have become the chief weed problem of cereal growers; Thurston (1956) has described contaminated seed as the commonest means by which they spread. Between 1953 and 1958 wild oats were reported in seed crops in every county of England where crops were inspected under the Cereal Field Approval Scheme (Hervey Murray, 1958); this excluded Cumberland and Lancashire, where the acreage was negligible, and Cornwall, Middlesex, Durham and Westmorland, where no crops were inspected.

The percentage frequency of contaminated samples in various seasons is given in Table 1a. It is interesting to note the relatively high rate of occurrence in 1928/29, but there is a reduction after 1930/31 possibly as a result of the falling cereal acreage of the inter-war years: this is followed by a rise until 1960/61, no doubt reflecting the intensive cereal production of the war and post-war years. However the figures for 1963/64 show a reduction in frequency for all three cereals, and this may be at least partly due to the introduction of the statutory declaration requirement in 1961.

Since 1961 it has been possible to make more sensitive comparisons, on the basis of frequency in larger samples (Table 1b); sufficient data have not yet accumulated on this basis to draw any firm conclusion on the relative contributions of the new legislation, cultural and seasonal factors to these changes.

Table 1

Frequency of occurrence of wild oats in cereal samples

(a) Percentage of samples containing at least one seed in 50 g

	1928/29	1930/31	1934/35	1943/44	1947/48	1951/52	1960/61	1963/64
Wheat	5	3	2	1	2	2	4	2
Barley	9	13	4	3	4	7	7	5
Oats	5	4	3	3	3	2	4	2

(b) Percentage of samples containing at least one seed in 8 oz

	1961/62	1962/63	1963/64
Wheat	2	4	5
Barley	7	8	10
Oats	5	5	6

Wild oats are infrequent contaminants of cleaned herbage seed, although about 1% of all samples of Italian ryegrass and meadow fescue contain one or more seeds in the 5 g working portion tested for purity. Contamination is almost entirely confined to seed of English origin.

DODDER

In 1905 the Royal Agricultural Society reported that red clover samples had been examined containing as much as 6% by weight of dodder seed, and the Board of Agriculture recommended that purchasers should insist on a guarantee from their suppliers that seed was absolutely free from contamination (Anon., 1906). In 1917 legislation was introduced requiring a declaration of the number of seeds of dodder, based on official analysis of a 4 oz sample of red clover or lucerne, 2 oz of white clover or 1 oz of wild white clover. In 1923 the Ministry of Agriculture reported that dodder, although still prevalent in East Suffolk and Northampton, was no longer a serious pest in the southern counties, where a few years before entire crops were often lost because of it. The improvement was attributed to the reduction of contaminated seed as a result of the declaration under the Seeds Act.

Wellington (1960) has described the decline in the proportion of samples of English red clover found to contain *Cuscuta trifolii* Bab. from 24% in 1917 to zero in 1936, and has attributed this to the discrimination of the purchaser. A similar reduction was not achieved in the case of Chilean seed, which was regularly imported until the last war, but not subsequently; however this was nearly always contaminated with *C. racemosa* Engelm., a species which does not establish in this country. Since the war samples of seed imported from the U.S.A. have been found to contain *C. campestris* Yuncker, another species which is unlikely to establish in England.

The only crop seed in which dodder is now encountered with any regularity is lucerne. Under the current Seeds Regulations only the number of seeds found in the purity test (5 g) has to be declared, but in order to obtain a more accurate assessment of its occurrence, during 1963/64 the entire sample of 2 oz has been searched in each case. Seeds of dodder were found in 4% of the samples. Identification of the species proved impossible, as this cannot be made on the basis of seed characters, and all the seeds failed either to germinate or to parasitise the hosts offered. However no samples of English-grown seed were contaminated, all affected samples being of French origin. Although fewer samples of lucerne now contain dodder than in 1920/21, when the frequency was 12% (Saunders, 1922), failure to eliminate contamination altogether, as in the case of red clover, is no doubt due to continued reliance on imported French seed, whereas in the case of red clover sufficient home-produced seed is normally available.

DOCKS AND SORRELS

Docks are troublesome weeds in a wide range of crops and soils. The two most important species, Rumex crispus L. and R. obtusifolius L., are both susceptible to herbicides in the seedling stage, but established plants are difficult to eradicate. R. crispus exhibits a high rate of seed production and germination (Salisbury, 1961). Madsen (1962) has demonstrated the longevity of seed of this species when buried in soil for 17 years, and Hitchings (1960) found it able to withstand storage in a saturated atmosphere which killed nearly all other weed seeds tested.

Sorrels occur less widely as agricultural weeds; although R. acetosella L. is common on the more acid soils, it is almost absent from calcareous soil and can usually be controlled by liming (Salisbury, 1961).

Although docks and sorrels were classed as injurious weed seeds under the 1922 Seeds Regulations, there was no very marked reduction in their frequency in samples of herbage seed between 1922 and 1951 (Wellington, 1960). Contamination in cereal samples is almost entirely by R. crispus, R. obtusifolius and R. acetosella being found only rarely. Its frequency showed little change between 1928/29 and 1951/52 (Table 2a), but the improvement by 1960/61 was probably due largely to the increased use of selective herbicides.

The figures in Table 2b, based on the examination of larger samples since the introduction of the Seeds Regulations 1961, show little change in the three seasons, except for some reduction in the proportion of contaminated oat samples.

The influence of geographical origin on the weed seed population of herbage seed has been stressed by Gooch (1963), and is illustrated in Table 3 which gives the frequencies of R. crispus and R. acetosella (R. obtusifolius is normally found only in English red clover). R. acetosella is not frequent in English seed, but fairly high rates are found in Irish ryegrass and New Zealand white clover. R. crispus on the other hand is common in both English and New Zealand red clover.

Docks and sorrels represent the most prevalent injurious species found in clover seed, no doubt due to the absence of satisfactory herbicides and their physical similarity to the crop seed, which makes cleaning difficult. However for all kinds of English grown herbage seed except red clover the frequency of contamination is lower in 1963/64 than in 1960/61 (when the new legislation had not yet come into force). Not only has the standard of home-produced seed improved under the influence of the new legislation and the expansion in production of British certified seed, but the figures indicate that efforts are being made in the main exporting countries to provide seed of a higher standard of freedom from these species.

Table 2

__Frequency of occurrence of docks in cereal samples__

(a) Percentage of samples containing at least one seed of __R. crispus__ in 50 g

	1928/29	1930/31	1934/35	1943/44	1947/48	1951/52	1960/61	1963/64
Wheat	1	2	2	2	6	2	<1	<1
Barley	4	4	3	3	5	4	1	<1
Oats	14	8	6	6	10	9	2	2

(b) Percentage of samples containing at least one seed of __Rumex__ spp. in 8 oz

	1961/62	1962/63	1963/64
Wheat	2	2	2
Barley	3	2	2
Oats	8	6	5

Table 3

__Frequency of occurrence of docks and sorrels in herbage samples__

Percentage of samples containing at least one seed in purity test

		__Rumex crispus__					__Rumex acetosella__				
		English	Irish	Danish	New Zealand	Canadian	English	Irish	Danish	New Zealand	Canadian
Perennial ryegrass	1960/61	4	<1	3	<1		<1	24	6	7	
	1963/64	3	0		2		<1	11		6	
Italian ryegrass	1960/61	7	1	8			2	26	11		
	1963/64	3		<1			0		7		
Cocksfoot	1960/61	8		16			<1		2		
	1963/64	6		8			0		0		
Timothy	1960/61	5				4	1				22
	1963/64	1				4	<1				8
Meadow fescue	1960/61	6		9			<1		5		
	1963/64	3		4			<1		4		
Red clover	1960/61	22			25	1	2			8	0
	1963/64	26				2	2				0
White clover	1960/61	15		4	3		8		14	39	
	1963/64	5			1		2			16	

BLACK GRASS

Black grass (Alopecurus myosuroides Huds.) is an annual weed particularly associated with arable farming on heavy soil, and especially troublesome with autumn sown cereals. Welbank (1963) has demonstrated its high competitive ability with wheat. Studies at Cambridge have shown that, although innate dormancy may be lost soon after shedding, secondary dormancy may be induced under cold, wet conditions; as many as 90% of seeds remained capable of germination after being buried for 17 months in heavy clay soil (Hitchings, 1960, Wellington, 1962). As germination can occur at almost any time of the year, and no herbicide is yet recommended for use after the crop is growing, black grass is a serious problem in grass seed crops; it is most important that it should not appear in the harvested seed as it is very difficult and expensive to remove in cleaning.

Table 4

Frequency of occurrence of black grass in cereal samples

	Percentage of samples containing at least one seed in 8 oz		
	1961/62	1962/63	1963/64
Wheat	2	3	3
Barley	2	3	4
Oats	3	2	2

The occurrence of black grass in cereal samples does not appear to have changed appreciably since its classification as an injurious weed in 1961 (Table 4); however the increased frequency in barley may represent a trend, or simply reflect differences in the relationship between the flowering and ripening patterns of crop and weed under different seasonal conditions.

Table 5

Frequency of occurrence of black grass in herbage samples

	Percentage of samples containing at least one seed in a purity test			
	1951/52	1961/62	1962/63	1963/64
Perennial ryegrass	4	6	6	6
Italian ryegrass	4	6	7	9
Cocksfoot	7	13	9	9
Timothy	5	5	5	6
Meadow fescue	14	23	15	16
Red clover	2	<1	1	3
White clover	3	1	2	2

The figures in Table 5 indicate the prevalence of A. myosuroides in grass seed, and its lower frequency in clover seed, in seasons both before and after the new legislation came into force in 1962. However as the species is more or less confined to seed of English origin (Gooch, 1963), the apparent increase in its frequency may reflect an increase in the proportion of home-produced grass seed used, rather than any change in its occurrence in seed crops. A comparison of the frequency of the weed in seed of English origin in 1960/61 and 1963/64 (Table 6) suggests that some progress has been made in reducing contamination.

Table 6

Frequency of occurrence of black grass in grass samples of English origin

	Percentage of samples containing at least one seed in a purity test	
	1960/61	1963/64
Perennial ryegrass	13	8
Italian ryegrass	10	12
Cocksfoot	13	9
Timothy	6	9
Meadow fescue	19	15
Red fescue	5	4
Tall fescue	27	16

COUCH GRASS

Couch grass (Agropyron repens (L.) Beauv.) is a serious and widespread agricultural weed largely because of its prolific production of rhizomes, which are difficult to eradicate and form the principal means of reproduction. It is self-sterile and seed production is therefore often low because of the spatial isolation of single clones imposed by vegetative reproduction. However when heads collected in a barley crop in Hampshire immediately before harvest in 1963 were examined at Cambridge, 10% were found to contain caryopses sufficiently developed to be potentially viable, while another 20% contained seeds which, though fertile, were too poorly developed to be capable of germination (Esbo, 1962, found that seeds of A. repens with a caryopsis less than one-third the length of the palea did not produce seedlings). Sagar (1960) describes a stand in which 58% of the flowers produced seed which germinated in soil, while Hitchings (1960) found up to 61% of caryopses in naturally crossed heads. The sowing of crop seed containing seed of couch grass may lead to the introduction of new clones to an area previously occupied by a single clone; substantial weed seed production could then occur. This represents a danger from the use of contaminated seed additional to the more generally recognised risk of contaminating clean land.

Table 7

Frequency of occurrence of couch grass in cereal samples

	Percentage of samples containing at least one seed in 8 oz		
	1961/62	1962/63	1963/64
Wheat	5	7	6
Barley	6	6	5
Oats	5	6	6

The frequency of couch grass seeds in cereal samples (Table 7) has changed little in the three seasons since the introduction of the Seeds Regulations 1961, and is similar for wheat, barley and oats. For herbage seed Table 8 shows the proportion of contaminated samples in the season before, and in the two seasons since, the new legislation became effective in 1962. Seeds of couch grass rarely occur in clover samples, but are more frequent in the grasses. No major change appears to have taken place in the three seasons, except for meadow fescue which shows a marked reduction in frequency.

Table 8

Frequency of occurrence of couch grass in herbage samples

	Percentage of samples containing at least one seed in a purity test		
	1961/62	1962/63	1963/64
Perennial ryegrass	8	8	8
Italian ryegrass	4	4	8
Cocksfoot	6	6	7
Timothy	6	6	5
Meadow fescue	10	5	4
Red clover	<1	0	<1
White clover	0	<1	0

Table 9 shows that the increased percentage of contaminated samples of Italian ryegrass in 1963/64 does not reflect a deterioration in the quality of English-grown seed, but probably represents an increase in the proportion of samples tested from other sources. Figures for the season 1960/61 showed a very high frequency of A. repens in seed from Denmark, but it was rarely found in Irish ryegrass: this difference is probably due to the greater frequency of the weed in the predominantly arable conditions of Denmark than in the grassland-based agriculture of Ireland.

Table 9

Frequency of occurrence of couch grass in grass samples

	Percentage of samples containing at least one seed in a purity test				
	1960/61				1963/64
	Swedish	Danish	Irish	English	English
Perennial ryegrass		64	<1	11	6
Italian ryegrass		25	1	5	5
Cocksfoot		17		8	7
Timothy	4			4	6
Meadow fescue	11	20		6	3

References

ANON. (1906) Dodder. J. Board Agric. 13, 331-338.

ANON. (1922) The Seeds Regulations, 1922. London, H.M.S.O.

ANON. (1923) Prevalence of dodder in Great Britain. J. Minist. Agric. 30, 38-41.

ANON. (1957) Report of the Committee on Transactions in Seeds, London, H.M.S.O.

ANON. (1961) The Seeds Regulations, 1961. London, H.M.S.O.

BROAD, P.D. (1952) The occurrence of weed seeds in samples submitted for testing by the O.S.T.S. J. nat. Inst. agric. Bot. 6, 275-286.

ESBO, H. (1962) Report of the Purity Committee, 1962. Proc. Int. Seed Test. Ass. 27, 48-67.

GOOCH, S.M.S. (1963) The occurrence of weed seeds in samples tested by the Official Seed Testing Station, 1960-61. J. nat. Inst. Agric. Bot. 9, 353-371.

HERVEY MURRAY, C.G. (1958) Unpublished.

HITCHINGS, S. (1960) The control and eradication of weeds in seed crops. In 'The Biology of Weeds' (ed. J.L. Harper), 108-115, Oxford, Blackwell.

HORNE, F.R. (1953) The significance of weed seeds in relation to crop production. Proc. Ist. Brit. Weed Control Conf., 1953, 372-398.

MADSEN, S.B. (1962) Germination of buried and dry stored seeds III, 1934-1960. Proc. Int. Seed Test. Ass. 27, 920-928.

SAGAR, G.R. (1960) Agropyron repens - an introduction. Proc. 5th Brit. Weed Control Conf., 1960, 259-263.

SALISBURY, E.J. (1961) 'Weeds and Aliens', London, Collins.

SAUNDERS, C.B. (1922) Fourth annual report of the Official Seed Testing Station for England and Wales, 13. Cambridge, N.I.A.B.

THURSTON, J.M. (1956) Wild oats, J. R.A.S.E. 117, 43-52

WELBANK, P.J. (1963) A comparison of competitive effects of some common weed species. Ann. appl. Biol. 51, 107-125.

WELLINGTON, P.S. (1960) Assessment and control of the dissemination of weeds by crop seeds. In 'The Biology of Weeds' (ed. J.L. Harper) 94-107. Oxford, Blackwell.

WELLINGTON, P.S. (1962) Seed testing activities in the United Kingdom and internationally. J. nat. Inst. agric. Bot. 9, 213-217.

WEED STUDIES IN WINTER WHEAT

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Summary Two weed studies are reported from Broadbalk field at Rothamsted, where winter wheat has been grown yearly since 1843 and yields, cultivations, weather and weeds recorded. (1) Changing from bare fallow every fifth year to continuous wheat with herbicides increased the total yield over a 5-year cycle by only 10 cwt/ac, decreased weed-seed content of the soil by only 15% and altered the proportion of weed species in favour of those not susceptible to the herbicides used. The responses of 14 species to herbicides and fallowing are compared by twice-yearly surveys of the weed flora on all plots and by the germination of weed seeds in soil samples from selected plots.
(2) The distribution of weed seeds between grain fractions and baled straw and the number left on the ground after combine harvesting were investigated by sampling grain and straw and by catching and sampling the straw and chaff discharged behind the combine before it reached the ground. Only 4% of the total weed-seeds were left on the ground after baling and 4.5% were in the baled straw. The 1st-grade grain contained 28%, the "seconds" 47.5% and the "rubbish" from the third spout 16% of the total weed-seeds present at harvest. The distribution between these fractions of 12 species differing in size and texture of seed is discussed.

INTRODUCTION

Winter wheat has been grown on Broadbalk field on Rothamsted farm yearly since 1843. The field is divided into 17 ½-acre strips, one unmanured and 16 with different organic or mineral fertilizers. Treatments are neither randomised nor replicated. Each strip has its characteristic weed flora of about 10 to 20 species out of a total of approximately 50 annuals and 10 perennials, determined by its fertilizer treatment. Most annuals germinate only at certain times of year (Brenchley and Warington, 1930).

Weed surveys have been made at intervals since 1843 and twice yearly since 1931 (Warington, 1958). Soil samples for weed-seed content have been taken from selected plots since 1925. Agricultural operations and weather are recorded. Broadbalk thus provides unique opportunities for weed studies, two of which are reported here, but the lack of replication is a disadvantage.

From 1931 to 1955, weeds were controlled only by fallowing 1/5 of the field each year in a strip at rightangles to the fertilizer treatments. In 1956 a narrow strip (section IA) crossing all fertilizer treatments was cropped while the rest of the top fifth of the field (section IB) was fallowed. From 1957 to 1963, IA grew winter wheat every year, sprayed in May with a herbicide intended to control broad-leaved weeds, while IB was fallowed every fifth year.

Broadbalk was formerly cut by binder, but from 1957 it has been combine-harvested. The distribution of weed-seeds between grain and straw and on the ground after combine-harvesting was studied in case the change in harvesting-method appeared to affect the weed-flora.

1) COMPARISON OF BARE FALLOW AND HERBICIDES FOR WEED CONTROL

METHOD

The weeds on section IA (continuous wheat with herbicides) and IB (fallowed every 5th year, no herbicides) were compared by two methods, starting in 1955 while section I was still treated uniformly.

Visual surveys were made twice yearly (mid-May and stubble). Each species seen was scored from 1 to 5 according to abundance. 1=occasional, 3==approx. 1 plant per sq.yd. 5=ground covered, i.e. on a logarithmic scale of plants per unit area. This gave approximate estimates of all species on all plots.

Soil samples were taken annually from the undisturbed stubble of 5 plots selected to include many species. Stones and clay were removed by washing over sieves. The remaining soil containing all the weed seeds was put in pans in a cool glasshouse and kept moist for 3 years.

Every 6 weeks all seedlings were identified, counted and removed and the soil was thoroughly stirred (Brenchley and Warington, 1930).

The seedling counts showed the total viable seeds in the soil (assuming that all germinated within 3 years), the percent germinating in each year and the time of year when each species germinated. The last year for which complete results were known when this Report was written was 1960.

The results of the two methods agree where they overlap, but each gives some information not obtainable by the other.

Herbicides and fallowing for weed control in winter wheat on Broadbalk sections IA and IB.

Year	Herbicides on Section IA			Number of years after fallow on section	
	Common name	Dose lb.a.e./ac	Date of application	IA	IB
1955	-	-	-	4	4
1956	-	-	-	5	F
1957	MCPA	1.20	May 7	6	1
1958	Mecoprop	2.40	April 30	7	2
1959	TBA/MCPA	0.25/0.75	May 12	8	3
1959	2,4-D	1.53	Sept. 8	8	3
1960	Mecoprop	2.25	April 28	9	4
1961	TBA/MCPA	0.25/0.75	May 5	10	F
1962	TBA/MCPA	0.25/0.75	April 24	11	1
1963	Mecoprop/2,4-D	2.63/0.66	May 16	12	2

In 1957 the herbicide was applied at 80 gal/ac and from 1958 to 1963 at 40 gal/ac.

RESULTS

a) GENERAL RESULTS

Yields of 1st grade wheat grain straight from the combine-harvester were only slightly greater on the sprayed than on the fallowed section, and in the first year after fallow they were much less. Over one 5-year fallow-cycle the continuous wheat with herbicides yielded only 10 cwt/ac more than the unsprayed, fallowed section although it carried 5 crops to the fallow section's 4. In its first year after fallow (1957 and 1962) IB outyielded IA by 30% and 10% and in its 4th year after fallow (1960) IB yielded only about 6% less than IA. How far these results are influenced by including weed seeds especially *Vicia sativa* (Common Vetch) in the uncleaned grain weights of unsprayed plots or by herbicide damage to wheat on sprayed plots is being investigated in some 1964 samples.

The total weed score for presence and abundance of all weed species on all plots was consistently less on IA than IB soon after spraying in May, but by harvest the score for IA was equal to or above IB.

The mean number of species per plot was larger on IB than on IA in May, but in the stubble IA had a mean of 12 species per plot, compared with 11 on IB, the extra species presumably invading the spaces left by removing earlier-germinating weeds.

There is no evidence of selection for late-germinating strains of weeds which could germinate after the herbicide had been applied, although seeds of susceptible species in soil from sprayed plots presumably came from late-germinating individuals. However, the germination records may be too far apart to show small changes in time of germination.

Herbicides tended to break dormancy of weed seeds.

The proportion of all weed seeds germinating in the first year of the 3-year test period was 10% more in the sprayed than in the fallowed section. This resulted from changes in dormancy of certain species and not from decreasing the proportion of very dormant species present. *Vicia sativa*, *Ranunculus arvensis* (Corn Buttercup), *Papaver rhoeas* and *P. argemone* (Poppies) and *Odontites verna* (Red Bartsia) were most affected, but never all four species in one year or one species in all 4 years for which there are complete records. Germination was from 10% to 49% more than in the fallowed section during the first year. Compensation for this was usually at the expense of second-year germination but in *Odontites* more of the difference came from the third year.

b) RESULTS - ANNUALS

No species has been eliminated by 7 years' spraying but Vicia sativa decreased to 5% of its original abundance and concentration of seeds in soil. Ranunculus arvensis, the second most severely affected species, decreased to 40% by 1961. Neither of these species was well controlled by fallow because only 50% of their seeds germinate in the first year. 26% of Vicia and 2% of Ranunculus seeds remain dormant for at least 3 years in soil samples in the glasshouse. Winter-germinating Ranunculus was greatly decreased on both sections in the 1961 crop, which was not sown until January because of wet weather in autumn 1960. The exceptionally cold winter 1962-3 delayed Ranunculus seedling emergence but scarcely affected its abundance (Thurston, 1964).

Medicago lupulina (Black Medick) is now less abundant on IA than IB but the reserve of seeds in soil on the sprayed section decreased slowly because it was replenished by plants emerging after the herbicide application and seeding before the stubble was ploughed. Medicago was not well controlled by fallow because less than half of the seeds germinated in their first year in soil. Germination may continue for at least 5 years and 16% germinate in the third year.

Up to 1963 there was no evidence of declining fertility on plots receiving no nitrogen where Medicago and Vicia (and hence their nodules with nitrogen-fixing bacteria) have been decreased by herbicides.

Other species substantially decreased by herbicides were Arenaria serpyllifolia (Thyme-leaved Sandwort), Polygonum aviculare (Knotgrass), Stellaria media (Chickweed) and Valerianella locusta (Lamb's Lettuce). All were also decreased by the fallow year but soon multiplied until they were more abundant than before.

Alopecurus myosuroides (Blackgrass) was not controlled by the herbicides used on IA, and multiplied there. However, only the 1960 crop was sown early (19.10.59) so Alopecurus increased only slowly in continuous wheat from 1955 to 1963; fallowing checked it on IB (see also Thurston, Germination of Alopecurus, in Forage Crops Section of this Conference).

Tripleurospermum maritimum (Scentless Mayweed) was also uncontrolled by the herbicides used; it multiplied on IA. A fallow year decreased the seeds in the soil by about 23% and hence the number of plants in the following year, but wheat-bulb fly (Leptohylemyia coarctata), which lays its eggs in bare ground, caused gaps in the first crop after fallow and in these the Tripleurospermum plants grew large, quickly replenishing the reserve of seeds in the soil (Thurston, 1963). Tripleurospermum produced more seeds in the warm dry summer of 1959 than in the wet seasons.

Aphanes arvensis (Parsley Piert), Specularia hybrida (Venus' Looking Glass), Veronica arvensis (Wall Speedwell) and Euphorbia exigua (Dwarf Spurge) all increased in continuous wheat in spite of the herbicides used. They are small plants which probably benefit from lessened competition when some of the larger weeds are killed. Of these four species, only Veronica with the smallest percent dormant seeds was much decreased by fallow and it quickly recovered; by 1960 its seeds were 9 times as numerous as at the end of the previous fallow cycle.

Myosotis arvensis (Forget-me-not) was less affected by herbicide than expected for a species germinating mainly before spraying and susceptible to all the herbicides used except mecoprop. It was decreased by fallow but soon multiplied under crop. Its seeds were more numerous and a greater proportion was dormant after wet seasons than after dry ones.

Avena ludoviciana and A. fatua (Wild Oats) were hand-pulled because neither herbicides nor fallow controlled them.

c) RESULTS - PERENNIALS

Perennial grasses, chiefly Agrostis stolonifera (Creeping Bent), Phleum pratense (Timothy) and Poa trivialis (Rough-stalked Meadow Grass) spread slowly in the continuous wheat. No grass-killing herbicides were used. Grasses did not increase on the fallowed section.

Equisetum arvense (Field Horsetail) increased by the same amount on both sections from 1956 to 1963, returning to the slightly above-average score recorded in 1955.

Cirsium arvense (Creeping Thistle) decreased slightly under continuous wheat with herbicides. It decreased after each fallow and multiplied again to its original amount under subsequent crops.

DISCUSSION

Five-sixths of the weed species on Broadbalk are annuals. Annual plants depend entirely on their seeds for propagation, so total seed production is very important. It depends on the number of plants per unit area, their size, and suitability of weather for pollination and ripening of seeds. Most of the annuals studied also had some dormant seeds, but the proportion varied with the species and sometimes also with weather and treatment.

Dormant seeds enabled species to survive 1-year destruction by herbicide or fallow and to resist destruction by spraying with herbicides for 7 consecutive years.

The total effect of herbicide or fallowing on weediness depends on the reaction of the different species to the treatment and the interaction of the surviving plants with each other and the crop.

On this weedy field, using herbicides increased the total yield of uncleaned wheat grain in a 5-year period by only 2 cwt/ac/year i.e. 10 cwt total yield over the 5-year period above that obtained by fallowing for one year of the five. The increases per plot varied with fertilizer treatment and weed flora from 0.5 to 5.0 cwt/ac/year. Discussion of differences in yield per plot is deferred, awaiting purity-analyses of 1st-grade grain samples. Although Vicia and Ranunculus were much less after 7 years' continuous wheat with herbicides than after fallowing every fifth year, and total weed seeds in the soil were 15% less than on the fallowed section, Alopecurus and perennial grasses, Tripleurospermum and several small annual weeds had increased in the continuous wheat. It is doubtful if the cost of spraying this field was justified either in increased wheat yield or in freedom from weed-seeds and rhizomes of perennial weeds in the soil. The appearance of the sprayed strip was, however, much improved by removing the Vicia climbing up the wheat, and the carpet of Medicago and Ranunculus beneath it, on the plots receiving no nitrogen.

2) FATE OF WEED-SEEDS IN COMBINE-HARVESTED WHEAT

METHOD

In 1958, samples of 1st grade wheat, "seconds" and "rubbish" were taken from the three spouts of the Massey-Harris 780 combine-harvester during harvesting of 4 plots where weed species with different seed-sizes occurred. Samples of the straw and chaff thrown out by the combine were collected on a cloth carried behind the machine on part of each plot. On the rest of each plot the straw and chaff were allowed to fall on the ground and were subsequently picked up and baled in the usual way. Samples were taken of the straw and chaff from the cloth and from the bales. The number of weed seeds left behind on the ground was calculated by difference. Unfortunately, the number of weed-seeds shed on to the ground before harvesting was not determined.

RESULTS AND DISCUSSION

Taking the average of the four selected plots, the numbers and distribution of weed-seeds in the produce from one acre were :-

Removed in 1st grade grain approx.	7	million	=	28.0%
" " "seconds"	12	"	=	47.5%
" " rubbish from 3rd spout	4	"	=	16.0%
" " baled straw	1.25	"	=	4.5%
TOTAL REMOVED	24.25	"		96.0%
Left behind on soil	1	"	=	4.0%
TOTAL SEEDS PRESENT AT HARVEST	25.25	"		100.0%

Only 4% of the total weed seeds still on the plants at harvest were returned to the soil and 4.5% were removed in the baled straw. Most weed-seeds were in the "seconds" so it would be advisable to grind this material before feeding it to animals, to avoid distributing live weed-seeds around the farm.

The 1st-grade wheat fraction contained more than a quarter of all the weed-seeds. It would require cleaning before sowing or milling.

The rubbish fraction is a discard, but it should be carefully disposed of (e.g. burnt) so that the weed seeds do not infest agricultural land.

The proportion of each weed species occurring in the different grain fractions depended on the size of the units. Large seeds of Vicia sativa occurred mainly with the 1st grade grain, medium sized seeds e.g. Aethusa cynapium (Fool's Parsley), Polygonum aviculare (Knotgrass), Chenopodium album (Fat Hen) and Alopecurus myosuroides mainly in the "seconds" and small seeds e.g. Tripleurospermum maritimum, Odontites verna and Papaver spp. mainly in the "rubbish". However, whole ears of Alopecurus, capsules of Papaver and Bartsia, and fruits of Aethusa with the two seeds not separated, were occasionally found in the 1st grade grain and small Vicia seeds in the "seconds" or rubbish. The small, shiny seeds of Myosotis arvensis were the only ones among the abundant species never found in the 1st grade grain - a few appeared in the "seconds" and most in the "rubbish".

The distribution of Medicago lupulina was unusual. Only 53% appeared in the "seconds" among similar-sized seeds and 13% (the smallest) in the "rubbish". The remaining 34% got into the 1st grade grain, still attached to whole inflorescences. Moreover, 300,000 more seeds per acre were found in the baled straw than in the material collected on the cloth behind the combine. Evidently the baler had picked up off the ground seed-bearing Medicago plants not cut by the combine. This also happened with Vicia, although only 4,600 extra seeds per acre were picked up.

In all other species some seeds cut by the combine were left on the ground by the baler. The proportion left was greater in the smaller-seeded species.

Polygonum aviculare, Chenopodium album (Fat Hen), and Atriplex patula (Orache) were the most numerous seeds in baled straw because the unripe seeds were not easily knocked off the stems.

Acknowledgement

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References

BRENCHLEY, W.E. and WARINGTON, K. (1930) The weed seed population of arable soil. I. Numerical estimation of viable seeds and observations on their natural dormancy. J. Ecol., 18, 235-272.

THURSTON, J.M. (1964) Broadbalk weeds. Rep. Rothamst. exp. Sta. for 1963, 89-90.

WARINGTON, K. (1958) Changes in the weed flora on Broadbalk permanent wheat field during the period 1930-1955. J. Ecol., 46, 101-113.

EMERGENCE OF WEED SEEDLINGS IN THE FIELD AND THE EFFECTS OF DIFFERENT FREQUENCIES OF CULTIVATION

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Summary. At the end of each month for twenty months, plots in a weedy field were hand-weeded and all seedlings identified and counted. After weeding, the plots were cultivated either monthly, three-monthly, yearly or never. The results show that species varied greatly in their periods of emergence and in their response to different cultivation frequencies. From the results it is suggested that germination response to soil disturbance is one of the most important factors that determine weed behaviour in arable land: furthermore, that herbicides can modify weed floras not only by direct toxic action, but by reducing the number of cultivations necessary and so affecting germination.

INTRODUCTION

Underlying one of the greatest problems of arable farming is the large reserve of weed seeds in the soil, which under present systems of agriculture in Britain give rise to flushes of seedlings at crucial periods of the year. Relatively little is known about periods of emergence of weed seedlings in the field (Salisbury 1961, Garese 1962) and it was thought that a better knowledge might assist in improving control measures. Three experiments were started in 1962 in weedy arable fields and the results of one of them are given here. They were designed to show which months are favourable for the germination of a number of species to see if any features of germination behaviour could be exploited as a means of improving existing control measures: also to investigate the effects of different frequencies of cultivation upon seedling emergence to see whether herbicides, by reducing the number of cultivations in agriculture, have thereby any indirect effect upon the occurrence and numbers of weeds.

METHODS AND MATERIALS

The experiment (W/4/62) was laid down at Begbroke Hill on 19 April, 1962 on a weedy, poorly-drained soil which had been worked down to a fine seed-bed. The field had been sown to spring barley in 1960 and 1961 following approximately thirty years of permanent pasture. The locality was chosen because it was characterised by *Ranunculus repens* and *Polygonum persicaria*, both indicating a high water-table, which is in contrast with the dryer locations of the other two experiments. The layout consisted of twenty four one-square-yard plots, each with a two-inch surrounding discard. The four treatments, each replicated six times, were: (a) plots cultivated at the end of each calendar month, (b) plots cultivated after every three calendar months (end of April, July, etc.), (c) plots cultivated once a year (end of April) and (d) plots left uncultivated. All cultivations were carried out by digging the soil to a depth of nine inches with a spade and smoothing it down to a seed-bed. Cultivations due at the end of December 1962 and January 1963 were prevented by frost and snow. Assessments, which began on June 6th, nearly seven weeks after the start of the experiment, were made by hand-weeding each plot at approximately the end of every calendar month and recording the number of each species. Cultivations were carried out as soon as each assessment was finished.

Table 1.

Monthly emergence of weeds and the effects of different cultivation frequencies:
Total seedlings on six 1 sq.yd. plots

(M = plots dug every month, 3-M = dug every three months, Y = dug once a year, N = never dug)

	May 1962	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Jan 1963	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
ANAGALLIS ARVENSIS																						
M	545	0	12	15	52	8	0	0	632	0	0	728	141	148	135	2	118	76	34	2	0	1384
3-M	588	248	3	8	48	40	0	0	935	0	0	1012	271	269	74	27	141	128	29	0	0	1951
Y	567	296	4	8	22	25	0	0	922	0	0	268	133	320	93	17	41	37	24	5	2	940
N	567	250	4	5	15	20	0	0	861	0	0	286	137	131	44	15	8	44	5	1	1	672
Tot.	2267	794	23	36	137	93	0	0	3350	0	0	2294	682	868	346	61	308	285	92	8	3	4947
VIOLA ARVENSIS																						
M	91	0	2	12	50	63	0	0	218	0	2	174	29	12	20	9	14	124	59	3	0	446
3-M	28	13	1	7	26	44	1	0	120	0	0	212	29	20	33	5	40	17	23	0	1	380
Y	70	10	2	2	15	25	4	0	128	0	0	129	35	19	33	0	14	53	47	13	0	343
N	50	9	1	0	6	43	6	0	115	0	0	94	18	9	1	2	7	37	16	10	4	198
Tot.	239	32	6	21	97	175	11	0	581	0	2	609	111	60	87	16	75	231	145	26	5	1367
TRIFOLIUM REPENS																						
M	24	0	3	0	1	5	0	0	33	0	0	24	27	8	4	19	6	9	10	1	0	108
3-M	24	22	1	2	3	3	0	0	55	0	0	23	11	20	16	22	5	15	10	2	0	124
Y	32	36	5	0	1	3	0	0	77	0	0	3	5	12	9	15	17	11	11	1	0	84
N	29	25	5	0	1	1	1	0	62	0	0	10	13	8	1	25	5	3	1	0	0	66
Tot.	109	83	14	2	6	12	1	0	227	0	0	60	56	48	30	81	33	38	32	4	0	382
SENECIO VULGARIS																						
M	3	0	1	11	18	6	0	0	39	0	0	10	4	3	68	23	153	191	168	6	0	626
3-M	4	0	1	9	33	10	0	0	57	0	0	4	5	11	104	54	62	126	91	12	3	472
Y	7	2	3	7	82	9	0	0	110	0	0	20	7	12	84	38	120	170	87	44	3	585
N	3	0	3	3	10	2	0	0	21	0	0	11	7	5	91	122	220	177	107	41	6	787
Tot.	17	2	8	30	143	27	0	0	227	0	0	45	23	31	347	237	555	664	463	103	12	2470

Table 1

Monthly emergence of weeds and the effects of different cultivation frequencies:

Total seedlings on six 1 sq.yd. plots

(M = plots dug every month, 3-M = dug every three months, Y = dug once a year, N = never dug)

APHANES ARVENSIS

	1962 May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	1963 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
M	35	0	9	213	305	216	0	0	778	0	0	182	3	0	29	2	385	363	213	7	0	1184
3-M	30	17	4	220	277	105	0	0	653	0	0	171	85	0	3	1	551	164	37	8	14	1034
Y	24	16	7	173	210	103	2	0	535	0	3	19	20	1	7	10	513	157	68	35	8	841
N	28	15	5	170	195	79	0	0	492	0	2	37	17	6	2	1	102	73	25	20	13	298
Total	117	48	25	776	987	503	2	0	2458	0	5	409	125	7	41	14	1551	757	343	70	35	3357

SONCHUS ASPER

	1962 May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	1963 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
M	3	0	2	0	11	2	0	0	18	0	0	6	5	4	3	0	24	16	4	0	0	62
3-M	4	0	0	1	13	7	0	0	25	0	0	3	5	3	0	2	31	16	5	0	0	65
Y	0	1	1	2	11	3	0	0	18	0	0	3	4	1	2	3	58	25	13	3	0	112
N	0	0	1	9	34	22	0	0	66	0	0	1	6	4	2	4	55	42	27	6	1	148
Total	7	1	4	12	69	34	0	0	127	0	0	13	20	12	7	9	168	99	49	9	1	387

POA ANNUA

	1962 May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	1963 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
M	0	0	0	0	0	0	0	0	0	0	0	4	0	0	4	13	7	8	3	1	0	40
3-M	0	0	0	8	29	15	1	0	53	0	0	14	0	0	8	22	23	10	4	2	0	83
Y	0	0	0	2	3	7	1	0	13	0	1	7	0	0	7	42	10	3	3	0	0	73
N	0	0	0	3	9	9	1	0	22	0	2	1	0	0	1	0	4	6	2	1	0	17
Total	0	0	0	13	41	31	3	0	88	0	3	26	0	0	20	77	44	27	12	4	0	213

CERASTIUM VULGATUM

	1962 May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	1963 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
M	0	0	0	0	0	0	0	0	0	0	0	7	1	0	2	0	5	41	3	0	0	59
3-M	0	0	0	0	0	0	0	0	0	0	0	8	4	0	4	0	4	7	1	0	0	28
Y	0	0	0	1	2	1	0	0	4	0	0	4	1	0	0	2	14	5	2	2	1	31
N	0	0	0	0	0	1	0	0	1	0	0	5	1	0	0	0	5	1	3	2	0	17
Total	0	0	0	1	2	2	0	0	5	0	0	24	7	0	6	2	28	54	9	4	1	135

Table 1

Monthly emergence of weeds and the effects of different cultivation frequencies:
Total seedlings on six 1 sq.yd. plots

(M = plots dug every month, 3-M = dug every three months, Y = dug once a year, N = never dug)

	1962 May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	1963 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
RAPHANUS RAPHANISTRUM																						
M	8	0	3	2	12	14	0	0	39	0	0	23	14	8	2	1	5	6	3	0	0	62
3-M	18	0	0	3	6	0	0	0	27	0	0	19	1	10	2	0	13	0	0	0	0	45
Y	12	0	0	1	0	0	0	0	13	0	0	2	2	29	2	0	1	0	0	0	0	36
N	16	0	0	0	5	1	0	0	22	0	0	5	0	0	0	0	1	0	0	0	0	6
Total	54	0	3	6	23	15	0	0	101	0	0	49	17	47	6	1	20	6	3	0	0	149
TARAXACUM OFFICINALE																						
M	4	0	3	3	0	0	0	0	10	0	0	1	1	4	4	0	3	11	4	0	0	28
3-M	6	2	1	5	3	3	0	0	20	0	0	3	1	2	10	4	5	4	2	0	0	31
Y	3	7	3	2	2	2	0	0	19	0	1	0	0	2	21	6	6	8	0	0	1	45
N	9	1	3	0	1	2	0	0	16	0	0	0	1	3	15	4	15	11	9	0	2	60
Total	22	10	10	10	6	7	0	0	65	0	1	4	3	11	50	14	29	34	15	0	3	164
SAGINA PROCUMBENS																						
M							0	0	0	0	0	25	0	0	1	0	0	0	2	0	0	28
3-M							0	0	0	0	0	85	69	0	0	0	0	0	9	0	0	163
Y	OVERLOOKED BEFORE						22	0	22	0	2	23	53	0	0	0	0	0	11	7	8	104
N	NOVEMBER ASSESSMENT						9	0	9	0	7	32	52	0	5	2	2	0	43	39	28	210
Total							31	0	31	0	9	165	174	0	6	2	2	0	65	46	36	505
RANUNCULUS REPENS																						
M	42	0	5	17	17	0	2	0	83	0	0	23	12	17	24	0	102	15	3	2	0	198
3-M	29	7	0	17	28	6	2	0	89	0	0	25	17	16	17	6	73	10	1	0	0	165
Y	36	11	2	4	4	2	7	0	66	0	0	9	5	8	33	4	21	24	2	1	0	107
N	31	15	2	2	2	1	6	0	59	0	0	0	2	3	3	3	14	8	0	1	0	34
Total	138	33	9	40	51	9	17	0	297	0	0	57	36	44	77	13	210	57	6	4	0	504

Table 1

Monthly emergence of weeds and the effects of different cultivation frequencies:
Total seedlings on six 1 sq.yd. plots

(M = plots dug every month, 3-M = dug every three months, Y = dug once a year, N = never dug)

	1962 May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	1963 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
POLYGONUM PERSICARIA																						
M	13	0	0	0	0	0	0	0	13	0	0	33	7	14	3	1	0	0	0	0	0	58
3-M	14	2	0	0	0	0	0	0	16	0	0	45	9	24	5	0	0	0	0	0	0	83
Y	20	0	1	0	0	0	0	0	21	0	0	27	8	22	3	0	0	0	0	0	0	60
N	24	4	0	0	0	0	0	0	28	0	0	8	6	1	0	0	0	0	0	0	0	15
Total	71	6	1	0	0	0	0	0	78	0	0	113	30	61	11	1	0	0	0	0	0	216
JUNCUS BUFONIUS																						
M	OVERLOOKED IN 1962									0	0	0	0	0	0	0	0	4	6	0	0	10
3-M										0	0	0	399	8	1	2	0	13	33	2	1	459
Y										0	0	0	250	6	2	0	0	18	41	26	9	352
N										0	0	0	268	79	13	2	0	12	28	20	14	436
Total										0	0	0	917	93	16	4	0	47	108	48	24	1257
GNAPHALIUM ULIGINOSUM																						
M	0	0	0	2	0	0	0	0	2	0	0	0	0	0	7	0	0	0	0	0	0	7
3-M	0	2	0	2	1	0	0	0	5	0	0	0	124	1	2	1	0	24	10	0	0	162
Y	0	0	0	5	10	0	0	0	15	0	0	0	149	1	0	0	0	5	0	0	0	155
N	0	0	0	5	9	0	0	0	14	0	0	0	224	94	6	2	0	14	3	1	0	344
Total	0	2	0	14	20	0	0	0	36	0	0	0	497	96	15	3	0	43	13	1	0	668
ARABIDOPSIS THALIANA																						
M	0	0	0	2	0	0	0	0	2	0	0	7	0	0	0	0	0	3	0	0	0	10
3-M	1	0	0	0	11	21	0	0	33	0	0	11	23	0	0	1	0	45	4	0	0	84
Y	1	0	0	0	21	22	2	0	46	0	1	12	11	0	0	0	0	28	11	14	2	79
N	0	0	0	2	14	14	2	0	32	0	0	10	15	5	1	1	1	19	3	3	2	60
Total	2	0	0	4	46	57	4	0	113	0	1	40	49	5	1	2	1	95	18	17	4	233

RESULTS AND DISCUSSION

Periods of germination. The sixteen species listed in table 1 contain five weeds which, because they germinate mainly in spring, can be considered to be summer annuals i.e. Anagallis, Gnaphalium, Polygonum, Juncus and Raphanus. Similarly there are four species which germinate mainly in autumn, i.e. Senecio, Poa, Aphanes and Sonchus, and seven other species that germinate at both times of the year, i.e. Viola, Trifolium, Cerastium, Taraxacum, Sagina, Ranunculus and Arabidopsis. It is known that different races of Senecio and Poa can germinate at any suitable period (Salisbury 1961) and in view of their short life-span they cannot therefore be classified as winter annuals like Aphanes and Sonchus.

The effects of cultivation frequency. The data in table 1 show three general categories of response by the plants to the different cultivation treatments:

(a) The "Arable Weed Response" which is characterised by the fact that, within reason, the more the soil is cultivated the more seeds germinate, e.g. Aphanes, Raphanus, Viola, Ranunculus and possibly Cerastium. This type of response is well illustrated by Raphanus in Fig.1. The plots cultivated monthly show the trends of seed emergence throughout the year. The results of plots dug every three months show, after the initial spring flush in March, two subsidiary flushes of emergence in May and August. These flushes followed the stimulatory effects of cultivation (lasting for less than a month) at the end of April and July respectively. Even more pronounced is the peak of emergence in May of the plots cultivated only once a year at the end of April. Several other important weeds have behaved similarly in the other experiments (data as yet unpublished).

(b) The "Inverse Response" is characterised by a decrease of germinations with increased frequency of cultivations e.g. Gnaphalium, Sonchus, Taraxacum, Juncus and Sagina. Details of this response are well-shown by Sonchus in Fig.2. Unlike Raphanus there is no direct response to particular cultivations, but the inverse relation between emergence and cultivations is noticeable during the autumn peak. The weeds in this group tend to occur more frequently in waste places, waysides and artificial habitats which are normally undisturbed, rather than on arable land and from this it is suggested that the germination responses of species to cultivation may well determine how serious they are as weeds or even whether they become weeds at all. It is possible that these two responses are conditioned solely by alteration of the oxygen concentration, which would influence weed germination (Müllverstedt 1963), but other factors may also be involved. The cultivation responses of several wild non-weedy plants will be investigated to obtain further information on this aspect.

(c) The "Intermediate Response" may be conditioned by more than one factor, for example Arabidopsis appears to prefer a few cultivations to too many or none, while Polygonum may have been greatly influenced by the fact that all three cultivation treatments occur at the end of April, which is normally the only month when appreciable germination occurs in this species. The possible multiplicity of causes for the intermediate responses of this group appears to be borne out by the differing degrees of importance of the weeds within it, e.g. Trifolium, Senecio, Anagallis, Poa, Polygonum and Arabidopsis.

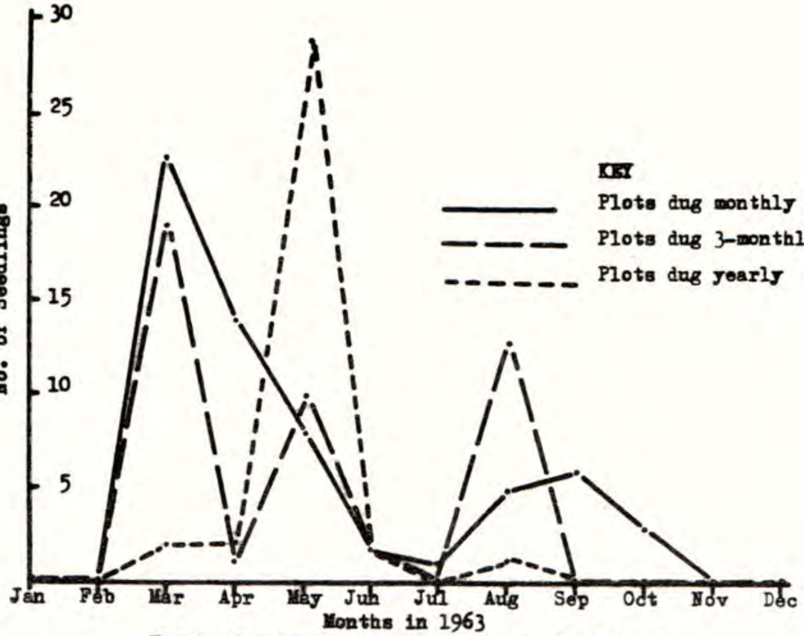

Fig.1. Germinations of Raphanus raphanistrum

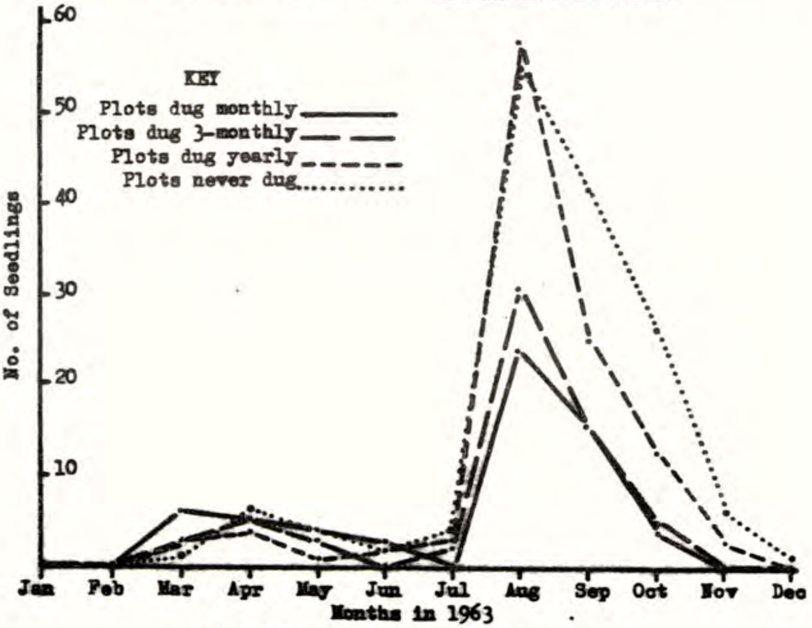

Fig.2. Germinations of Sonchus asper

<u>The differences between the two years.</u> Because the experiment did not start until April 1962 a direct comparison can only be made of the autumn peaks of emergence. The autumn peaks of emergence of six species occurred a month earlier in 1963 than in 1962 and all but one of these six showed higher emergence totals in the autumn of 1963.

<u>Dry weather in June 1962.</u> Five species, <u>Anagallis</u>, <u>Viola</u>, <u>Trifolium</u>, <u>Aphanes</u> and <u>Ranunculus</u>, did not emerge at all in June 1962 on plots dug every month, although they did on other plots. This is attributed to the low monthly rainfall (0.19 inches) which allowed the uncapped soil on these plots to dry out to a level insufficient for the germination of these species. A similar effect is shown by <u>Sagina</u>, <u>Juncus</u>, <u>Gnaphalium</u>, <u>Arabidopsis</u> and <u>Aphanes</u> in April 1963, out as the months rainfall amounted to 1.93 inches and was well distributed, this indicates that a factor other than drought was the main operating factor, especially as three species belong to the "Inverse Response" group, unlike those species showing the effect in June 1962, which mostly belong to the "Arable Weed Response" group.

<u>A possible cause of change in weed floras.</u> The most significant feature of these results lies in the possibility of marked changes in weed floras that could occur following a reduction in cultivations made possible by extensive use of herbicides. Fewer cultivations could reduce the numbers of weeds belonging to the "Arable Weed Response" group, but equally they may increase the numbers of other species showing an "Inverse Response", so that populations of weeds treated with relatively non-persistent herbicides, but undergoing fewer cultivations, may not necessarily alter greatly in density, although they could change greatly in species composition.

<u>Better weed control.</u> The other practical conclusion from this work is that an aspect of weed seed germination behaviour that can be exploited for weed control, particularly of dense infestations of one species, lies in choosing crops and sowing dates in relation to the emergence of the weeds. For example, growing winter cereals in fields infested with <u>Polygonum persicaria</u>, and similarly spring cereals with weeds that emerge in the autumn.

Acknowledgements

Acknowledgement is made to Miss J. McLellan, Miss P. Adams and Miss A. Janson-Smith for their assistance both in assessing the experiment and preparing this paper.

References

GARESE, P. (1962), [Germination of Weeds in relation to the sowing time of Crops] , Idia, 179, 36–40 [Spanish]

MÜLLVERSTEDT, R. (1963) [Investigations on the Germination of Weed Seeds as influenced by Oxygen Partial Pressure] Weed Res, 3, 154–163 [German]

SALISBURY, E.J. (1961) Weeds and Aliens. Collins, London pp.384.

THE DEPTH OF WEED SEED GERMINATION IN THE FIELD

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Summary. Batches of one hundred seedlings of each of eighteen weed species were dug up in arable fields after they had germinated naturally and the depth of each seed from the soil surface measured. The measurements were duplicated where possible in peat, clay and sandy soils, in spring and autumn and repeated in two successive years. The results show that a few species emerge only from very shallow layers of soil (1.2 inches or less). A few others can emerge from relatively great depths (down to 5.1 inches), but the majority arise from shallow to moderate depths (98% of all the seedlings measured came from less than two inches depth). Changes in the pattern of germination depths with time were investigated at regular intervals in *Veronica hederifolia*. The results showed a progressive increase in maximum depths of germination between January and March, 1964. This is taken as indicating the rate at which the soil at increasing depths attains conditions suitable for germination.

INTRODUCTION

During 1962 the question of what depth weed seedlings emerged from was raised in connection with the depth to which relatively insoluble herbicides should be incorporated in the soil to obtain efficient control of emerging weed seedlings. No previous work on this aspect of weed seed germination is known (except that of Roberts 1962), so in 1963 and 1964 a series of *ad hoc* measurements were made on a number of common arable weeds occurring naturally in the field under a wide range of conditions, to discover whether species differ greatly from each other in this respect, and the extent, if any, to which depth of germination is influenced by soil or other conditions.

METHODS AND MATERIALS

Batches of one hundred seedlings of each of eighteen common weeds were dug up after they had germinated under natural conditions in cultivated fields and assessments of their depth of germination were made. Only very common annual weeds of arable ground were selected. If possible the seedlings chosen for digging up were at the cotyledon to two true-leaf stage. This growth stage was chosen because at later stages it is often difficult to determine the precise point of attachment of the seed; furthermore, in older seedlings it was occasionally noticed that appreciable soil erosion had occurred from around the hypocotyl, which could also lead to incorrect depth measurements. No note was made of the time elapsed since the last cultivation in each field. This may possibly have influenced the measurements slightly by altering the rate of soil compaction or erosion.

After washing the seedlings, the distance between the seed (if present) or its point of attachment and the point along the hypocotyl at which it had emerged from the soil surface (marked in most species by the beginning of the zone of coloration by chlorophyll or other pigments) was measured.

Where possible, the measurements were repeated for each species at two periods of the year, i.e. spring and autumn and in two successive years, 1963 and 1964, although the poor weed germination in the dry autumn of 1964 prevented any measurements being made then. To increase the range of conditions investigated, three different soil types were selected and species were measured on two of them if their seedlings were present in sufficient numbers. These soils were: (a) a clay loam at the Oxford University Field Station, Wytham, (b) a peat soil at Broad Fen Farm, Methwold, Norfolk, and (c) a sandy loam at the Weed Research Organisation. No attempt was made to obtain similar conditions with regard to crops or previous cultivations.

The investigation of changes of germination depth trends with time was carried out with Veronica hederifolia because it can germinate from relatively great depths. These measurements were made at the Weed Research Organisation in Deal Ground, a field of light sandy soil which in 1964 carried both winter wheat and spring barley. In the winter wheat area, batches of one hundred seedlings were measured every two weeks, starting on 9th January, but after the 20th February measurements were made weekly until the 26th March when the wheat was sprayed with herbicide. Later, weekly measurements were started in the spring barley (sown mid-March) on 24th April and ended on 15th May, when this too was sprayed. The youngest seedlings were selected at each assessment to ensure that only the most recently emerged were measured.

RESULTS

All the figures obtained, are given in table 1 below and are expressed as the percentage of each batch of seedlings germinating at soil depth intervals of one centimetre.

Table 1.

Percentages of seedlings of eighteen common weeds germinating from various depths.

Soil types:- S = sandy loam, C = clay loam, P = peat

Weed	Aethusa cynapium			Atriplex patula	Chenopodium album				Chrysanthemum segetum		
Year	'63	'63	'64	'63	'63	'63	'64	'64	'63	'63	'64
Date	23/4	22/4	24/4	22/4	23/5	17/5	14/5	29/5	15/5	25/9	13/5
Soil	S	C	S	C	C	P	C	P	S	S	S
Depth (cm)											
0 - 1	58	33	57	57	9	31	86	71	11	70	63
1 - 2	26	37	30	24	46	53	10	23	40	23	22
2 - 3	15	15	10	9	32	14	3	4	38	7	7
3 - 4	1	12	1	6	10	2	0	2	6		6
4 - 5		10	2	3	2		0		5		1
5 - 6		2		0	1		1				1
6 - 7		0		1							1
7 - 8		1									

Weed	Fumaria officinalis			Matricaria recutita		Papaver rhoeas			Polygonum aviculare	
Year	'63	'63	'64	'63	'63	'63	'63	'64	'63	'64
Date	1/4	25/9	15/4	15/5	9/9	15/5	9/9	24/4	19/4	15/4
Soil	S	S	S	S	S	S	S	S	S	S
Depth (cm)										
0 - 1	14	23	33	97	96	48	70	63	36	47
1 - 2	50	29	27	3	4	46	24	31	37	43
2 - 3	21	24	16			6	6	6	21	7
3 - 4	11	17	16						4	3
4 - 5	1	7	4						2	
5 - 6	1		1							
6 - 7	2		1							
7 - 8			1							
8 - 9			1							

Weed	Polygonum convolvulus				Polygonum lapathifolium				
Year	'63	'63	'64	'64	'63	'63	'63	'64	'64
Date	23/5	23/5	13/5	14/5	14/6	23/5	17/5	14/5	29/5
Soil	S	C	S	C	S	C	P	C	P
Depth (cm)									
0 - 1	6	0	11	42	17	7	14	75	52
1 - 2	25	12	24	27	31	28	45	13	26
2 - 3	32	24	14	19	23	33	29	6	10
3 - 4	20	25	16	6	12	23	10	4	5
4 - 5	4	15	13	2	9	8	2	1	4
5 - 6	8	10	11	0	4	1		1	2
6 - 7	2	11	7	3	2				1
7 - 8	2	2	2	0	2				
8 - 9	1	2	1	1					
9 - 10			0						
10 - 11			0						
11 - 12			1						

Weed	Polygonum persicaria			Raphanus raphanistrum			Senecio vulgaris				
Year	'63	'63	'64	'63	'63	'64	'63	'63	'63	'64	'64
Date	21/5	17/5	29/5	15/5	25/9	13/5	15/5	9/9	17/5	14/5	29/5
Soil	S	P	P	S	S	S	S	S	P	S	P
Depth (cm)											
0 - 1	7	35	71	6	63	52	35	93	40	79	80
1 - 2	14	32	24	32	19	22	29	7	58	15	19
2 - 3	29	10	5	29	7	12	24		2	4	1
3 - 4	22	11		14	9	6	7			2	
4 - 5	18	2		11	2	5	4				
5 - 6	6			7		1	0				
6 - 7	4					2	1				

Weed	Sinapis arvensis	Stellaria media				Urtica urens				
Year	'63	'63	'63	'63	'64	'63	'63	'63	'64	'64
Date	23/5	22/5	9/9	17/5	29/5	21/5	7/9	17/5	23/5	29/5
Soil	C	S	S	P	P	S	S	P	S	P
Depth (cm)										
0 - 1	12	40	75	52	48	54	81	26	35	56
1 - 2	38	46	17	44	41	26	19	44	38	30
2 - 3	29	12	8	4	10	17		17	21	11
3 - 4	10	2			1	3		8	5	3
4 - 5	7							3	0	
5 - 6	3							2	1	
6 - 7	1									

Weed	Veronica persica					Viola arvensis		
Year	'63	'63	'63	'63	'64	'63	'63	'64
Date	23/5	25/9	22/4	16/9	14/5	19/4	25/9	24/4
Soil	S	S	C	C	C	S	S	S
Depth (cm)								
0 - 1	36	71	46	99	43	77	51	24
1 - 2	38	26	26	1	32	22	36	36
2 - 3	18	3	13		18	1	11	32
3 - 4	7		8		6		2	6
4 - 5	1		3		1			2
5 - 6			4					

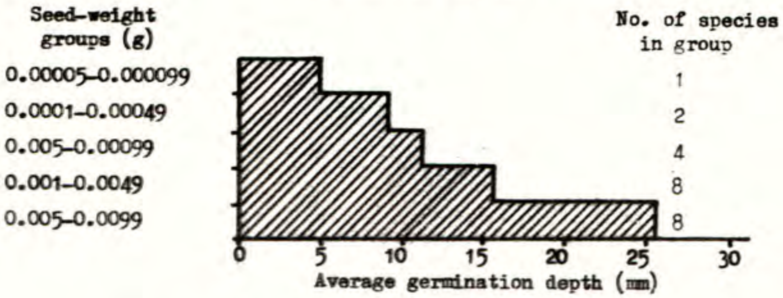
Assessments of the changes in the percentages of Veronica hederifolia at different depths with time are given in table 2 as the percentage of each batch of seedlings germinating from soil depth intervals of one centimetre.

Table 2

Percentages of seedlings of Veronica hederifolia germinating from various soil levels over five months.

Depth (cm)	Dates of assessments in winter wheat									spring barley		
	9/1	23/1	6/2	20/2	27/2	5/3	12/3	19/3	26/3	24/4	1/5	8/5
0 - 1	25	16	17	16	24	14	11	19	13	25	12	37
1 - 2	20	24	23	14	8	7	9	8	14	32	38	18
2 - 3	26	22	16	10	18	6	22	9	10	28	25	18
3 - 4	10	19	16	10	14	12	8	14	10	7	10	12
4 - 5	13	14	11	19	8	15	21	8	13	8	8	7
5 - 6	5	2	14	13	9	9	8	10	13		5	2
6 - 7	1	2	1	11	9	16	8	16	10		2	5
7 - 8		1	2	5	6	10	7	10	7			0
8 - 9				2	3	8	0	4	6			0
9 -10					1	2	3	1	1			0
10 -11						1	2	0	1			1
11 -12							1	1	1			
12 -13									1			

Fig.1. The relationship between seed size and average germination depth



DISCUSSION

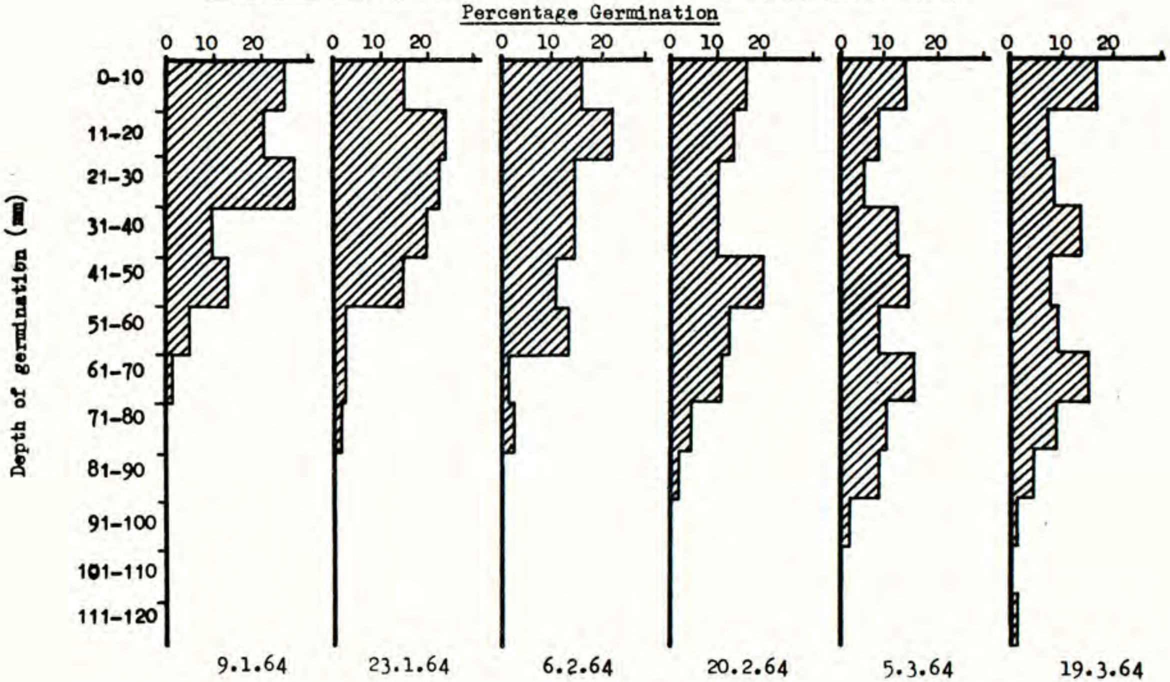
Differences between species. The results in table 1 indicate that some species germinate only in the topmost layers of the soil e.g. *Matricaria recutita* and *Papaver rhoeas* from 0 - 3 cm., while other species can germinate from relatively great depths, e.g. *Polygonum convolvulus* and *Veronica hederifolia* from 0 - 13 cm. The majority, however, arise from shallow to moderate depths (0 - 7 cm). These results agree very well with those obtained at the National Vegetable Research Station (Roberts, 1962). Species that germinate shallowly may be reflecting a particular requirement for germination e.g. *Matricaria recutita* germinates better in light (Gleisberg, 1954; Klein, 1956) or the seed size may be a limiting factor. Conversely, species that germinate from considerable depths may be able to do so by virtue of their larger seeds (fig. 1), and greater food reserves; it may also be because their germination requirements are fewer or less restricting.

It is not known whether small-seeded weed species germinate at greater depths than those recorded and fail to reach the surface, but it is suspected that relatively few do because by natural selection they would have become adapted to germination in the uppermost layers: otherwise the loss of seedlings germinating at greater depths would represent a serious depletion of reproductive capacity.

The effects of soils, seasons and years. The variability within a species (table 1) is presumably conditioned by fluctuations in both soil conditions and the distribution of seeds of various ages in different layers of the soil. However, it is apparent that there are no definite differences between the three soils in the sixteen comparisons that were possible in these experiments. There were eleven comparisons between seasons (spring and autumn 1963) on the same soil. In seven of these, germination occurred over a greater range of depths in spring and in one only was it shallower (*Viola arvensis*) than autumn. Similarly, comparisons between spring 1963 and spring 1964 on the same soil showed that ten species germinated from greater depths in 1963 than in 1964 and in one only (*Viola arvensis* again) was it shallower. The differences between these results could be explained by the fact that suitable conditions might have been available at a greater depth in spring 1963 than in the other two seasons, or conversely, that conditions at the surface in spring 1963 were so unfavourable that a greater percentage of the seedlings selected for measure-

Fig. 2.

The increasing depth of germination of Veronica hederifolia between January and March 1964 measured at fortnightly intervals.



ment had perforce originated from greater depths. This cannot be resolved from the data because no knowledge of the density and distribution of the populations is available.

Change of germination depth with time. This investigation was started because in the 1963 measurements, no account was taken of what part of the germination peak of each weed species was being sampled. It was suspected that seasonal variations in such factors as moisture, temperature, etc. between different layers of the soil might result in changes in the pattern of germination depths over an extended germination period. *Veronica hederifolia* was chosen for investigation because it germinates over an extended period (October - May), germinates under a wide range of conditions and can also germinate from considerable depths (5.1 inches). The results in table 2 (see fig.2) indicate that a considerable increase in depth of germination occurred during the period covered by the measurements. The consistent increase in germination depth between January and March is presumably due to a progressive increase in soil depths at which conditions were favourable for germination of this particular species.

Conclusions. The main result of practical interest is that, apart from the multiple counts on *Veronica hederifolia*, 98% of all the seedlings measured had germinated from depths of less than two inches. This suggests that herbicides need not be incorporated to a greater depth than this to obtain reasonable control of seedlings of the species investigated.

It appears that weeds with small seeds can only emerge from shallow soil layers while large-seeded ones can germinate from greater depths if conditions are suitable. Apart from this consideration there are probably several other factors governing the range of depths of seed germination of a particular species. Soil type does not, however, appear to be a very important one.

Acknowledgements

The author wishes to thank Mr. Francis Darby of Darby Bros. for his assistance in providing areas of weed seedlings for measurement at Broad Fen Farm, and Professor G.E. Blackman for allowing the use of fields at the Oxford University Field Station. The author also wishes to thank Miss J. McLellan, Miss P. Adams and Miss A. Janson-Smith for their help in measuring the seedlings and preparing the data for this paper.

References

GLEISBERG, W. (1954) [Seed and Seed germination research on medicinal and culinary plants]. Gartenbauwiss 1, 181-217 [German]

KLEIN, W. (1956) [Researches on the determination of the minimum temperature for germination of agricultural weeds] Z.Acker-u. Pfl.Bau., 101, 395-430 [German]

ROBERTS, H.A. (1962) Personal Communication (National Vegetable Research Station)

SALISBURY, E.J. (1961) Weeds and Aliens. Collins, London pp.384.

THE SURVIVAL OF WILD OATS (Avena fatua) UNDER CONTINUOUS SPRING BARLEY GROWING.

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Summary Under conditions of continuous spring barley, from 1957 - 1964, stubble cultivations caused more seeds of *Avena fatua* to germinate in the autumn, but they were not able to prevent wild oats from increasing in barley sown at the normal time. More wild oats germinated in the autumn after burning straw and this resulted in a slower increase in wild oat numbers compared with straw baled and carted off. Late spring drilling at the end of April reduced wild oat numbers rapidly and kept them down to a low level. Yields of normal sown barley were higher than late sown in the first three years of the trial, but in the following years, late sown barley without wild oats gave higher yields than normal sown barley with many wild oats.

INTRODUCTION

The common wild oat (*Avena fatua*) is a long standing problem to the cereal grower, which the trend in recent years towards more intensive cropping with cereals has increased.

Apart from its obvious similarities to the cultivated cereals, the wild oat possesses two attributes which make it extremely difficult to eradicate from cereal crops. They are, firstly, the variable dormancy of the seeds, and secondly the ability to mature and shed seed within the normal growth and maturation period of the cultivated cereals.

Dormancy in *Avena fatua* is mainly due to the impermeability of the seed coat to oxygen although Naylor et al (1956) have reported the presence of a germination inhibitor in the hull of the seed. Under natural conditions the main peak of germination of *Avena fatua* occurs in late March or April, with a lesser one in the autumn. They coincide roughly with the peaks of soil microbiological activity which suggests that soil bacteria may play an important part in the natural breakdown of dormancy. (Thurston 1951)

There seems little opportunity for cultural methods of controlling wild oats apart from the use of sound rotations and the allied operations necessary for the growing of row crops. The problem has been accepted in the heavy land arable districts of East Anglia where the proportion of cereal crops has increased, and many farmers now devote as much as four fifths of their acreage to corn.

However, the key to successful cultural control in cereal crops would appear to lie in the breaking of seed dormancy at a point in time when a crop is not present. If dormant seeds can be induced to germinate in the absence of a crop then the task of killing the resulting seedlings is simple. This philosophy is the basis of the work described below.

METHOD

A trial was laid down in spring 1957 on a field suspected of being infested with a moderate level of common wild oats (Avena fatua.) Cropping was continuous spring barley. The treatments were designed to encourage germination of wild oat seeds at times when the ground was not occupied by barley.

Straw burning is a common operation after harvest in the corn growing districts of East Anglia and it was felt desirable to estimate its value as a dormancy breaker, comparing it with straw baled and removed from the field.

Rotary cultivation and shallow ploughing of the stubble were also tried since previous work reported by Dadd (1957) in a review of the subject suggested that stubble cleaning provided a suitable opportunity for germinating wild oat seeds. Other plots were left untouched after harvest. Cross ploughing for spring barley was normally carried out in December or January.

Spring treatments consisted of two times of drilling. The first time, "normal", was carried out as soon as possible when the heavy boulder clay of Boxworth had dried sufficiently for crawler tractors and their heavy equipment to work the plough furrow down. The actual date varied from 7th March in 1962 when soil conditions were good, to 13th April in 1963 when the hard winter and a late spring made it impossible to drill any earlier. The other time of drilling, "late", was timed to take place at the end of April or the first week in May, three or four weeks after the main spring germination of wild oat seeds.

The variety Proctor was chosen for the early sowing and Rika for the late sowing. The reason for this choice laid in the management problems associated with the trial. At Boxworth, grown under comparable conditions, the two varieties give similar yields, but in this particular case all plots would have to be harvested together to allow the burning of straw on some plots, and it was felt that a late maturing variety, such as Proctor, sown early and an earlier variety, Rika, sown late would probably come to harvest at about the same time. In any case, it was felt that the yield factor, although of great interest, was not so important as the observations on wild oat numbers.

Techniques

Each plot was 25 by 13 yards, and allowed three drill widths. Only the centre drill width of 13 feet was harvested. It was hoped by this means to avoid the results being affected by wild oats spreading from plot to plot.

Straw was burnt in the swath as it came from the combine. Rotary cultivation and shallow ploughing were carried out as soon as possible after the straw had been burnt.

The whole trial area was worked down in the spring as soon as the land was fit and the early sown plots drilled shortly after. The late drilled plots were then left untouched to allow any wild oat seeds to chit: the final seed bed was worked down just before the late drilling and any wild oat seedlings killed. The implements used for the first seed bed operations were duckfoot harrows and disc harrows if necessary, and the final seed bed for the late sowing was normally prepared with spring tine harrows.

Counts of wild oat plants were made to assess the effectiveness of the post harvest operations in the late autumn. In the spring a further survey was carried out to assess any germination of wild oats before the first drilling.

The most important count was, however, that which was made just before harvest. This count gave an estimate of the rise or fall of the effective wild oat population; it showed how many had successfully competed with the crop, and also was the ultimate test of the value of the post harvest operations for the control of wild oats.

RESULTS

Treatments in the tables have been designated in the following way for the sake of compactness.

B - = straw burnt stubble untouched
B R = straw burnt stubble rotary cultivated
B P = straw burnt stubble ploughed

O - = straw carted off stubble untouched
O R = straw carted off stubble rotary cultivated
O P = straw carted off stubble ploughed

Table 1

Wild oat seedlings (per sq yd) in late autumn						
Normal sown plots						
	1958	1959	1960	1961	1962	1963
B -	5.39	0.18	2.94	1.02	2.10	4.50
B R	7.17	1.26	5.93	3.24	22.30	92.40
B P	0.22	0.18	2.52	2.10	5.04	32.88
O -	0.54	0.50	1.40	3.06	0.72	3.06
O R	5.65	2.20	3.30	1.74	5.88	33.12
O P	0.36	0.13	1.20	1.86	2.57	9.06
Late sown plots						
B -	0.83	0.0	0.06	0.06	0.0	0.0
B R	1.33	0.13	0.0	0.06	0.0	0.06
B P	0.61	0.0	0.0	0.12	0.0	0.24
O -	0.86	0.04	0.0	0.12	0.0	0.06
O R	2.66	0.0	0.0	0.06	0.0	0.06
O P	1.94	0.0	0.0	0.0	0.0	0.06

The germination of wild oat seeds during the autumn has been very variable and seems to depend mainly on the moisture available after harvest. For example a dry autumn occurred in 1959 and 1961 and the number of wild oat seedlings recorded in the autumn counts was much lower than might reasonably have been expected. By contrast, the autumns of 1958 and 1960 gave high wild oat counts. 1958 followed a very wet summer, and 1960 was a very wet autumn following a wet harvest.

Overall, more seeds chitted on plots where straw had been burnt except in the two dry autumns of 1959 and 1961. Rotary cultivation of the stubble was the most effective means of encouraging autumn germination. Fewest seedlings were counted on the plots which were left untouched.

Table 2 shows the effect of post harvest operations on wild oat plants in barley sown in early spring.

Table 2

Wild oat plants at harvest in normal sown barley (Per sq yd)							
	1958	1959	1960	1961	1962	1963	1964
B -	1.03	0.45	0.89	1.37	7.23	9.56	59.0
B R	1.46	1.01	1.70	5.07	31.2	42.4	189.0
B P	1.44	0.82	0.99	3.55	25.7	36.2	147.0
O -	1.75	0.89	1.58	2.69	13.0	17.8	102.0
O R	2.32	2.18	4.34	10.3	66.0	74.0	226.0
O P	1.77	1.54	2.18	7.36	37.6	57.9	153.0
Coeff. of variation*	16.9%	25.4%	15.6%	16.9%	7.6%	8.2%	6.1%

(*analysis carried out on transformed data)

Throughout the period of the trial wild oats have increased on the plots sown at the normal date. The rate of increase has varied according to the post harvest treatment of the plot, and has also been influenced by the weather and soil conditions during the winter and spring before drilling. In 1959 the land was very wet during early spring and the earliest that drilling could take place was at the beginning of April. Many wild oat seeds had therefore germinated before the seed bed was worked down. This operation naturally killed the seedlings off and the nett result was a decrease in the number of wild oat plants at harvest. Similarly good soil conditions in the spring of 1960 encouraged early germination of wild oats and although drilling was done on March 7th many wild oats were killed off by the seed bed preparations; consequently the nett increase in wild oats at harvest was small.

Rotary cultivation of the stubble was effective in promoting the germination of wild oat seeds in the autumn. As has been shown, however, it became clear as time elapsed that it also resulted in a more rapid build-up of wild oats, presumably through partial damage to the seed coat which was completed by microbiological activity in the spring thus breaking dormancy at a time which was most advantageous to the seed.

Shallow ploughing also produced a similar result but not to the same extent. The smallest increase was found on plots which received no stubble cultivations. Straw burning, although it did not prevent wild oat numbers from building up over the period of the trial was partially successful in that the rate of increase was slowed down.

Table 3 shows the mean figures for wild oats at harvest in the late sown barley.

Table 3

Wild oat plants at harvest (per ac) in late drilled barley						
1958	1959	1960	1961	1962	1963	1964
298	65	77	139	167	385	706

Complete figures are available but have been excluded to save space. They show a similar pattern to the early drilling as far as straw and stubble treatments are concerned but at a very much lower level.

Comparative yield figures are given in table 4.

Table 4

Yield of early and late sown barley at 85% dry matter (cwt/ac)							
	1958	1959	1960	1961	1962	1963	1964
Early	29.2	40.1	40.5	26.7	37.0	24.8	20.1
Late	24.8	36.1	31.5	28.0	37.8	30.2	29.8
S.E. per plot	± 1.89	± 2.04	± 2.16	± 2.30	± 2.87	± 3.19	± 2.83

The trial was conducted at a modest level of fertiliser to ease management problems; each plot was combine drilled with a compound fertiliser supplying about forty units of phosphate and twenty units of nitrogen.

Early sown barley, in the absence of significant numbers of wild oats outyielded late sown barley by an average of 5.8 cwt in the first three years of the trial; but as the wild oats increased so the yield difference went in favour of late sowing.

DISCUSSION

Dadd (1957) in a review of the wild oat literature, states that as a method of cultural control autumn cultivation to encourage germination is generally recommended. This seems to be at variance with the results presented here. However, in 1958 Cumming et al reported that in Canadian field tests, when autumn tillage was practised, wild oats germinated earlier and in greater numbers the following spring. Again Thurston (1958-59) reported that stubble burning stimulated germination of Avena fatua in a badly infested field but found that there were ten dormant seeds in the soil; for every one that germinated in the burnt areas. She followed this report by saying that the following spring, after several cultivations, the site was drilled with peas which became so badly infested that they had to be cut for silage before the wild oats shed their seed. No drilling date was given but it is extremely unlikely that late drilling was carried out on this occasion. In 1958 wild oat populations were similar on all the early sown plots, but as the trial progressed the untouched stubble treatment showed no sign of the same build up which was occurring on the other treatments. No ready explanation was forthcoming at the time but as the situation continued a suspicion grew that outside influences were at work.

An observation made during the autumn of 1963 threw considerable light on the problem. The possibility of birds or small mammals eating large quantities of seed was tested by the simple device of setting up small mesh wire netting cages on the untouched stubbles after harvest. They were left in position for about ten weeks during the early autumn. At the end of the period, six inch square quadrat samples were taken at random within and without the caged areas. All wild oat seeds visible were carefully removed and counted. The result showed that for every single wild oat seed recovered from the uncaged areas seventeen were recovered from within the cages. Although the figures were obtained from small samples it seems clear that the role of birds and/or small mammals in the removal of wild oat seeds from the surface of the soil is no small one and should not be dismissed lightly.

The behaviour of the wild oats on the late drilled plots has been fairly close to the expected pattern but there has been a development which needs an explanation.

Wild oat numbers fell rapidly during the first two years to the very low level of sixty-five plants per acre, after this time a slow build up has taken place so that in 1964 eleven times this number were present on the late drilled plots. Two possibilities seem likely; either continuous late drilling has been acting as a selection mechanism for a race of late germinating wild oats or the physical difficulties of keeping wild oats in their proper place in the trial were too great. Certainly visual observation of the rest of the field (which has always been late drilled) does not suggest that wild oats have increased there.

It seems clear from these results that straw burning and stubble cultivations do little to check the increase of wild oats by themselves but may serve as a useful addition to late drilling or if used in conjunction with chemical weed control.

The most effective control of wild oats has been obtained by delayed drilling and the preparation of a seed bed well in advance to encourage germination. Canadian work reported by Korven (1959 and 1961) and Howden et al (1959) and also American work at the same period Anderson (1960) agree that under their conditions delayed drilling was the most effective cultural control method.

The cost to the farmer of delayed drilling will most certainly be a lower yield and malting quality compared with corn sown at the normal date so long as the competition from wild oats is negligible. If however wild oats are present in any numbers then their effect on yields may be so great that delayed drilling becomes an attractive method of reducing wild oats.

Acknowledgments

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References

ANDERSON, E.G. (1960) A National Organisation for Weed Control and Some Significant Results' Proc. N.E. Weed Control Conf (U.S.A.) 1960 14 7 - 15

CUMMING, B.G. and HAY, J.R. (1958) Light and Dormancy in Wild Oats (*Avena fatua* L.) Nature Lond. 182 4635 609 - 10

DADD, C.V. (1957) Wild Oats. Review Article Field Crop Abstracts 10 1 - 10

HOWDEN, J.S. et al (1959) Weeds Committee Report. Rep. Annu. Conf. Manitoba Agronomists 35 - 40.

KORVEN, N.A. (1959) Delayed Seeding for Wild Oat Control. Proc. N. Cent. Weed Control Conf and 10th W. Canad. Weed Control Conf 1959 36

KORVEN, N.A. (1961) Note on Wild Oat Control by Delayed Seeding of Wheat. Canad. J. Pl. Sci. 41 685 - 6

NAYLOR, J.M. and CHRISTIE, L.A. (1956) The Control of Dormancy in Wild Oats Proc. 10th W. Sect. Nat. Weed Cttee 1956 - 9

THURSTON, J.M. (1951) Some Experiments and Field Observations on the Germination of Wild Oat (*Avena Fatua* and A. Ludoviciana) Seeds in Soil and Emergence of Seedlings. Ann. app. Biol. 38 812 - 32

THURSTON, J.M. (1958) Weed Studies: Wild Oats. Rep. Rothamsted exp. Sta. 1957 Harpenden

THURSTON, J.M. (1959) Weed Studies: Wild Oats. Rep. Rothamsted exp. Sta. 1958 Harpenden

THE EMERGENCE AND GROWTH OF AVENA FATUA FROM DIFFERENT DEPTHS IN THE SOIL

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Summary. Samples of soil were taken in a naturally occurring population of *Avena fatua* 1) on the 4th May before final seed bed preparation and sowing spring barley and 2) 4th July and 4th August after the crop and the *A.fatua* had headed. Washing out the plants of *A.fatua* showed that although 60-80% arose from seed in the top 3 in. of the soil, some came from seed as deep as 7.5 in. It was also observed that the largest plants tended to arise from the 5-6 in. layer in the soil; this is attributed to the depth (2-3 in.) and timing (mid-April and early May) of the final seed-bed cultivations. Implications of the results are discussed in relation to the use of soil applied herbicides such as di-allate and tri-allate.

INTRODUCTION

The biology of *Avena fatua* and *Avena ludoviciana* in the British Isles has been very fully investigated (Thurston, 1962) and it has been shown that seed of both species can remain viable in the soil for seven years or more and produce plants from depths of up to nine inches (Thurston, 1951). However there is no published evidence of what proportion of the plants in a naturally occurring population arise from seed at the different depths in the soil during any one season. This has become of particular importance with the development of the soil-acting herbicides di-allate and tri-allate for the control of *Avena* spp.. in cereals crops, for it is known that there is a close relationship between the susceptibility of *Avena* spp. to these herbicides and the depth of their seed in the soil (Parker, 1963, Holroyd, 1964). Plants arising from seeds buried relatively deeply in the soil are more resistant to these herbicides when mixed with a relatively shallow layer of soil, than those plants arising from seeds which are nearer to the soil surface; and vice versa if the herbicidal treatments are incorporated more deeply (Holroyd, 1964). Many factors such as soil type and condition, weather conditions, type and timing of cultivations, and previous history will have some influence on the number of seeds at the various depths and the number of plants arising from them in any one season, at a particular site. A complete investigation of all these factors would require a very large and extensive programme of experiments and this paper which is based on a minimum of observations, should be regarded as only an introduction to the problem.

METHOD AND MATERIALS

Site of Experiment. This was at Harwell, Berks. on a field which is in continuous cereals and known to be heavily infested with *Avena fatua*. The soil is 7-9 in. of chalky clay over chalk.

Cultivations. The stubble of the 1963 barley crop had been ploughed to a depth of 5-6 in. (the usual ploughing depth on this farm) in November, cultivated to a depth of 3-4 in. with discs in February and again to a depth of 2-3 in. with spring-tine harrows in March - at which time the *A.fatua* seed had just begun to germinate. The area was harrowed again in mid-April. In the final seed-bed preparation a further two harrowings (depth 2-3 in.) were carried out before the crop of spring barley was sown on the 7th May at a depth of 0.5-1.5 in.

Sampling. Soil samples were taken from areas where the density of the A.fatua appeared to be relatively high, by hammering open-ended metal boxes (size 12 in. x 12 in. x 9 in. deep) into the soil. The boxes were excavated, one side removed and A.fatua which had germinated separated from the soil by washing with a fine jet of water. The following data were noted:-

1) the depth of the A.fatua seed from the soil surface,
2) the depth of the unemerged coleoptile tips from the soil surface,
3) the stage of growth and vigour of the emerged plants as shown by
    a) the number of main stem leaves and shoots
    b) the number and size (approx. number of spikelets) of the panicles.

Dates of sampling. Six samples were taken on 4th May, before final seed bed preparation and six from within the growing crop: three on 24th July and three on 4th August. Of the first six samples one was assessed on the 7th May ('A') and the remaining five on the 14th July ('B'). The second set of samples was counted on the 28th July ('C') and the third on the 5th August ('D'). The five samples taken on the 4th May, but not counted until the 14th July ('B'), were kept in the open and watered at intervals to maintain growth.

RESULTS

Fig. 1 illustrates the individual plants of A.fatua which were found in the first soil sample ('A') and shows the depth of their seed and stage of growth. The density in this first sample was high with 147 plants in 1 ft.^{2} Numerous growth stages were present, from seed which had just germinated to relatively large plants with 4.5 main stem leaves. Over 50% of the plants were in the top 4 in. of the soil and these included almost 80% of the plants which had emerged. Germinating seed were found to a depth of 8.5 in. and rather surprisingly, in view of the ploughing depth of 5-6 in., 30% of the total were found below 5 in. Either the farmer seriously underestimated his depth of ploughing or considerable numbers of seed fell down cracks in the soil or were carried down by soil animals. The ability of A.fatua to emerge from deep in the soil is emphasised by the number of plants which had already emerged from 6 in., and 6.5 in.

Fig. 2 shows the data which were obtained from the other soil samples, as follows:

(i) the number of A.fatua plants which had emerged from the different soil depths at the four times of assessment ('A', 'B', 'C' & 'D') expressed as a percentage of the total emerged population,

(ii) the vigour of these plants as indicated by the mean number of either main stem leaves ('A') or shoots ('B', 'C' & 'D') per plant, and

(iii) the number of panicles ('B', 'C' & 'D') or spikelets ('D') on plants emerging from the different soil depths as a percentage of the total number.

In these samples the greater proportion of the germinating A.fatua seed was in the top 3 in. of the soil but whereas in the 'B' samples the largest proportion of plants arose from seed in the top inch of the soil in 'C' & 'D' they arose from the 2 and 3 inch layers. This was

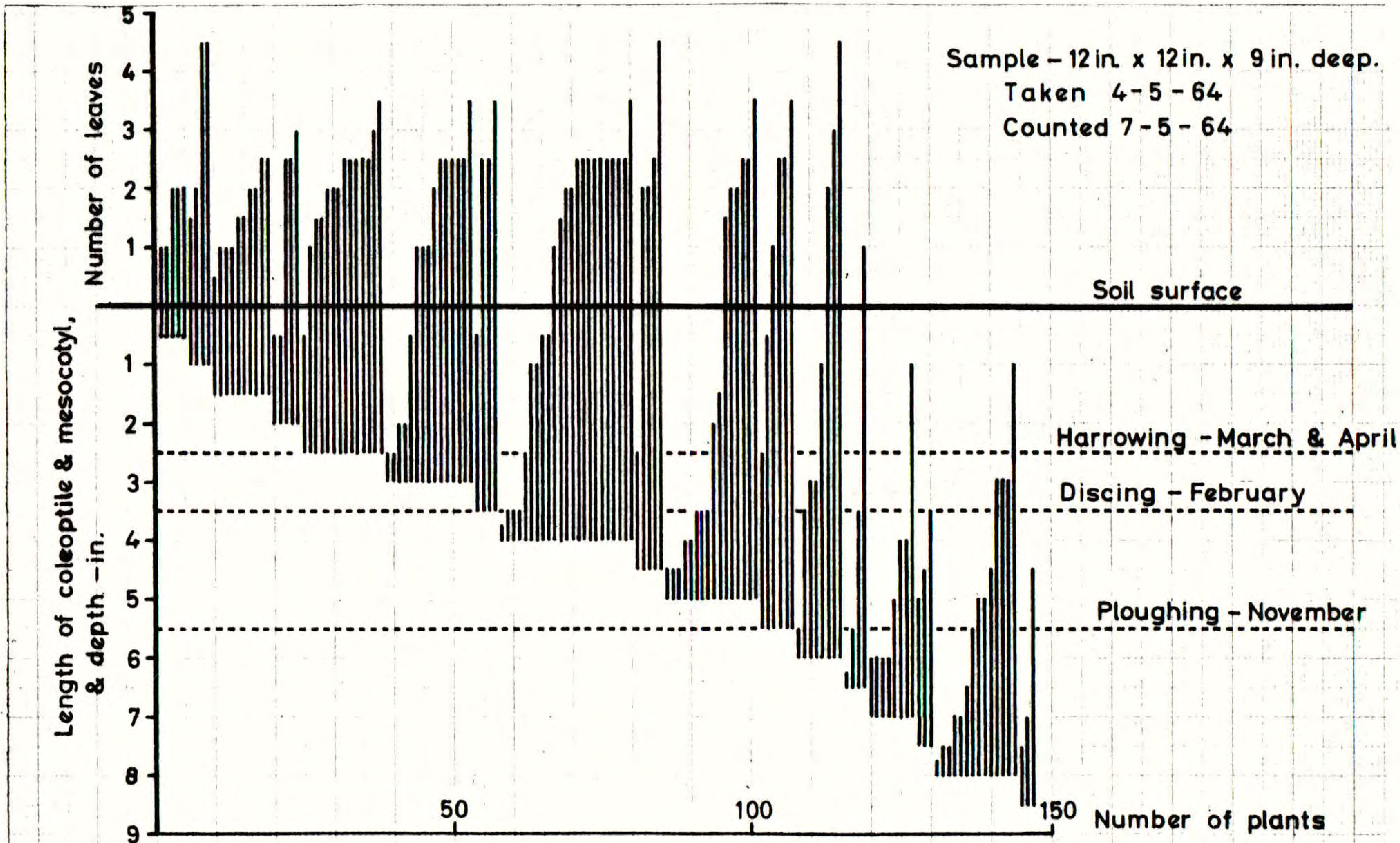
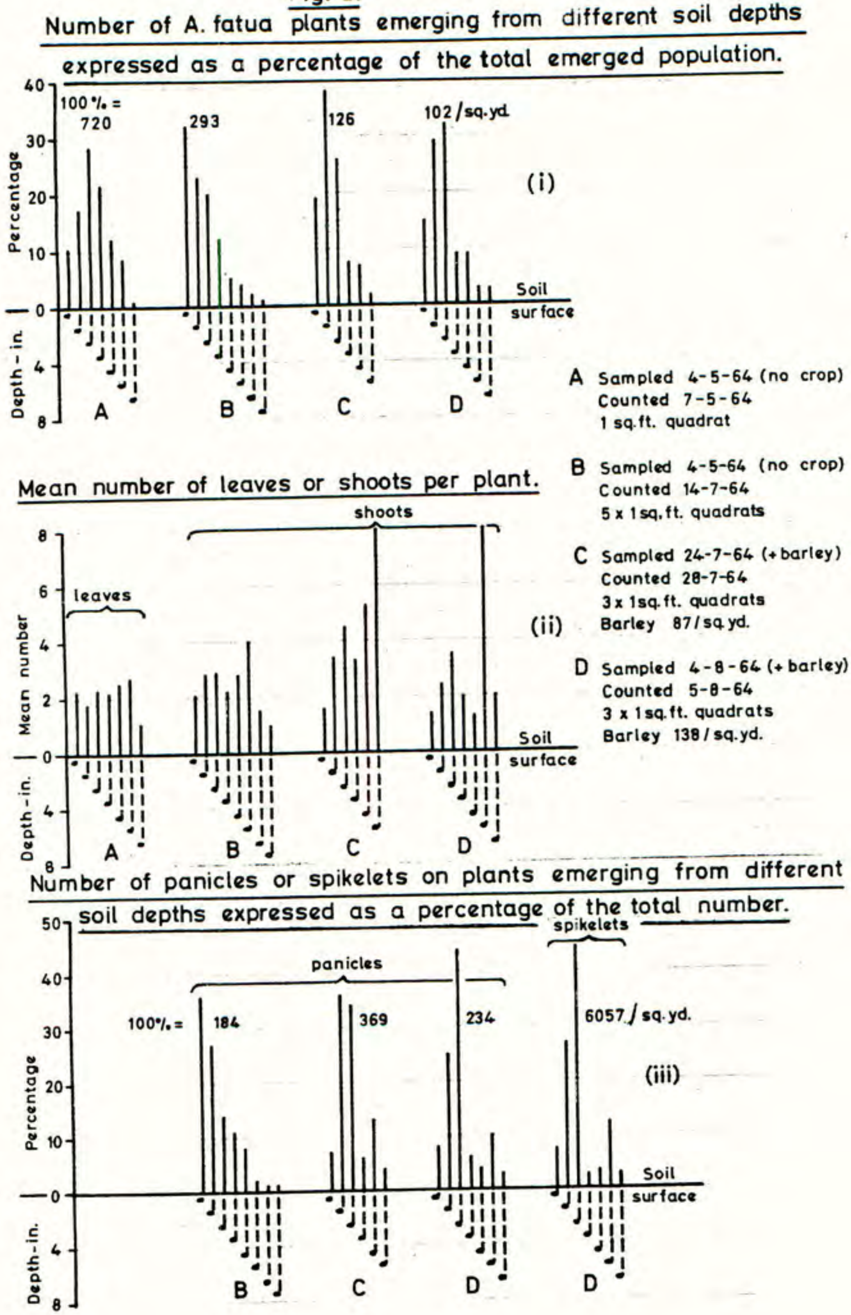


Fig. 1. Stage of growth of individual oat plants germinating at different depths in the soil

Fig. 2.



Number of A. fatua plants emerging from different soil depths expressed as a percentage of the total emerged population.
Percentage
Depth - in.
100 % = 720
293
126
102 / sq. yd.
(i)
Soil surface
A
B
C
D
A Sampled 4-5-64 (no crop)
Counted 7-5-64
1 sq. ft. quadrat
B Sampled 4-5-64 (no crop)
Counted 14-7-64
5 x 1 sq. ft. quadrats
C Sampled 24-7-64 (+ barley)
Counted 28-7-64
3 x 1 sq. ft. quadrats
Barley 87 / sq. yd.
D Sampled 4-8-64 (+ barley)
Counted 5-8-64
3 x 1 sq. ft. quadrats
Barley 138 / sq. yd.
Mean number of leaves or shoots per plant.
Mean number
Depth - in.
leaves
shoots
(ii)
Soil surface
A
B
C
D
Number of panicles or spikelets on plants emerging from different soil depths expressed as a percentage of the total number.
Percentage
Depth - in.
panicles
spikelets
100 % = 184
369
234
6057 / sq. yd.
(iii)
Soil surface
B
C
D
D

probably because after the 'B' samples were taken on the 4th May they were kept watered until they were assessed on the 14th July, thus any seed near to the surface was encouraged to germinate. The harrowings used for the preparation of the final seed bed after the 4th May may also have had more effect on the plants in the 0-1 in. layer than those in the 1-3 in. layer, as those left in the top inch after harrowing were more vulnerable to drying out. April and May this year were relatively wet months, with 63 mm and 53 mm respectively, but there was a drier period from the 4th May to the 18th May when only 1.8 mm of rain fell in this area. The plants from the top three inches of soil produced more than 75% of all the panicles and spikelets, due to their relatively large numbers (Fig. 2 (iii)). However the largest plants as shown by the mean number of leaves or shoots per plant (Fig. 2 (ii)).came from the 5-6 in. layer in the soil, at all four dates of assessment. These plants were relatively few in number but could contribute very considerably to the numbers of seed produced. Thus at the final date of assessment ('D') 3% of the plants came from the 5-6 in. layer but produced 12% of the total spikelets.

The success of the Avena growing from this depth can be attributed indirectly to the effects of the final cultivations in April and May with the spring-tine harrows (depth 2-3 in.). It seems likely that all the plants in the 0-3 in. layer were disturbed and, even if not killed, were given a severe check while they re-established their root systems. Plants from below whose coleoptiles extended into the cultivated layer almost certainly died when their coleoptiles were damaged. Plants whose coleoptiles had not quite reached this layer (3 in.) were undisturbed and on reaching the soil surface were able to establish themselves before the competition from either the crop or other Avena plants became severe. The 5-6 in. layer provided the optimum conditions; from this depth the mesocotyl was able to elongate sufficiently to allow the tip of the coleoptile to reach the soil surface but from greater depths the unprotected first leaf had to force its way through to the surface for the plant to survive. Thus plants originating from seed deeper than 5-6 in. were not able to reach the soil surface and establish themselves so rapidly. Further germination of seed from these deeper layers which could have reduced the size of the 'average plant' did not occur as the soil below 3 in. was undisturbed by the cultivation and in addition the main period for germination for the A.fatua was over.

The crop (spring barley) was present in the two later sets of samples ('C' and 'D'), and as might be expected the effects of competition on the Avena plants were generally greater, as shown by the reduced mean number of shoots per plant, where the barley plants were more numerous ('D').

DISCUSSION

It must be emphasised that although it is possible to make a number of useful hypotheses based on the results, they have the limitation that the soil samples were relatively few and were taken at only one site in one particular season.

The soil samples were not taken at random but from areas more densely populated with A.fatua. The overall density of A.fatua in the crop was 30-40 plants/yd^2 rather than the 100-120 plants/yd.^{2} indicated by the samples ('C' and 'D'). It is rather surprising that in spite of three shallow cultivations in the preparation of the final seed bed most of the plants arose from the 0-3 in. layer of soil. The cultivations may have encouraged further germination in these shallow layers, although the period for germination of the Avena should have been almost finished. A large number of plants disturbed by the cultivations must have re-established themselves, aided to some extent by relatively moist soil conditions. It is difficult to see how cultivations and the late sowing of a spring cereal can ever achieve a satisfactory degree of control at a site such as this, where the reservoir of Avena seed in the soil is already very large. The farmer has in fact attempted to control the A.fatua at this site by using these methods for several years, with very little success, as is shown by the number of A.fatua still present.

The main significance of these results and in particular the success of the plants germinating from the 5-6 in. layer of soil is in relation to the use of the soil-acting herbicides di-allate and tri-allate. Both these herbicides, when incorporated into the surface layers of the soil, can give an excellent control of A.fatua growing from the shallower layers of the soil (0-3 in.). However, it is known that 1) the region in Avena spp. which is most sensitive to these herbicides is located within the 10 mm above the coleoptile node (Parker, 1963), 2) with increasing seed depths up to 3 in. (the greatest depth tested), there is a corresponding increase in the depth of the coleoptile node in the soil (Parker, 1960), 3) Avena spp. arising from 3-4 in. in the soil are relatively resistant to these herbicides if they are incorporated into only the top inch of the soil, because this sensitive region does not enter the treated soil, until comparatively late in the development of the plant, when it has become much less sensitive, (Holroyd, 1964, Parker, 1963). It seems probable therefore that A.fatua arising from 5-6 in. could be relatively resistant to a deeper layer of soil treated with these herbicides. These plants (from 5-6 in.) in one set of samples ('C') produced 13% of the total panicles and in another set ('D') 10% of the total panicles and 12% of the total spikelets - approx. 1,200 seeds/yd^2, if each spikelet is considered to have two seeds.

In the present experiment the number of Avena succeeding from the 5-6 in. layer would probably have been reduced if the cultivations at the time of seed-bed preparation had been somewhat deeper, for as has already been discussed, conditions for their survival were optimum. Deeper cultivations would have disturbed them and broken their root systems and/or damaged their coleoptiles. Even if they had managed to re-establish themselves emergence would have been delayed. Similarly any dormant seed which was stimulated to germinate from these depths by the cultivations would have emerged too late to compete successfully with the crop. It is known that A.fatua seedlings are very sensitive to competition (Thurston, 1962) and any delay in emergence in relation to the crop increases their mortality and also reduces the size of the plants which they produce (Holroyd, 1960). Thus the degree of control of Avena spp. given by di-allate and tri-allate could be almost as dependent on the depth of penetration of the cultivations used in the preparation of the final seed-bed, as on the depth of incorporation of the herbicide itself.

Acknowledgements

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References

HOLROYD, J. (1960) unpublished

HOLROYD, J. (1964) Field investigations concerning the selective phytotoxicity of di-allate to *Avena* spp. in wheat and barley. Weed Res., *4*, 142-166.

PARKER, C. (1960) Personal communication.

PARKER, C. (1963) Factors affecting the selectivity of 2,3-dichloroallyl di-isopropylthiol carbamate (di-allate) against *Avena* spp. in wheat and barley. Weed Res. *3*, 259-276.

THURSTON, J.M. (1951) Some experiments and field observations on the germination of wild oat (*Avena fatua* and *A. ludoviciana*) seed in soil and the emergence of seedlings. Ann. appl. Biol. *38*, 812-832.

THURSTON, J.M. (1962) Biology and control of wild oats. Rep. Rothamsted exp. Sta. 1962, 236-253.

VARIATIONS IN THE AFTER-RIPENING REQUIREMENT OF POLYGONUM AVICULARE L. SEEDS

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Summary. Laboratory experiments on the after-ripening or chilling requirement of knotgrass seed show that there are considerable variations between seed samples from different localities. Attempts to relate the chilling requirement to the winter climate of the locality of origin have, so far, been unsuccessful.

INTRODUCTION

Freshly harvested seed of *Polygonum aviculare* L. (Knotgrass) is dormant, and requires after-ripening before it will germinate. Justice (1941) concluded that moist storage at a constant temperature slightly above freezing was more favourable to after-ripening than either a constant higher temperature or an alternating temperature. Light is not required for after-ripening. Knotgrass seed can lie dormant in the soil for long periods of time: the data of Brenchley (1918) for example suggest that *P. aviculare* seed can remain dormant beneath pasture for at least 58 years.

P. aviculare L. is widely distributed in Great Britain, and is a common weed of cultivated land. Another widely distributed knotgrass, *P. arenastrum* Bor., may also occur in arable land, but is more commonly found on paths, roadways and at the edges of fields (Styles, 1962). The other British knotgrass species are locally distributed only.

This paper is concerned solely with *P. aviculare* L., and is a preliminary report of an investigation still in progress.

METHODS

Seed of *P. aviculare* was collected during the summers of 1961 and 1962 from the localities shown in Table 1. In 1962 plants were grown at Aberystwyth from the samples collected in 1961, and seed was collected from these plants. Seed samples were cleaned, rubbed to remove the persistent calyx and perianth, and stored dry at room temperature for 4 - 5 months before use.

Experiment 1. (Seed collected in 1961). Subsamples of 150 seeds were placed on moist filter paper in petri dishes which were put into a cold store at 1 - 2°C. Sets of 30 seeds were withdrawn from each dish after 3, 6, 9, 12 and 15 weeks. These seeds were put into petri dishes to germinate, the dishes being kept in a warm laboratory at about 20°C. Subsamples of 30 seeds were put to germinate without any chilling at the start of the experiment.

Experiment 2, (Seed collected in 1962) and 3. (Seed grown at Aberystwyth in 1962). Subsamples of 50 seeds were put on to moist filter paper in petri dishes, which were then placed in a cold store at 1 - 2°C. Dishes were withdrawn after 3, 6, 9, 12, and 15 weeks and transferred to an incubator at 22°C. As in experiment 1, there were sets of control dishes that received no chilling.

Table 1
Localities from which seed of P. aviculare L. was collected, and the localities represented in the three experiments.

	Locality	Experiment 1	2	3
A	Aberystwyth, Wales	x	x	x
C	Copenhagen, Denmark	x		x
H	Newport, Shropshire, England	x		x
I	Inverness, Scotland		x	
L	Tadcaster, Yorkshire, England	x	x	x
N	Sprowston, Norwich, England	x		x
O	Kidlington, Oxford, England	x	x	x
R	Rothamsted, Harpenden, England	x	x	x
U	Uppsala, Sweden	x	x	x
W	Wageningen, Netherlands	x	x	x

In all experiments, there were three replicates. Seeds were treated with a fungicidal seed-dressing at the start of each experiment and the filter paper in the dishes was kept moist without being flooded. The germination or incubation period was 3 weeks in all experiments. In the case of experiments 2 and 3, dishes which at the end of the germination period contained ungerminated seed were returned to the cold store for a period of about 3 months, after which they were again placed in the incubator. Scarification and addition of a nitrate solution etc. were used on this seed, where necessary, to promote germination. This was done to obtain an estimate of the total viability of each sub-sample.

This paper is concerned solely with the data on % germination in the 3 week incubation period. In the case of experiment 1, % germination is calculated on the basis of the number of seeds per dish (i.e. 30), but in experiments 2 and 3 the % germination was calculated on the basis of the number of viable seeds per dish (usually between 45 and 50). Tests on the total viability of the samples used in experiment 1 showed it to be uniformly high, so that comparisons between samples and between experiments may safely be made.

RESULTS

Analyses of variance of the data on % germination show that, in all three experiments, the effect of length of chilling period, locality of origin of the seed, and the interaction between them, are highly significant. The data are summarised in Fig. 1 and Table 2. Fig. 1 shows that, for all seed samples, the % germination was very low when the seeds received no chilling at all. In general, the response to increase in the chilling period was initially large, falling off rapidly as the chilling period reached its maximum of 15 weeks. In experiment 1, seed from three localities gave a lower % germination after 15 weeks than after 12 weeks chilling, but this behaviour was not repeated in either of the subsequent experiments.

Before considering Fig. 1 in more detail, reference to Table 2 will emphasize the effect of locality of origin. There was clearly a marked effect of locality on the mean % germination in all three experiments, but differences between localities were not consistent between experiments.

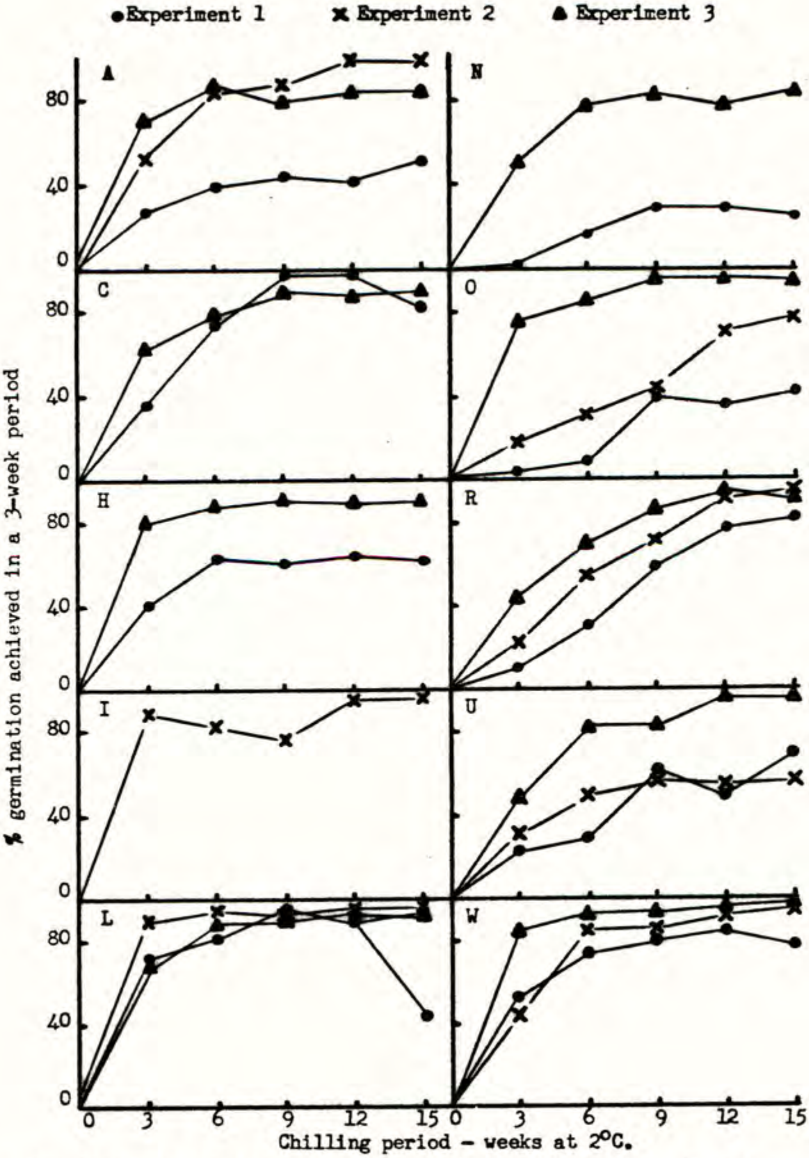
Table 2
Mean % germination of seed from different localities. Means after 3, 6, 9, 12 and 15 weeks chilling.

Expt.	Locality of Origin										L.S.D.	
	A	C	H	I	L	N	O	R	U	W	P=0.01	P=0.05
1	41	79	58	-	78	20	26	54	47	76	8.1	5.9
2	85	-	-	88	97	-	48	69	70	82	2.7	2.0
3	80	81	86	-	89	73	88	79	81	93	2.7	2.0

Fig. 1 shows that there were a number of fairly clear differences between localities in the pattern of response to length of chilling period. Seed from Inverness (I) and Yorkshire (L) for instance reached a near-maximum % germination after only 3 weeks chilling. This constrasts with seed from Rothamsted (R) where there was a fairly steady response up to 12 weeks chilling. Seed from Copenhagen (C) and Norfolk (N) required 9 weeks chilling to reach a maximum % germination, while 6 weeks chilling appeared to be necessary for the Aberystwyth (A), Shropshire (H) and Wageningen (W) seed. In the case of seed from Oxford (O) and Uppsala (U) there were no clear trends.

With a few exceptions, there were only small variations in the form of the response curve between experiments. These differences are perhaps most clearly evident in the value of the mean or maximum % germination, and presumably result from differences in the conditions of growth and harvesting of the seed, though they might also be due to differences in sampling (see discussion). In a few cases deviations from a smooth trend were statistically significant (I and U for instance); such deviations may or may not be biologically significant.

Fig. 1



The effect of chilling period on the % germination of seed samples of Polygonum aviculare from ten localities of origin.

The very low % germination without chilling has already been mentioned. In only one instance was there any breakdown of dormancy with dry storage. Seed from Yorkshire (L) in experiment 2 gave 1.5% germination without chilling after 4 - 5 months dry storage. This increased to 15% after about 9 months dry storage. All seed samples proved capable of germinating in the cold store (i.e. at 1 - 2°C.). The % germination occuring during chilling increased with increase in the chilling period, and there appear to be differences between samples from different localities in this respect. However, it is not intended to discuss this phenomenon further in this paper.

The data presented above indicate the presence of considerable variation within P. aviculare in the response of the seeds to chilling. It is likely that this after-ripening or chilling requirement is of adaptive value to the species. Seed shed in August for instance is unable to germinate until it has experienced low winter temperatures, and hence does not germinate in the autumn, when it would be destroyed by frosts, but germinates in the spring when conditions are likely to favour establishment and growth. It is of interest to investigate the extent to which variations in the response to chilling (as found in these laboratory experiments) are associated with variation in the winter climate of the locality of origin. Meteorological data for the localities have therefore been examined as a first step in such an investigation, and correlation coefficients between % germination after 0, 3, 6, 9, 12 or 15 weeks chilling, and a number of meteorological variables have been calculated. As there were a large number of variables involved, an electronic computer was used for these calculations. With a large number of correlation coefficients, it is possible for some of them to achieve statistical significance purely by chance. Consistency in sign and size is therefore necessary before accepting any relationship as significant.

Although a number of correlation coefficients were statistically significant, there was no consistency between experiments. Table 3 illustrates this point; the signs of the coefficients in experiment 2 are the opposite of those in 1 and 3. Many of the meteorological variables are closely correlated among themselves, so partial correlation coefficients were calculated. These do little to clarify the relationships (if any) between germination behaviour and winter climate.

Table 3
Correlation coefficients between % germination after 15 weeks chilling and certain meteorological characteristics.

	Mean temperature °C Oct.-Mar.	Number of frost days Oct.-Mar.	Mean temperature °C March	Mean temperature °C Feb.-March.	Mean temperature °C Jan.-April
Experiment 1	-0.496	+0.648	-0.502	-0.461	-0.537
Experiment 2	+0.824*	-0.688	+0.815*	+0.833*	+0.788*
Experiment 3	-0.382	+0.499	-0.311	-0.328	-0.272

DISCUSSION

Justice (1941) found considerable variation between species of the genus Polygonum in their after-ripening requirements. He also found differences within species between seed from different localities. This latter observation is amply confirmed, for P. aviculare at least, by the data presented above. In addition to such variation between localities, there may also be considerable differences in after-ripening and germination requirements between individual plants within a locality. Examples of such variation have been reported by Matumura et al. (1960) for species of Digitaria, and by J. L. Harper (personal communication) for a number of weed species. If such inter-plant variation is present in P. aviculare, any measure of germination behaviour for a locality must be regarded as being the mean for a more or less variable population. In addition, unless samples from different localities are based on a large number of plants, they may not be representative of the locality. It is clear, at any rate, that there are differing degrees of dormancy within P. aviculare, and that there is no single after-ripening requirement for the species.

It frequently proved difficult to induce germination of the seeds remaining at the end of the incubation period. A further period of chilling was effective for some of these seeds; such seeds might have a total of more than 5 months chilling. Fracture of the pericarp was sometimes effective in breaking dormancy, but use of a stimulator, such as nitrate, was not very successful. Abnormal germination occasionally resulted from the use of the last two methods. In the field, this "residual" seed could probably lie dormant for many years, even if relatively near the surface, a feature of possible value to the species in ensuring survival. The importance of dormancy in weed control has been discussed by Harper (1957), who points out that seed dormancy prevents isolated acts of weed control from having any permanent effects on weed problems. Brenchley & Warington (1936) found that P. aviculare seed could remain dormant in soil frequently disturbed (in pans) for more than three years, so that this species is not dependent for survival on successful seeding in the previous year. P. aviculare is clearly a difficult weed to eradicate.

The seeds of many species will germinate in the field only under certain conditions of temperature and moisture. Examples of such adaptation have been cited by Went (1957) mainly for California desert species. The present investigation was concerned with possible adaptations within a single species. It was reasoned for example, that seed from Aberystwyth, the mildest of the localities with a mean temperature October - March of 6.5°C. and 36 frost-days, might well require less chilling to achieve a high % germination than seed from, say, Copenhagen with a mean temperature of 2.8°C. and 110 frost-days. The failure to demonstrate any relationship with the environment of the locality of origin is capable of several explanations. Firstly the meteorological variables selected may be inappropriate. Such data are, in any case, only a very crude approximation to the microclimate of the actual locality in which the seed was collected, and furthermore represent only one aspect of the total environment. Secondly, the germination characteristics studied may inadequately represent the properties of adaptive value to the species, and the chilling treatments of these experiments probably bear little resemblance to the chilling experienced by seed lying in the soil. Such seeds probably receive intermittent periods of chilling, and a fluctuating temperature and moisture supply.

It is undoubtedly naive to expect a simple relationship between germination and a single expression of climate. It was hoped, however, that the experiments and the correlations would indicate some relationship between environment and after-ripening requirement. These investigations are continuing and other weed species of Polygonum are also being studied.

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References

BRENCHLEY, W. E. (1918) Buried weed seeds, J. agric. sci. 9, 1 - 31.

BRENCHLEY, W. E. & WARINGTON, K. (1936) The weed seed population of arable soil. III The re-establishment of weed species after reduction by fallowing. J. Ecol. 24, 479 - 501.

HARPER, J. L. (1957). The ecological significance of dormancy and its importance in weed control. 4th Internat. Cong. of Crop Protection, Hamburg, 415 - 20.

JUSTICE, O. L. (1941) A study of dormancy in seeds of Polygonum. Cornell Univ. Agric. exp. Sta. Mem. 235.

MATUMURA, M., TAKASE, N. & HIRAYOSHI, I. (1960) Physiological and ecological studies on germination of Digitaria seeds. I. Difference in response to germinating conditions and dormancy among individual plants. Res. Bull. Fac. Agric. Gifu Univ. (Japan), 12, 89 - 96.

STYLES, B. T. (1962) The taxonomy of Polygonum aviculare and its allies in Britain. Watsonia, 5, 177 - 214.

WENT, F. W. (1957) The experimental control of plant growth. Chronica Botanica Co., Waltham, Mass, U.S.A.

SOME FACTORS INVOLVED IN THE SELECTIVITY OF PYRAZON ON SUGAR BEETS

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Summary In 1964, practical and trial uses of pyrazon proved that the material was well tolerated by beets when applied at the correct rates. Only in few cases crop injury was observed. From these instances, it was obvious that certain factors tended to influence the selectivity of pyrazon. On light soils the rate of application should not exceed 3.2 kg/ha. Particulary on lighter soils and under dry conditions high rates of fertilizer applied pre-seedingly may increase the salt concentration in the soil and therefore, in combination with pyrazon, endanger the emergence of the beets. Applications of seed dressings and insecticidal soil treatments may, together with pyrazon, cause beet injuries when one of the compounds is used in abnormal high rates. Injury may also occur when the germination of beets is weakened by deep drilling, soil crusting or low temperatures. Pre-seeding incorporation of pyrazon, which gave a better weed control under dry conditions than the normal post-seeding application, did not influence the growth of the beets and confirmed the good selectivity of the material.

INTRODUCTION

Since its introduction by Fischer (1962), 1-phenyl-4-amino-5-chlor-pyridazon-6 (suggested common name pyrazon) has proved itself succesful in trial and commercial uses in many sugar beet growing countries of the world. During 1964 an area of about 200,000 ha has been treated with pyrazon and OMU + BiPC in Germany, i.e. about 60 % of the sugarbeet area. Also in France approximately 10 - 15,000 ha of sugar beets were treated with pyrazon.

The practical applications have confirmed experimental results achieved in 1962 and 1963: 3.2 kg/ha of techn. pyrazon resulted in good compatibility to beets even on lighter soils.

Some factors influencing the selectivity of pyrazon such as stage of beet development, soil type, climatic conditions and dosage rate were already reported by Fischer (1962) and Beinhauer (1964). The correlations between such factors and the selectivity of pyrazon have been studied in detail in connection with the few cases of beet injury occured in 1964. The following factors were also found to be involved: fertilizing, insecticidal treatment, depth of drilling and application techniques.

Another important factor was found to be soil moisture. Where conditions were rather dry, a satisfactory standard of pre-emergence weed control could not be achieved. Pre-seeding incorporation of pyrazon led, under dry conditions, to a better utilization of the soil moisture present. In 1963, good results in respect to selectivity and weed control were observed by this method in Germany. Therefore this application time was once more examined during 1964.

METHODS AND MATERIALS

Beside field trials in Germany and France pot experiments were carried out for investigation of certain factors.

The material used in 1964 was pyrazon formulated as a wettable powder containing 80 % technical 1-phenyl-4-amino-5-chlorepyridazon-6. This formulation is known as PYRAMIN. The rates of application expressed as per kg/ha active ingredient (a.i.) refer to technical pyrazon. The following dosage rates were used in the experiments:

2.4 kg/ha	=	2.1 lb/ac
3.2 "	=	2.8 "
4.8 "	=	4.2 "
6.7 "	=	5.7 "
7.2 "	=	6.4 "

Detailed trials in Germany:- The trials were conducted by the B.A.S.F. field and advisory staff in different parts of Western Germany. Plot sizes used were generally 25 m^2 with 4 replicates laid out in randomised blocks. Overall applications of pyrazon were made by knapsack-sprayer.

The details of each trial are given in the tables. Assessments of beet injuries were made up to the following scale:

Assessment scale for crop injuries	% damage
1 = no injury	0
2 = very slight injury	2.5
3 = slight injury	5
4 = slight to moderate injury	10
5 = moderate injury	15
6 = moderate to severe injury	25
7 = severe injury	35
8 = very severe injury	67.5
9 = complete mortality	100

Field trials in France:- One series of 47 trials were conducted by the I.T.B. (Institute Technique Français de la Betterave Industrielle). They were carried out according to an identical trial key by the strip method and sprayed with a band sprayer attached to a precision drill. The band width was normally 15 cm. The results gained in these uniform trials were very representative.

In some of the experiments beet injuries were observed. Therefore the I.T.B. together with the field staff of the PROCIDA Co. issued for each experiment a query sheet. The details of these sheets were examined at the B.A.S.F. Experimental Station, Limburgerhof.

Pot experiments of the B.A.S.F. laboratory for agricultural chemistry:- The factors "fertilizing" (trial A) and "seeding depth" (trial B) were studied in glass dishes (Neubauer-dishes) which had a surface of 100 cm^2, a height of 6 cm and no drainage holes.

Soil type in trial A comprised of Limburgerhof sand containing 13 % silt and clay.

Soil type in trial B was Gartelshausen loam with 37 % silt and clay.

In both cases, "silt and clay" means soil fractions with a particle size of less than 0.02 mm.

In trial A, a complex fertiliser 13 : 13 : 21 was used.

Evaluations were made by counts, photographs and determination of the dry weights.

Pot experiments of the B.A.S.F. laboratory for herbicidal research:- The factor "insecticidal treatment" was investigated from experiments carried out in the open. Plastic pots with a diameter of 8 cm and with drainage-holes were used.

Soil-type: Limburgerhof sand
Number of beet seeds per pot: 30; depth of seeding: 2 cm
Watering: 3 - 6 mm daily
Evaluation by: counts of beetplants

RESULTS

The results of the experiments considering the different factors are described in the following.

Soil type

A series of experiments in Germany - conducted by the B.A.S.F. advisory staff-were designed to investigate the influence of different soil types on the selectivity of pyrazon. To ensure similar climate conditions, only light and heavy soils situated in a narrow area were chosen. There was no variation in time of drilling and application. The results from the 4 parallel experiments are given in table 1.

Table 1.

Response of beets to pre-emergence applications of pyrazon on different soil types.

Soil type	Injury rating 1 - 9 pyrazon kg/ha				Number of trials
	0	2.4	3.2	4.8	
Light soils (sand-loamy sand)	1	1	1.1	2.1	4
Heavy soils (loam-clay)	1	1	1	1.4	4

On all soil types, the normal rate of 3.2 kg/ha pyrazon generally caused no growth retardations or damages. A 50 % overdosage (= 4.8 kg/ha a.i.) applied on heavier soils was practically tolerated by the beets, whereas on lighter soils, a temporary growth depression occurred. Although these depressions are of minor importance, attention should be paid as the inter-action of other unfavourable factors tend to make the results worse. The analysis of the French experiments carried out with a dosage rate of 4.8 kg/ha a.i., also showed a certain correlation between soil type and beet injury. The details are given in table 2. The heavier the soil, the less the number of experiments with heavier injuries.

Table 2.

Relations between soil type and beet injury after application of 4.8 kg/ha pyrazon.

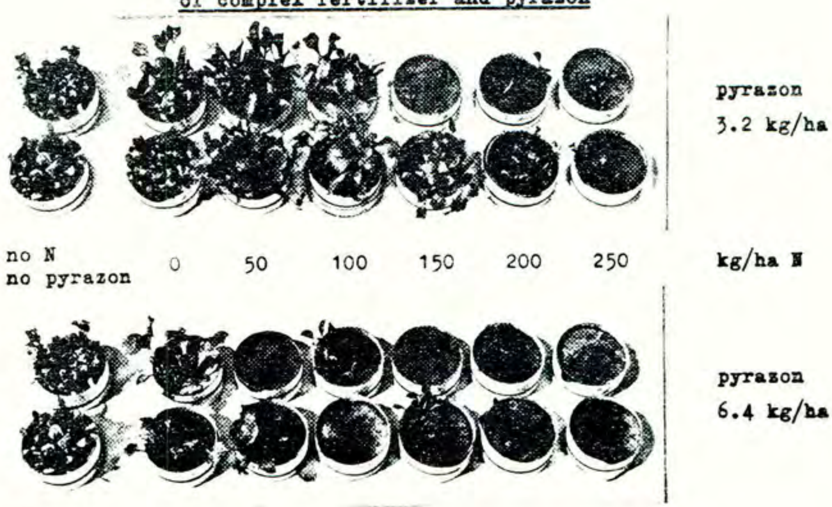
Soil type	Number of treatments with no injury	slight injury	heavier injury	Number of trials
sandy soils	1	4	6	11
loam/clay	10	4	2	16
calcareous loam and clay	12	4	1	17

Fertilizer

This factor was investigated in pot experiments at the B.A.S.F. laboratory for agric. chemistry. The lighter soil under examination was taken from a field on the B.A.S.F. Experimental Station Limburgerhof. Beets seeded on these fields already showed some injury probably due to overhigh fertilizer amounts applied in springtime. This light soil was chosen because studies on correlations between fertilizer- and pyrazon-applications should be carried out under extremely hard conditions. The results of the experiments achieved can be seen from figure 1 photographed 33 days from starting the test.

Figure 1.

The response of beets on the application of complex fertilizer and pyrazon



From this trial it was clear that the normal rate of 3.2 kg/ha pyrazon was tolerated by beets when the fertilizer amount did not exceed 100 kg/ha N. The amounts of 6.4 kg/ha pyrazon and 50 kg/ha N caused a marked retardation of beet growth. However, these results are valid only under the hard experimental conditions explained.

Countings of the beets showed that increasing amounts of N reduced the emergence of the beets. The mortality of plants observed at a later stage of development was mainly dependent on the pyrazon rates. Accordingly, the injuries shown in figure 1 are a summary of fertilizer and pyrazon effects on beets.

It is noteworthy that the germinating capacity in the check was not more than about 80 %.

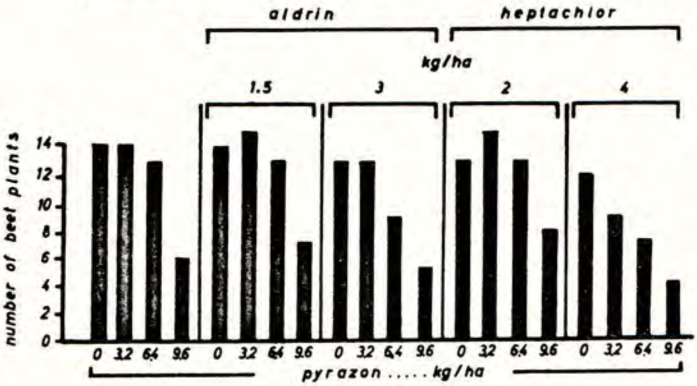
Insecticidal treatment

For the control of soil born insects the soil or the seed has to be treat et with insecticides. The effects of increasing amounts of pyrazon on beets in combination with aldrin/heptachlor soil treatments was investigated by pot experiments at the B.A.S.F. laboratory for herbicidal research. Aldrin was applied to the soil at rates of 1.5 and 3 kg/ha a.i. and heptachlor at rates of 2 and 4 kg/ha a.i..

The effect was critically examined by counting the number of beet plants where 12 - 15 plants per pot were considered normal.

Figure 2.

The influence of pyrazon on beets in combination with soil application of aldrin and heptachlor.



From figure 2 it can be concluded that beets tolerate a single pyrazon application at doses of 3.2 or 6.4 kg/ha. However, at the very high rate of 9.6 kg/ha thinning was observed. Beets also tolerated "normal" and "doubled" pyrazon rates in combination with soil treatments of 1.5 kg/ha aldrin as well as 2.0 kg/ha heptachlor, but double doses of insecticides in connection with increased amounts of pyrazon caused severe thinning.

Seeding depth

In springtime 1964 the fields had a very good tilth. On lighter and medium soils this often resulted in deeper than normal drilling, causing unfavourable germinating conditions particularly when the soil surface became crusted. Although this is a known fact farmers were inclined to believe that inhibited germination only originated with sprayings of pyrazon.

As a result, the B.A.S.F. laboratory for agric. chemistry carried out a pot experiment to investigate possible correlation between depth of drilling and pyrazon treatment (table 3).

Table 3.

Effect of seeding depth and pyrazon on the dry weights of sugar beets.

Treatment	kg/ha	Seeding depth cm	Dry weight g
Untreated	-	1.5	11.0
pyrazon	3.2	1.5	9.3
		3.5	7.0
pyrazon	6.4	1.5	6.6
		3.5	3.5

The results reported in table 3 indicate that, due to the beet reduction in numbers, the dry weights became less when seeding depths and rates of pyrazon were increased.

Field trials carried out in France confirmed the influence of deep drilling on the development of beet seedlings. If these trials were divided into two different seeding depths (table 4) it was obvious that deeper seedings resulted in a higher precentage of trials with beet injuries than shallow seedings. The rate of pyrazon was 4.8 kg/ha.

Table 4.

Influence of seeding depth on beet injury in French field trials.

Seeding depth	Number of treatments with no injury	slight injury	heavier injury	Number of trials
2 cm and less	17	3	2	22
Deeper than 2 cm	7	9	6	22

The French trials were carried out with different types of precision drills. Special stress should be given to the fact that the type of drilling equipment may have an influence on the uniformity of the seeding depth.

Application techniques

The trials of the I.T.B. in France were planned with a dosage rate corresponding 4.8 kg/ha at overall application. The application techniques involved band sprayers attached to precision drills. The band width was supposedly 15 cm, but exact measurements showed that band width was sometimes reduced to 10 cm. In these instances pyrazon doses of up to 7.2 kg/ha a.i. were reached. The correlation between degree of beet injuries and band width is demonstrated in table 5.

Table 5.

Relations between beet injury and band width

	Number and percentage of treatments with no injury	slight injury	heavier injury	Number of trials
Band width of 15 cm and more	20(= 69%)	6 (= 21 %)	3 (= 10 %)	29
Band width of less than 15 cm	5(= 31%)	5 (= 31 %)	6 (= 38 %)	16

It was found that beets in trials with a band width of less than 15 cm were damaged to a greater extent than those from experiments with a band width of 15 cm and more. From these trials it was apparent that even on medium to heavy soils, as occurred in France, overdosages of pyrazon should be avoided.

Pre-seeding incorporation

From many trials it became evident that pre-seeding incorporation of pyrazon improved weed control, when climatic conditions were rather dry. The B.A.S.F. advisory staff conducted a series of field trials to investigate the effect of pyrazon when incorporated alone and combinated with a triallate/diallate treatment.

Table 6.

The influence of different application methods of pyrazon on beets.

	3.2 kg/ha pyrazon post-seeding	3.2 kg/ha pyrazon pre-seeding incorp.	2.4 kg/ha pyrazon + 1.2 kg/ha di/triallate pre-seeding incorp.	Number of trials
Injury rating 1 - 9	1.1	1.3	1.2	17

As shown in table 6, practically the same good selectivity was achieved by both methods and by the addition of di-/triallate. The addition of these materials is important in the control of grassy weeds.

DICUSSION

During 1964, approximately 150,000 ha of beets in Europe were treated with pyrazon and in very few cases were there complaints concerning beet injuries. These complaints were carefully examined and it was concluded that a coincidence of certain unfavourable factors may influence the selectivity of pyrazon.

3.2 kg/ha i.a. is considered the normal rate of pyrazon. Rates of more than 50 % above normal should be avoided. With this in mind, we stress the importance of a uniform band width when band spraying. Soil insecticides in addition to pyrazon will not cause adversive effects when recommended rates are observed.

Fertilizer rates of 130 - 150 kg/ha N with a pyrazon dosage of 3.2 kg/ha appear to be safe. Particularly on lighter soils and under dry conditions, a very high fertilizer rate forms an unfavourable level of salt concentration, thus endangering the emergence of beets. In such a case the selectivity of herbicides may be reduced.

Factors delaying the emergence of beets, e.g. too deep drilling, soil crusting, cold weather conditions etc., could also cause a weakening of the beet seedlings so that high rates of pyrazon may increase possible injuries.

In the trials the most suitable drilling depth for beets has been approximately 2.5 cm. As far as drilling depths were concerned, different types of precision drills were found to drill differently. This warrants special attention.

Taking the above mentioned factors into account, pyrazon, at rates of

3.2 kg/ha on light and medium soils and
4.8 kg/ha on heavier soils

may be safely applied. The unfavourable influence of other factors on beets may decrease the selectivity of pyrazon. Therefore strict observations to the fertilizing and insecticidal recommendations must be observed.

Under these conditions also, a pre-seeding incorporation of pyrazon is possible.

We have studied all the above named factors in detail because they may concern many other soil herbicides.

Acknowledgments

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References

BEINHAUER, H. (1964) Neuere Versuchsergebnisse zur Unkrautbekämpfung in Zuckerrüben mit Alipur und Pyramin. Zucker 17, 59-64

FISCHER, A. (1962) 1-Phenyl-4-amino-5-chlor-pyridazon-6 als ein neues Rübenherbizid. Weed Res. 2, 177-184

Research Summary

FURTHER EXPERIMENTS WITH THE USE OF PYRAZON IN SUGAR BEET

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INTRODUCTION

Work reported by Fischer (1961) and by a number of authors at the Sixth British Weed Control Conference demonstrated the potential selectivity of this herbicide and indicated the need for further study of the problems associated with variations in soil type and moisture status, together with the need for study of the different methods by which the herbicide could be applied. With this aim experiments were undertaken in 1963 in which applications made just after drilling were compared with applications made at the cotyledon to early 2-leaf stage of the crop. The results showed that responses to post-emergence applications were so variable as to cast doubt upon the value of the technique except as an emergency treatment. Meanwhile Lush and his colleagues reported the low activity of pre-emergence applications under dry conditions and suggested a possible improvement from working the herbicide into the seedbed before drilling. Accordingly the series was modified in 1964 so that applications made just after drilling were compared with applications worked into the seedbed before drilling. Seven experiments were completed both in 1963 and 1964. Soil types ranged from very light sands to medium silt soils but no experiments were satisfactorily concluded on heavy clay soils. In 1963 all experiments received substantial amounts of rain during the three weeks after spraying with the possible exception of one late drilled site. This was also true in 1964 and in fact the earlier part of the season was notable for extremely cool and wet conditions.

All experiments were sprayed with an Oxford Precision Sprayer at a volume rate of 50 gals/ac. The experiments were all laid out to a 4 x 4 latin square design, plots being split for method of application. The main treatments in both years were 0, 1.5, 3.0 and 6.0 lb/ac a.i. of pyrazon.

RESULTS

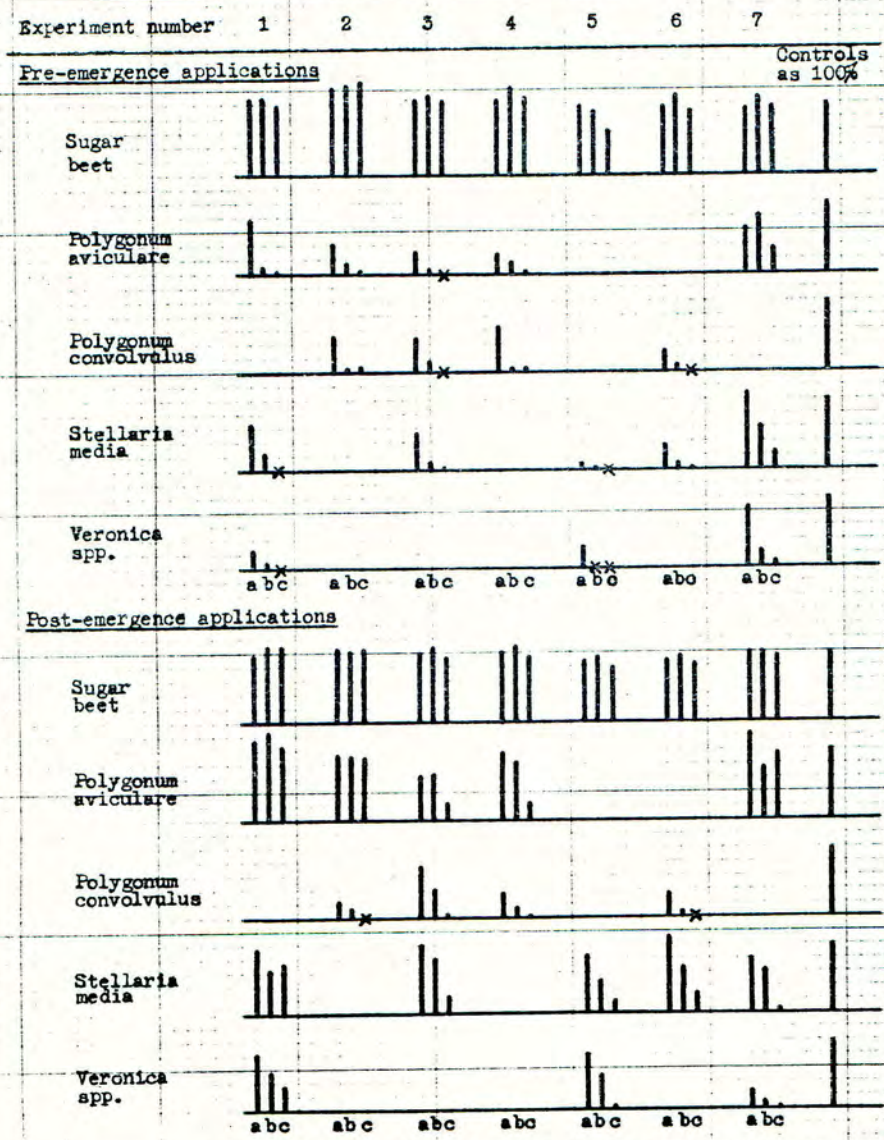
The 1963 experiments

Some results of these experiments are shown in Fig. 1 which illustrates the seedling counts of sugar beet and the four most commonly occurring weed species. In all cases these have been expressed as a percentage of the counts on control plots.

Pre-emergence applications had little or no effect on the beet seedling counts except in experiment No. 5. However, in some cases where numbers were unaffected the early vigour of the crop was reduced, but recovery was apparently rapid and complete. At site No. 5 seedling numbers and vigour were markedly reduced by the dose rate of 6.0 lb/ac and this was reflected in a reduced plant population and lower yield. In general the effects of pre- and post-emergence applications on beet were similar, except in experiment No. 6 where post-emergence applications of 3.0 and 6.0 lb/ac resulted in marked reduction in vigour and some seedling mortality with subsequent loss of yield.

Figure 1

1963 Experiments - Seedling counts of sugar beet and some major weeds

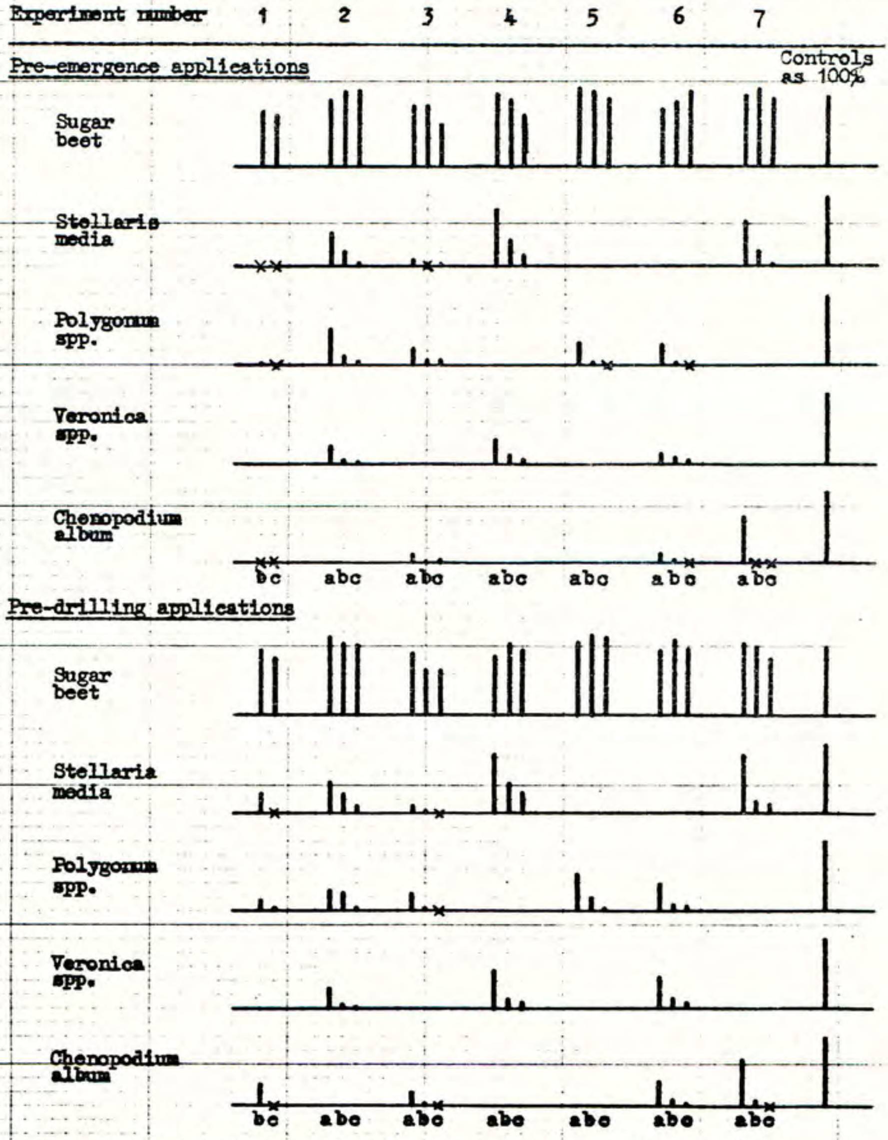


Dose of PCA lb/ac (a.i.) - a = 1.5 b = 3.0 c = 6.0

x = No survivors

Figure 2

1964 Experiments - Seedling counts of sugar beet and some major weeds



Dose of PCA lb/ac (a.i.) - a = 1.5 b = 3.0 c = 6.0

x = No survivers

Fig. 1 clearly demonstrates that pre-emergence applications were the most effective for weed control. There were no great differences in the susceptibility of the main weed species to pre-emergence applications but there was a striking difference between the susceptibility of Polygonum aviculare and P. convolvulus to post-emergence applications. Pre-emergence activity in experiment No. 7 was comparatively low.

The 1964 experiments

Seedling counts of sugar beet and the four most common weeds expressed as a percentage of counts on control plots are shown in Fig. 2.

Results were generally similar to those recorded in 1963 but pre-emergence activity was higher in experiments 1 and 3 where doses of 3.0 and 6.0 lb/ac resulted in marked effects upon the numbers and vigour of sugar beet seedlings. Most weed species were very well controlled but Viola tricolor proved relatively resistant.

No major change in selectivity resulted from soil incorporation but at all sites, except that of experiment No. 7, activity of pyrazon was reduced by this method of application. This reduced activity was most marked at sites 1 and 5.

DISCUSSION

Application of pyrazon immediately after drilling was the most satisfactory technique tested and a dose of 3.0 lb/ac applied in this way in most cases resulted in over 80% reduction in seedling population of a range of weeds, without damage to the crop. Activity was exceptionally high on some sites where applications were made to very light soils early in the season. It would appear therefore that the dose rate of 3.0 lb/ac which is generally acceptable for a range of loam soils might be reduced on very light soils. Conversely at one experiment in the series (No. 7 in 1963) activity of pyrazon was relatively low. This site was drilled rather late in the season so that soil moisture could have been the limiting factor, but the effect of soil type cannot be ruled out completely since this was the only experiment of the series to be carried out on a silt soil.

The post-emergence applications in 1963, made in every case at the very early 2-leaf stage, were not satisfactory. In some cases crop damage was caused and, with the exception of Polygonum convolvulus and Sinapis arvensis, weeds were not well controlled. Despite these results the impression was formed in the field that post-emergence applications, whilst not so efficient as pre-emergence applications, were worthy of consideration as emergency treatments.

The main significance of the soil incorporated treatments included in the 1964 experiments was that such incorporation might reduce dependence upon rainfall. This could not be tested as the 1964 experiments all received adequate rain and, indeed the earlier part of the season was notably cool and wet. Under these conditions the soil incorporation technique reduced activity presumably due to dilution of the herbicide by its admixture into the soil. In most cases this reduction in activity was not so great as to rule out the technique for practical use and more work needs to be carried out on the effects of different methods of incorporation and if possible the interaction between incorporation techniques and climatic conditions.

TRIALS ON MIXING PYRAZON

INTO THE SOIL FOR SUGAR BEET CROPS

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Summary Mixing pyrazon into the soil before drilling has given satisfactory results for selectivity, as well as beet germination and weed control. This method has the advantage of making the treatment efficiency independent of rainfall.

INTRODUCTION

Selective weed control in crops by means of the pre-emergence method very much depends on weather conditions. For the spread of the herbicide in the top layer of the soil and its coming in touch with the young weed seedlings mainly depends on the amount of rainfall after the application.

So as to lessen the incidence of this factor that the farmer cannot control, we have mixed the herbicide, pyrazon (1) in this case, into the top layer of the soil where beet were to be drilled.

MATERIALS AND METHODS

Trials were carried out according to the method recommended by the Biological Trial Committee of the French Phytiatry and Phytopharmacy Society (2).

The trial sites were chosen because of their characteristics, as different as possible from each other. Some information concerning the trial conditions are given hereafter.

Experiment 1

This experiment was conducted at Aulnat, Puy-de-Dôme, France.

Soil type:	Clayey-siliceous
Seed:	Maribo Poly

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(1) - Pyrazon: 1 phenyl - 4 amino - 5 chloro - 6 pyridazone

(2) - This method can be obtained at the following address: Société de Phytiatrie et Phytopharmacie, 57, bld. Lannes, Paris 16e, France.

Pyrazon application date:	April 9th, 1964 for mixing-in April 10th for surface treatments
Drilling date:	April 10th
Mixing-in technique:	One going-over with a heavy harrow
Rainfall:	35 mm (counting 16 mm between April 1st and 10th) 38 mm during May

Experiment 2

This experiment was conducted at Poupry, Eure et Loir, France.

Soil type:	Clayey lime
Seed:	Ordinary Desprez seed
Application date:	April 11th for mixing-in April 14th for surface treatment
Drilling date:	April 13th
Mixing-in technique	Two crossed going-overs with a light harrow
Rainfall:	From April 15th to 18th - 39 mm.

Experiment 3

This experiment was conducted at Maulers, Oise, France.

Soil type:	Plateau silt
Seed:	Rubbed and graded Polybeta Desprez
Precision drilling:	1 seed every 6 cm.
Application date:	April 22nd for mixing-in May 5th for surface treatment
Drilling date:	May 5th
Mixing-in technique	Spring-tined cultivator working down to about 30 cm.
Rainfall:	From April 22nd to 24th - 15 mm. During May - 22mm.

Experiment 4

This experiment was conducted at Fresnay-le-Gilmer, Eure et Loir, France.

Soil type:	Clayey lime, wet at treatment time
Seed:	Ordinary Desprez seed
Application date:	July 11th for mixing-in July 16th for surface treatment
Drilling date:	July 11th
Mixing-in technique:	A light harrow crossed twice and a spring-tined cultivator working down to 10 cm.
Rainfall:	July 11th to August 8th - traces

The Aulnat, Poupry, Maulers trials were carried out on sugar beet and the Fresnay-le-Gilmer trial on stecklings.

RESULTS

The results are given in the following table. The data we are giving allow the following remarks to be made:-

RESULTS OF THE PYRAZON MIXING IN TRIALS IN SUGAR BEET CROPS

Pyrazon rate of use in kg/ha	Application method	OBSERVATIONS			
		On weeds		On beet	
		Number destroyed %	Weight loss %	Number of seedlings per meter	Variation of seedling weight compared to control plot
Aulnat					
3.2	Mixed-in	72.2	78.2	29 (4)	+ 16 %
3.2	Surface	62.0	70.7	29	+ 16 %
Pouprry					
3.2	Mixed-in	93.7	98.4	23 (5)	+ 16.7 %
3.2	Surface	91.4	92	27	+ 23.1 %
Maulers					
3.2 + fertiliser (1)	Mixed-in	86.2	97.7	17 (6)	- 2.6 %
3.2 + fertiliser (1)	Surface	21.3	65.5	15	- 17.3 %
Fresnay-le Gilmer					
1.6	Mixed-in(2)	37.2	41.9	23 (7)	- 1.8 %
1.6	Mixed-in(3)	95.0	98.8	38	- 1.8 %
2.4	Mixed-in(2)	44.3	58.2	29	+ 18.9 %
2.4	Mixed-in(3)	69.3	86.7	35	+ 12.5 %
2.4	Surface	14.3	13.1	29	+ 18.9 %
3.2	Surface	9.4	42.6	27	+ 9.7 %

(1) - The fertiliser is a liquid (Solonia) containing N. 14, P. 14, K. 0, spread at 1,000 litres per hectare

(2) - Harrow
(3) - Spring-tined cultivator
(4) - Un-sprayed control plot 25
(5) - Un-sprayed control plot 21
(6) - Un-sprayed control plot 13
(7) - Un-sprayed control plot 33

Efficiency

Compared to the surface treatments, mixing pyrazon into the soil appeared to increase its efficiency on weeds. Efficiency was higher when the herbicide was mixed-in more deeply (Fresnay-le-Gilmer and Maulers trials).

This kind of application makes it possible to control correctly the weeds coming from deeply buried seed, such as Galium aparine (L.) and Avena fatua (L.).

Incidence on beet seedlings

During this first experimental year, mixing-in at various levels does not seem to have increased the toxicity of pyrazon toward beet seedlings.

However, it must be mentioned that in the Poupry trial (clayey lime soil), a temporary depressive action was noted at the rate of 3.2 kg of active ingredient per hectare.

DISCUSSION

The trials concerning the mixing-in of pyrazon with various equipment (light harrow, heavy harrow, spring-tined cultivator) have shown that the efficiency of pyrazon seems all the more important that the product comes in touch with the wet layer of soil. Furthermore, for the same weed control action, the rate of use of pyrazon mixed into the soil can be lowered by about one fourth (Fresnay-le-Gilmer trial) compared to the rate used in the pre-emergence treatment. Finally, mixing pyrazon into the soil can provide the following advantages:-

It does not slow the speed of precision drills (the chemical being mixed-in before this operation).

Weed control is done on the whole area under beet.

It enables to achieve good efficiency whatever the rainfall before drilling may be.

It makes it possible to destroy weeds that germinate deep in the soil, such as Galium aparine (L.), Avena fatua (L.) etc.

As the mixing-in technique does not require a high rate of pyrazon, the chemical's selectivity toward beet seems greater.

FURTHER EXPERIENCES WITH 1-PHENYL-4 AMINO-5 CHLOROPYRIDAZONE-6 (PYRAZON) FOR THE CONTROL OF ANNUAL WEEDS IN SUGAR BEET

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Summary 1963 trials gave a clear indication of the greater reliability of pre-emergence application and the need of adequate moisture for effective weed control by pyrazon. Incorporation of the herbicide produced greater efficacy under drier conditions.

In 1964, the Lenton trials formed an integral part of a wide programme. This comprised detailed trials examining rates, methods and timing of use and country wide user trials examining application under farm conditions. Application during the wet spring gave good weed control where drilling was early enough. Late applications under drier conditions were less successful. Incorporation under the moister conditions was generally of little advantage. Soil type was found to be of significance. On light soils greater weed and crop effect was noted showing the need for a differential rate of use in the U.K.

INTRODUCTION

Fischer[1] first reported the promising selective herbicidal properties of PCA (later to be known as pyrazon).

Fischer[2], Cussans[3], Lhoste et al and Lush et al[4] reported results in the field in Germany, France and the U.K. There was an indication that in the U.K., pre-emergence application might be more selective. Incorporation was suggested as a means of improving weed control.

Further trials were arranged in 1963 to establish the relative efficacy of pre- and post-emergence application and to gain information on incorporation. This work led logically to a large scale joint programme in 1964.

METHODS AND MATERIALS

Trials sites were selected with the assistance of the British Sugar Corporation and members of Boots fieldstaff.

a) Detailed trials:- plot size was $^1/_{120}$th acre with three replicates, application of pyrazon was overall by boom sprayer at 20 g.p.a.

b) Farmer user trials:- application of pyrazon was made by band sprayer or overall with farm equipment calibrated beforehand. Plot size was generally between ½ and 1½ acres without replication.

The experimental material used in both 1963 and 1964 was pyrazon formulated as a wettable powder containing 80% technical 1-phenyl-4 amino-5 chloropyridazone-6 (pyrazon). This formulation known as Pyramin was supplied by Badische Anilin und Soda Fabrik.

1963

In 5 detailed trials in Nottinghamshire and Lincolnshire on soils varying from sand to clay loams, rates of use, timing of application, and incorporation were examined. Treatments were as follows:-

a) Incorporated pre-drilling application at 2.0, 2.8 and 3.6 lb/ac a.i. (pre-emergence)

b) Non-incorporated immediate post-drilling application at 2.0, 2.8 and 3.6 lb/ac a.i.

c) Post-emergence application at 2.0, 2.8, 3.6 and 5.6 lb/ac a.i.

Beet stages were from the initial appearance of the first leaf until the first leaf was fully expanded.

Drilling in the locality where the detailed trials were laid down was generally later than in East Anglia and occurred in the trials between the latter half of April and early May. Soils were sufficiently moist to ensure crop and weed emergence but only slight rain occurred within the three weeks after drilling. A demonstration trial in Hampshire was drilled earlier in the season under moist conditions.

1964

7 detailed trials in Nottinghamshire, Lincolnshire, Leicestershire and Staffordshire on soils from sands to clay loams were laid down to examine rates of use and the effect of incorporation with different implements compared with surface pre-emergence applications. Three types of trials were carried out:-

a) Comparison of 2.0, 2.8 and 3.6 lb/ac a.i., made by incorporated pre-drilling and by non-incorporated post-drilling (pre-emergence) methods.

b) Comparison at 2.8 lb/ac a.i. of the following incorporating implements; light and medium harrows, chain harrows, weeders and the Kombi Krumbler by the pre-drilling method with non-incorporated post-drilling (pre-emergence) application at 2.0 and 2.8 lb/ac a.i.

c) Comparison of different dates of drilling in the same trial. Incorporated pre-drilling application at 2.8 lb/ac a.i. and non-incorporated post-drilling (pre-emergence) application at 2.0 and 2.8 lb/ac a.i. were made.

In a further detailed trial the response to pyrazon of different seed types and varieties was compared.

27 farmer user trials covered a wide range of soils and climatic conditions. Application was by band or overall sprayer, generally immediately after drilling. Rate of use was 2.8 lb/ac per sprayed acre.

Drilling was generally late in 1964, but unlike the late drilling in certain areas in 1963, it coincided in most instances with wet conditions.

Assessments of the 1963 and 1964 trials were made by qualitative and quantitative methods.

RESULTS

Details are given in the tables of six typical detailed trials - all that space limitations allow.

1963 Trials

The beet and weeds emerged simultaneously and with post-emergence applications both crop and weed tended to be equally susceptible to pyrazone. At the early first leaf stage when some measure of weed control was obtained serious beet damage occurred. At Marston beet sprayed at the fully expanded first leaf was damaged and there was no weed control.

Pre-emergence applications were superior. Unincorporated pre-emergence application although giving somewhat greater selectivity was still unsatisfactory. Incorporated pre-drilling application showed improved weed control and crop safety. At Marston where drilling was rather earlier and conditions rather moister a satisfactory standard was achieved by this technique. In Hampshire where drilling was early and moisture high, good results were achieved without incorporation.

1964 Trials

Under the far wetter conditions results were far superior to 1963. Generally weed control was good to excellent and little adverse crop effect occurred. Late applications gave poorer standards of weed control which could be correlated to drier conditions. Under drier soil conditions as at Marston, the incorporated pre-drilling method showed some improvement. Under the wetter conditions prevalent this year, little improvement was noted with incorporation. In one replicated trial some blocks showed poorer others gave better control. No consistent difference was found between different implements.

A differential response according to type of mineral soil was apparent. On medium and clay loams, provided adequate moisture was available, weed control was excellent at 2.8 lb, whilst 2 lb gave quite good control. Under these conditions the crop tolerated 3.6 lb of pyrazon and only slight retardation was recorded. On sandy soils both crop and weed response was often more marked. Provided moisture was adequate 2 lb pyrazon gave excellent weed control. Often 2.8 lb caused no crop effect on sandy soils, but in three trials marked crop effects occurred. At Lichfield rates above 2 lb and at Coddington rates above 2.8 lb sufficiently thinned the crop to make singling a more difficult task. At both these sites the highest rate - 3.6 lb left just sufficient beet to make an adequate plant population. At Sleaford however 2.8 lb caused up to 80% thinning and yields will be depressed because of an inadequate population. For all sandy sites records of the manurial programme, pH, coarse/fine sand ratio were examined; no correlation between any of these factors and increased herbicidal activity was apparent.

In line with continental experience activity against weeds on fen and peat soil was found to be negligible at the rates used in this series of trials.

Prolonged residual weed control after singling was noticeable at several sites where there was no disturbance of the soil after overall application. No differences in response by different types and strains of beet seed have been found. Differences in weed susceptibility were observed. The more commonly occurring weeds are categorised in Table I.

DISCUSSION

Post-emergence application of pyrazon to sugar beet would appear to be of less value in the U.K. because of difficulties of timing. A post-singling technique described by B.A.S.F. but not included in the series of trials reported in this paper would appear to be worthy of evaluation.

With pre-emergence application which at present appears to be the more promising method of use for the U.K., a greater margin of selectivity was shown. Weed control and crop safety in 1963 were further improved by incorporation. This further improvement was considered to be due to placing the herbicide in more intimate contact with soil moisture. At the Hampshire trial in 1963 soil moisture and rainfall soon after application were more plentiful, consequently weed control was good without incorporation.

The importance of soil moisture and rainfall was demonstrated very clearly in 1964. Drilling of beet in the main sugar beet areas was later than in 1963 but since the delay was due to wet soil conditions this ensured adequate soil moisture at the time of drilling and application. Only in a few of the trials were weed control results inadequate. Except where these failures were on fen soils they were associated with the very last applications of the season when conditions were becoming drier. Since early drilled beet is more likely to be associated with the adequate soil moisture and following rain so necessary to successful pyrazon usage, it appears important in future seasons to apply pyrazon to early drilled crops.

Another important feature emerging from the 1964 trials is the relationship between activity and soil type. On medium soils, 2.8 lb a.i. per acre proved to be the optimum rate. On sandy soils, where activity was greater than on other mineral soils a lower rate of use is necessary in the U.K. This is in contrast to continental European countries where the minimum rate employed is 2.8 lb. The major acreage of beet in the U.K. is grown in soils not heavier than medium loam, hence the concentration of trials on loams and lighter soils. The need for further work is indicated on heavier soils at the increased rates which are currently employed in Europe for heavy soils.

Generally, due to adequate rainfall, incorporation did not give the improvement demonstrated under 1963's drier conditions. It is therefore not possible to comment on the relative efficacy of the different implements tested. Further investigation into this technique should be considered.

Acknowledgments

The authors wish to acknowledge the valuable advice of the staff of Badische Anilin und Soda Fabrik; the collaboration of the British Sugar Corporation; Messrs. Sharpe Limited, Sleaford; members of Boots fieldstaff and staff of Lenton Experimental Station, together with the many farmers who have been involved in field trials.

References

FISCHER, A. (1961) EWRC/COLUMA Symposium on herbicides, Paris, 1961.

FISCHER, A. (1962) 1-Phenyl-4-amino-5-chlor-pyridazon-6 (PCA) Als ein neues Rübenherbizid. Weed Res. 2, 177-184.

FISCHER, A. (1962) Private communication.

CUSSANS, G. (1962) Some Preliminary Investigations into the selectivity of 1-phenyl-4 amino-5 chloropyridazone-6 in sugar beet. Proc. 6th Brit Weed Cont Conf 2, 725-733.

LHOSTE, J. et al (1962) Field Trials with 1-phenyl-4-amino-5-chloro-pyridazone-6 a selective weedkiller for sugar beet culture. Proc. 6th Brit Weed Cont Conf 2, 753-755.

LUSH, G.B. et al (1962) Preliminary results with 1-phenyl-4 amino-5 chlor-opyridazone-6 for the control of annual weeds in sugar beet. Proc. 6th Brit Weed Cont Conf 2, 735-749.

Table I - Weed Susceptibility List

Susceptible

Sinapsis arvensis	Charlock
Spergula arvensis	Corn Spurrey
Poa annua	Annual Meadow Grass
Polygonum persicaria	Redshank
Raphanus raphanistrum	Wild radish
Thlaspi arvense	Pennycress
Capsella bursa pastoris	Shepherds purse
Galeopsis tetrahit	Hempnettle
Urtica urens	Annual nettle
Matricaria spp.	Mayweed
Chenopodium album	Fat Hen
Papaver rhoeas	Corn Poppy
Lamium purpureum	Red Dead Nettle
Stellaria media	Chickweed
Polygonum convolvulus	Black Bindweed

Moderately resistant

Polygonum aviculare	Knotgrass
Veronica spp.	Speedwells
Anagallis arvensis	Scarlet Pimpernel
Fumaria officinalis	Fumitory
Galium aparine	Cleavers

Resistant

Avena fatua	Wild oats

and all perennial weeds.

Assessment Scale used in Tables II - V

	Crop	Weed
0.	No injury	No control.
1.	Slight injury, no mortality	Up to 20 per cent weed control.
2.	Slight to moderate injury, up to 15 per cent mortality.	Up to 40 per cent weed control.
3.	Moderate injury, up to 25 per cent mortality.	Up to 60 per cent weed control.
4.	Severe injury, up to 50 per cent mortality.	Up to 80 per cent weed control.
5.	Very severe injury, over 50 per cent mortality.	Over 80 per cent weed control.

Timing of spraying is defined in the table as follows:

"Pre-" = Pre-drilling - refers to spraying before drilling.
"Post-" = Post-drilling - refers to spraying after drilling.

Table II - Typical Results of Detailed Trials

Site	Date and timing of spraying	Date of drilling	Temp. °C air	Temp. °C soil	Soil moisture and rainfall	Pyrazon lb/ac a.i.	Incorporation	Crop injury rating	Weed Stage	Weed control rating
Marston 1963 sandy	a)22 Apr.(Pre-)	23 Apr.	16	17	adequate for germination of crop and weed. Slight rain only between drilling and emergence.	2.0	once	0-2	unemerged	3-4
	b)23 Apr.(Post-)					2.8 3.6	nil	0-3		2-3
	c) 6 May(*)	23 Apr.	15	12		2.0 2.8	nil	3-5	cotyledon	2-5
	d)23 May(*)		10	10		3.6 5.6	nil	0-3	1-4 leaves	0-1
Caunton 1964 heavy loam	a) 9 Apr.(Pre-)	10 Apr.	11	7	good moisture followed by frequent rain.	2.8	once	0-1½	unemerged	4-5
	b) 9 Apr.(Pre-)		11	7		2.8	twice	0-1		
	c)10 Apr.(Post-)		14	8		2.0,2.8	nil	0-½		3-5(2.8 lb)
	d)27 Apr.(Pre-)	27 Apr.	18	12	adequate for good germination significant rainfall during germination.	2.8	once	0	unemerged	3-5
	e)27 Apr.(Post-)					2.0,2.8	nil	0-2		3-4
	f) 1 May(Pre-)	1 May	12	8	germination poor and patcy - rather dry conditions.	2.8	once	0	unemerged	0-1
	g) 1 May(Post-)					2.0,2.8	nil	0		0-1

*Post-emergence application; 1 sugar beet at cotyledon stage 2 sugar beet at cotyledon stage

Table III

Site	Date and timing of spraying	Date of drilling	Temp. °C air	soil	Soil moisture and rainfall	Pyrazon lb/ac a.i.	Incorporation	Crop injury rating	Weed State	Weed control rating
Lichfield	a) 1 Apr. (Pre-)				good moisture followed	2.0		2		
1964	b) " "				by	2.8	once	3		
sandy	c) " "	1 Apr.	3	3	frequent rain	3.6		4	unemerged	4-5
	d) " "					2.0		2		
	e) " "					2.8	twice	3		
	f) " "					3.6		4		
	g) 2 April (Post-)					2.0		2		
	h) " "					2.8	nil	3		
	i) " "					3.6		4		
Coddington	a) 16 April (Pre-)				soil moist	2.0		0-2½		4½-5
1964	b) " "				followed	2.8	once	1-2		4-5
sandy to	c) " "				by frequent	3.6		1-3		5
sandy loam	d) " "	29 Apr.	15	10	rain	2.0		0-1	unemerged	4½-5
	e) " "				until drilling.	2.8	twice	1-2½		4½-5
	f) " "				Moderate rain	3.6		1-4		4½-5
	g) 30 Apr. (Post-)				after	2.0		0-2	*early	4-5
	h) " "		12	11	drill-	2.8	nil	½-2½	cotyledon to 1st	4-5
	i) " "				ing.	3.6		0-3½	leaf	5

*This was the single instance of treatment pre-crop emergence and post-weed emergence.

Table IV

Site	Date and timing of spraying	Date of drilling	Temp. °C air	Temp. °C soil	Soil moisture and rainfall	Pyrazon lb/ac a.i.	Incorp-oration	Crop injury rating	Weed Stage	Weed control rating
Prestwold 1964 sandy loam	a)13 Apr.(Pre-)	14 Apr.	11	-	good moisture followed by frequent rain	2.8	once	0	unemerged	3-5
	b)14 Apr.(Post-)					2.0, 2.8	nil	0		3-5
	c) 6 May(Post-)	6 May	16	14	germination of crop and weed rather slow - rather dry after drilling.	2.0, 2.8	nil	0		0-4
Gonalston 1964	a)10 Apr.(Pre-)	10 Apr.	12	8	soil moist followed by frequent rain	2.8	twice	0	unemerged	4-5
	b)11 Apr.(Post-)	10 Apr.	11	7		2.0, 2.8	nil	0		3-4 (2.8 lb) 3 (2.0 lb)

Table V - Summary of User Trials, 1964.

Number of trials per soil type		Moisture rating: good	moderate	poor	Crop Effect: nil	slight	severe	Weed Control: 5	4	3	2	1	0
		No. of trials			No. of trials			No. of trials					
light	4	4	0	0	4	0	0	2	2	0	0	0	0
sandy loam	3	2	1*	0	3	0	0	0	2	1*	0	0	0
medium	14	10	2*	2*	14	0	0	4	5	3*	0	1*	1*
organic	4	4	0	0	4	0	0	0	0	0	0	1	3
unclassified	2	2	0	0	2	0	0	0	2	0	0	0	0

*In every instance moderate or poor moisture rating is directly related to a poor weed control rating.

THE USE OF PYRAZON FOR PRE-EMERGENCE WEED CONTROL IN SUGAR BEET

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Summary A programme of twenty nine trials was carried out to determine the performance of Pyrazon (1-phenyl-4-amino-5-chloro-pyridazone-6) as a pre-emergence herbicide under a variety of soil and weather conditions; this work was combined with studies on the methods and effects of soil incorporation. The conclusions are that with the use of different rates according to soil type and with the assistance of soil incorporation in dry weather satisfactory weed control can be obtained without risk of crop damage.

INTRODUCTION

Since this chemical was introduced by Fischer (1) in 1961 a considerable amount of further investigation has been done both in Europe and in Britain. At the 6th British Weed Control Conference several papers were given on the subject (2), (3), (4). It was shown that the crop could tolerate a high rate of the chemical (4 lbs/ac.a.i.) during most stages of growth, and it was found that the majority of common weeds could be satisfactorily controlled at this rate provided that the application was made before the weeds reach the 2 true-leaf stage. The mode of action is primarily through the root system via the soil.

Soil type and soil moisture play an important part in determining the activity of the material. Since the soil surface can dry out rapidly at drilling time, it was thought that incorporation of the chemical into the soil would help to bring it into contact with the available moisture. It was decided to try to find a simple method of incorporation for use in commercial practice, as well as determining the optimum dose rate for each soil type.

METHOD AND MATERIALS

Field experiments were carried out in three series. In Series I the layout was a randomized block design in which an overall spray of Pyramin* was applied at different rates; these experiments will be harvested to determine crop yields. In Series II single plots were sprayed with a band sprayer with various soil incorporating mechanisms attached to a precision drill. The Series III trials also combined comparisons of incorporation with different rates of chemical.

* Pyramin is an 80% wettable powder formulation of Pyrazon.

Series I

The rates tested in terms of active ingredient were 2.4, 2.8 and 3.2 lbs. of Technical Pyrazon per acre, and a comparison was made between soil incorporation and no incorporation, at each rate. Trials were carried out at ten centres; the design was Randomized Block with three replicates, the plot size being $^1/_{127}$ acre. The application was made before the crop was drilled, with a knapsack sprayer at a volume of 30 g.p.a. and a pressure of 40 p.s.i. The details at each site are given in Table 1.

The efficiency was assessed by counts of weed species in 4' x 3' quadrats on each plot, and by visual scoring.

Series II

Twelve trials were carried out, using the same rates as in Series I, except at Site 15, on Fen peat, where the rates were 4, 5 and 6 lbs/ac.a.i. The sugar beet was drilled with a 5-row Stanhay Precision Drill. The seed was $^7/_{64}$ - $^{11}/_{64}$th. rubbed and graded, sown at 1½" spacing within the row. Spray treatments were applied with a Dorman band sprayer spraying a 7" wide band at 10 p.s.i. at 26.5 gallons per band acre.

The different incorporating mechanisms were used with the five seeder units as follows:-

1. Kombi Krumbler unit mounted in front (a free riding roller with rows of 1" tines).
2. No incorporation. Spray unit behind rear press wheel of seeder.
3. Kombi Krumbler unit mounted behind seeder unit. As this had little effect on the soil a set of spring tines was also attached behind.
4. Stanhay rigid tine harrow unit rear mounted.
5. Spring tine harrow mounted in front of seeder unit.

In each case the spray unit was mounted directly in front of the incorporation attachment.

Weed control was assessed by counts of weed species in two 6" x 18" quadrats in each drill of each plot, the results being expressed as totals of all species. The details of each trial are given in Table 2.

Series III

Seven trials were carried out, using the same rates of Pyramin as in Series I and II. The chemical was applied on an overall treatment with an Oxford Precision Sprayer at a volume of 30 g.p.a. The layout was a Latin Square design, the plot sizes being 40 - 80 sq.yds. Incorporation was done by hand raking. The details at each site are given in Table 3.

TABLE 1

Site	Soil Type	Drilled	Sprayed	Incorporation	Seed	Seed Rate/ Acre	Rainfall after spraying Week 1	Week 2	Week 3
1. Middleton Norfolk.	Light, sandy.	3.4.64	3.4.64	Drag Harrow	Klein E	5½ lbs.	0	1.11	0.69
2. Snettisham, Norfolk.	Light, Sandy.	7.4.64	1.4.64	Cultivator and drag harrow	-	4 lbs.	0.42	0.19	1.58
3. Guestwick, Norfolk.	Med/light soil.	10.4.64	10.4.64	Drag harrow and roll	Johnsons Bush N.	5 lbs.	1.11	0.69	0.45
4. Wisbech, Cambs.	Med. loam	15.4.64	15.4.64	Chain harrow	Klein E	6 lbs.	1.3	0.36	0.38
5. Sawtry, Hunts.	Heavy clay	23.4.64	22.4.64	Drag harrow	-	-			
6. Castle Camps Cambs.	Med/ heavy soil	13.4.64	13.4.64	Chain harrow	-	5¼ lbs.	1.13	0.30	0.63
7. Mereside, Hunts.	Fen peat	5.4.64	3.4.64	Chain harrow and roll	Hilleshog E	5 lbs.			
8. Methwold Hythe, Norfolk.	Fen peat	4.4.64	21.3.64	Chain harrow	Hilleshog E	5 lbs.	0.31	0.44	0.19
9. Somerleyton, Norfolk.	Med/light soil	25.4.64	23.4.64	Spring tine harrow	-	-	0.35	0.40	0.19
10. Stowmarket Suffolk.	Med/ heavy soil	13.4.64	23.4.64	Hand raking	Triple X	-	approx. 0.35	0.40	0.19

TABLE 2. Experimental Conditions Series II Trials

	Site	Soil Type	Date of drilling and spraying	Soil Condition	Rainfall after spraying Week 1	Week 2	Week 3
11.	Newmarket, Cambs.	Light, sandy	13.4.64	Fine tilth, well consolidated	1.36	0.33	0.81
12.	Babraham, Cambs.	Light, flinty	14.4.64	Fine tilth, moist ¾" below surface	1.20	0.46	0.47
13.	Thriplow, Cambs.	Light, chalky	15.4.64	Good tilth, moist at ¾"	1.33	0.59	0.48
14.	Ickleton, Cambs.	Med. loam	14.4.64	Lumpy tilth, moist at ¾"	1.48	0.48	0.57
15.	Burwell, Cambs.	Fen peat	14.4.64	Good tilth, moist at surface.	1.27	0.35	0.43
16.	Linton, Cambs.	Light loam	30.4.64	Hard on surface, moist at ½"	0.44	0.09	0.30
17.	Newmarket, Cambs.	Light, sandy	27.4.64	Compacted, very hard	0.81	0.13	0.04
18.	Babraham, Cambs.	Light, flinty	30.4.64	Crust on surface, moist at ½"	0.44	0.09	0.30
19.	Teversham, Cambs.	Chalky clay	1.5.64	Moist on surface, rather sticky	0.15	0.03	0.48
20.	Shelford, Cambs.	Light loam	1.5.64	Crust on surface, moist at ¼"	0.31	0.04	0.40
21.	Thriplow Cambs.	Light loam	4.5.64	Moist on surface	0.10	0.24	0.36
22.	Hadstock, Cambs.	Light clay	30.4.64	Moist on surface, rather sticky.	0.44	0.09	0.30

TABLE 3. Experimental Conditions Series III trials

	Site	Date of drilling and spraying	Soil Type	Seed	Method of incorporation
23.	Cupar, Fife.	7.4.64	Light, sandy, loam	Sharp's Klein E	None
24.	Cupar, Fife.	30.4.64	Light, sandy loam	Sharp's Klein E	None
25.	St.Monance, Fife.	3.4.64	Medium loam	Sharp's Klein E	Hand raking
26.	Kingshettle, Fife.	7.4.64	Sandy loam	West Zone Klein E	Hand raking
27.	Alyth, Perthshire.	10.4.64	Medium loam	West Zone Klein E	Hand raking
28.	Brechin, Angus.	13/14.4.64	Medium heavy loam	Sharp's Klein E	Hand raking
29.	Inchture, Angus.	15/17.4.64	Heavy loam	East Zone, Klein E	Hand raking

RESULTS

At the time of preparing this paper the trials had not been harvested, so that figures for crop yield and sugar content are not available. Analyses are also being carried out for chemical residues in the soil and in the crop.

Counts were taken of numbers of beet seedlings in all plots, and visual assessments made of seedling vigour; the counts have been summarised in Table 4 below. In only one plot in one trial was the crop seriously affected. In other trials where a slight reduction in size or vigour was noted at the first assessment the crop had completely recovered by thinning time.

TABLE 4

Numbers of beet seedling in treated plots as % of control.

Series I

2.4 lbs.	105.4
2.8 lbs.	99.3
3.2 lbs.	107.3
2.4 lbs. inc.	110.8
2.8 lbs. inc.	108.3
3.2 lbs. inc.	108.6

Series II

	All Treatments	Drill No.5 (as % of unincorporated treatment)
2.4 lbs.	97.5	99.3
2.8 lbs.	88.0	104.5
3.2 lbs.	92.0	126.3

The weed control results, expressed as percentage reduction in weed numbers, by comparison with the control plots, are given in Table 5. In the Series II trials the unincorporated treatments comprised only one drill out of the five and therefore where the weed numbers are very low the only figures are for the incorporated treatments.

TABLE 5

Site	Total No. of weeds in control	Soil Type	% reduction in weed numbers — Surface sprayed (2.4 lbs.	2.8 lbs.	3.2 lbs.)	Incorporated (2.4 lbs.	2.8 lbs.	3.2 lbs.)
1.	377	Light, sandy	65.5	65.4	81.7	72.5	80.2	83.6
2.	289	Light, flinty	55.1	86.9	79.8	76.9	81.0	85.5
3.	446	Med/light	89.1	90.8	91.3	92.0	96.7	94.9
4.	221	Med.loam	58.0	62.9	70.2	74.3	80.1	85.5
5.	221	Heavy clay	0	20.9	22.7	34.7	44.8	35.2
6.	173	Med/heavy	1.2	48.6	45.1	49.8	48.0	66.5
7.	316	Fen peat	18.1	19.1	25.0	33.3	36.3	31.1
8.	250	Fen peat	23.6	25.4	3.6	25.6	19.6	21.2
9.	182	Med/light	74.8	91.6	92.0	81.4	80.6	92.9
10.	472	Med/heavy	56.4	29.3	19.5	56.6	51.7	50.5
11.	163	V.light sandy	100.0	98.4	100.0	94.0	98.4	100.0
12.	32	Light, flinty				97.0	100.0	100.0
13.	111	Light, chalky	92.0	100.0	100.0	94.0	86.0	100.0
14.	204	Med.loam	48.9	75.8	72.8	69.5	83.5	84.0
15.		Fen peat	No control at 4, 5 or 6 lbs.					
16.	30	Light loam				90.0	80.0	100.0
17.	163	V.light sandy	97.5	100.0	100.0	86.5	100.0	100.0

TABLE 5 (contd)

Site	Total No. of weeds in control	Soil Type	% reduction in weed numbers: Surface sprayed (2.4 lbs.	2.8 lbs.	3.2 lbs.)	Incorporated (2.4 lbs.	2.8 lbs.	3.2 lbs.)
18.	32	Light, flinty				97.0	100.0	100.0
19.	111	Chalky clay				57.2	90,9	81.8
20.	49	Light loam	39.3	5.5	5.5	85.6	55.5	79.3
21.	111	Light loam	44.5	40.6	44.5	93.2	77.2	98.0
22.	19	Lighter clay				55.3	75.5	75.5
Series III	Scores for Weed Control (10 = 100% control, 7 = Commercially Satisfactory)							
			Surface sprayed pre-sowing			Surface sprayed post-sowing		
23.		Light sandy loam	8.5	8.5	8.75	7.75	8.0	8.0
24.		Light sandy loam	8.5	8.5	9.0	7.5	7.5	7.75
			Surface sprayed			Incorporated		
25.		Medium loam	8.5	8.5	9.0	8.5	8.5	9.0
26.		Sandy loam	9.5	9.5	9.5	9.5	9.5	9.5
27.		Medium loam	8.5	8.5	8.5	7.0	8.0	8.0
28.		Medium heavy loam	7.5	7.5	8.25	7.5	7.5	8.25
29.		Heavy loam	5.0	6.0	6.5	4.2	5.7	6.3

These results are best considered by dividing them up according to soil type. It should be remembered throughout that the figures given are for actual numbers of weeds. In all cases the size and vigour of the weeds in the sprayed plots were reduced, and hence the amount of competition they offered to the crop. In some cases, therefore, visual assessments have shown the trials to be satisfactory where the percentage alone might leave the matter open to doubt.

On the two trials on very light soils and the nine trials on light soils the 2.4 lbs/acre rate, surface sprayed, proved satisfactory throughout. On the light/medium soils (four trials) the 2.4 lbs. rate was satisfactory when the spraying was done in April, but in the two trials applied in May it was satisfactory only with incorporation. On the medium soils the 2.4 lbs. rate was completely satisfactory in only three out of six trials, but the 2.8 lbs. rate was quite adequate. On the two clay soils the 2.8 lbs. rate was satisfactory on the lighter clay, but none of the rates was satisfactory on the heavy clay. No rate was quite satisfactory on the one heavy soil, and on fen peat soils (three trials) no satisfactory pre-emergence weed control could be obtained even at rates of 4, 5 and 6 lbs/acre.

DISCUSSION

The moist soil conditions during April gave the chemical an ideal environment for demonstrating its weedkilling properties; at the same time they provided conditions which could have resulted in crop damage and it may be assumed that since the compound appeared safe this season there will be still less danger in drier years. The single case of crop damage occurred with the 3.2 lbs. rate on a very light sandy soil, where there was a $\frac{1}{3}$ reduction in the beet population.

It would appear that in moist soil conditions the 2.4 lbs. rate is suitable for light soils, and the 2.8 lbs. rate for medium soils. At these rates a very wide spectrum of weeds is controlled provided that they are treated before reaching the 2 true-leaf stage. The only common arable weeds not controlled in these trials were, Avena fatua, Agropyron repens, Agrostis stolonifera, Cirsium arvense and Sonchus spp.

One group of trials was put down later in the season to determine the effect of drier soil conditions. Out of the eight trials drilled between April 27th and May 4th six gave satisfactory results, but in the other two cases (trials 20 and 21) the weed control was unsatisfactory at all rates where the chemical was not incorporated into the soil. With soil incorporation, however, the performance was thoroughly satisfactory. There was regular rainfall throughout the second half of April and up till May 4th but in the following two weeks there was very little rain (0.1 to 0.2 ins.) at any of the late drilling sites. It can be said, therefore, that when drilling is carried out late in the season soil incorporation though not essential is a desirable precautionary measure.

Soil incorporation can be carried out either before drilling or at the time of drilling. In the Series I trials, where the chemical was applied as an overall spray incorporation was done by harrowing and the seed drilled directly afterwards or on the following day. Taking the series as a whole, this method was safer on the crop than the Series II methods, though inferior to the best method (drill No.5), but gave slightly inferior weed control.

The incorporating devices in Series II have already been described. Their relative efficiency is shown in Table 6.

Table 6

Drill No.	Total weed Numbers as % of Treatment without Incorporation
1	58
2	100
3	77
4	73
5	50

It can be seen that the two front mounted attachments gave the best results, the better of the two being the spring tine harrow attachment. This is a simple device and from observation in the field gave the most efficient mixing of the soil under all conditions.

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References

FISHER, A. (1961) E.W.R.C./columa Symposium on Herbicides, Paris.

CUSSANS, G.W. (1962) Some preliminary investigations into the selectivity of 1-phenyl-4-amino-5-chloro-pyridazone-6 in sugar beet. Proc. 6th British Weed Control Conf. 2, 725-734.

LUSH, G.B. et al. (1962) Preliminary results with 1-phenyl-4-amino-5-chloro-pyridazone-6 for the control of annual weeds in sugar beet. Proc. 6th British Weed Control Conf. 2, 735-749.

LHOSTE J and DURGEAT L-A Field trials with 1-phenyl-4-amino-5-chloro-pyridazone-6. A selective weedkiller for sugar beet culture. Proc. 6th British Weed Control Conf. 2, 753-755.

SOME EXPERIMENTS WITH 3-CYCLOHEXYL-5, 6-TRIMETHYLENE URACIL IN SUGAR BEET

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Summary Experiments are described in which 3-cyclohexyl-5, 6-trimethylene uracil was worked into the seedbed before drilling sugar beet or applied immediately after drilling. In the only case where these techniques were directly compared, soil incorporation appeared to enhance activity although conditions appeared to be favourable to the activity of soil applied herbicides. In addition to reliance upon soil moisture a relationship between soil type and the activity of 3-cyclohexyl-5, 6-trimethylene uracil is suggested.

Although the level of activity varied from site to site, in each of these experiments selectivity was recorded between sugar beet and the weeds encountered, with the exception of Veronica species and Avena fatua.

INTRODUCTION

After a preliminary investigation in 1962 3-cyclohexyl-5, 6-trimethylene uracil was included in two replicated experiments carried out in 1963 under the auspices of a working party of the I.I.R.B. (Institut International de Recherches Betteravieres). Following the 1963 work it was suggested that activity of this herbicide was increased by soil incorporation and was strongly dependent on soil type. Accordingly this herbicide was omitted from the international trial series in 1964 but was included in six experiments designed to evaluate its performance when applied in two ways. Three experiments were carried out in which the herbicide was applied to the soil surface immediately after drilling, the dose range being arbitrarily selected to suit the soil type. In two experiments the herbicide treatments were thoroughly worked into the soil before drilling the crop and in these experiments the uracil was tested alone and in mixture with propham. One further experiment compared the activity of the herbicide thoroughly worked into the seedbed and applied immediately after drilling.

In some cases where applications of 3-cyclohexyl-5, 6-trimethylene uracil were part of a more comprehensive experiment, results obtained with other compounds have been omitted from this report as have results of some unsuccessful post-emergence applications.

METHOD AND MATERIALS

In all experiments applications were made by means of the Oxford Precision Sprayer at volume rates of 50 gals/ac (all 1963 experiments) and 25 gals/ac (all 1964 experiments). The formulation used was a wettable powder containing 80% a.i. *

In every case the plot size was 12 yards by 8 rows of sugar beet (around 4.5 yards). assessments being made on 10 yards of the centre 6 rows. Assessments were made at three stages during the development of the crop.

At around the 4-leaf stage of the crop counts were made of sugar beet and weed seedlings, and in most cases seedling vigour was also assessed by visual scoring. In each case counts were made on twelve quadrats per plot, the quadrat size being 18 inches by 4 inches. An exception was made to this technique in the case of the 1964 trials at Paston and Tilbury, where wild oats were counted on two areas 18 inches by 10 yards on each plot.

A second assessment was made during July when the final plant population of sugar beet was counted on the harvest plot area and estimates of vigour were made if any differences were apparent.

Finally plots were harvested during October or November but results are only quoted for the 1963 experiments.

RESULTS

Results of surface applications - effect on weeds

Full details of these results are given in Tables 1 and 3, from which it may be seen that in four out of five experiments most species were controlled by doses of 0.95 to 1.5 lb/ac, Matricaria species being notably susceptible and Veronica species markedly resistant. No differences in susceptibility were observed between Veronica persica, V. arvensis and V. hederaefolia. There was little difference between the activity of the herbicide on the two sites in 1963 but in 1964 there were marked differences between the three sites. Activity was greater at

* Du Pont herbicide 634 - no recognised common name exists for this compound.

1963 Experiments

Table 1

Effect on weeds (counts as % control)

Dose of uracil lb/acre a.i.	BROOM'S BARN Matricaria matricarioides	Polygonum convolvulus	Veronica spp.	Stellaria media	Other dicot. weeds	SPROWSTON Total dicot. weeds
0.95	0	21	69	5	8	11.4
1.90	0	4	16	0	4	7.3
3.80	0	4	12	1	3	3.0
Control	100	100	100	100	100	100
	63 plants /sq.yd.	17 plants /sq.yd.	20 plants /sq.yd.	19 plants /sq.yd.	37 plants /sq.yd.	109 plants /sq.yd.

Table 2

Effect on sugar beet

Dose of uracil lb/acre a.i.	BROOM'S BARN Germination as % control	Final population /acre	Sugar yield cwt/acre	SPROWSTON Germination as % control	Final population /acre	Sugar yield cwt/acre
0.95	106	32,800	60.1	102.1	35,000	53.6
1.90	76	31,000	59.3	99.2	31,900	55.1
3.80	44	25,000	54.5	84.3	33,600	56.4
Control	100	30,300	52.7	100	33,100	52.3
	60 seedlings /100"			47 seedlings /100"		
S.E. as % G.M.	13.7	6.6	6.2	9.7		5.5
Sig. diff. 5%	15	2.3	4.1	11.5		N.S.
1%	20	3.1	5.5	15.5		

1964 - Results of surface applications

Table 3

Effect on weeds (counts as % control)

Dose of uracil lb/acre a.i. SPROWSTON SALHOUSE	Dose of uracil lb/acre a.i. KIRTON	SPROWSTON Poa annua	SPROWSTON Stellaria media	SPROWSTON Polygonum spp.	SALHOUSE Total dicot. weeds	KIRTON Urtica urens	KIRTON Stellaria media
1.0	1.5	1	7	7	52	11	3
2.0	3.0	Nil	1	1	39	5	3
4.0	6.0	Nil	Nil	Nil	24	1	1
Control		100	100	100	100	100	100
		74 plants /sq.yd.	39 plants /sq.yd.	27 plants /sq.yd.	93 plants /sq.yd.	79 plants /sq.yd.	55 plants /sq.yd.

Table 4

Effect on sugar beet

Dose of uracil lb/acre a.i. SPROWSTON SALHOUSE	Dose of uracil lb/acre a.i. KIRTON	SPROWSTON Germination as % control	SPROWSTON Final population /acre	SALHOUSE Germination as % control	SALHOUSE Final population /acre	KIRTON Germination as % control	KIRTON Final population /acre
1.0	1.5	101	33,900	92	29,800	88	32,400
2.0	3.0	80	30,500	101	30,200	75	32,400
4.0	6.0	58	29,200	99	29,400	61	31,500
Control		100	33,200	100	29,900	100	33,300
		41 seedlings /100"		30 seedlings /100"		50 seedlings /100"	
S.E.as % G.M.		16.3	6.7	14.2	9.7	22.0	
Sig.diff. 5%		20	3,100	N.S.	N.S.	26	
1%		27	4,200			35	

Sprowston than at Kirton so that a dose of 1.0 lb/ac at Sprowston produced about the same results as a dose of 1.5 lb/ac at Kirton. This difference had been predicted on the basis of soil type but at Salhouse on a soil very similar to that at Sprowston activity was much lower so that only a dose of 4.0 lb/ac produced an adequate degree of weed control. This site received a reasonable amount of rainfall after spraying but drilling and spraying were carried out rather late in the season (27th April) on to a very dry seedbed.

Results of surface applications - effect on sugar beet

The herbicide was well tolerated by the crop at Sprowston in 1963 - only the top dose of 3.80 lb/ac produced any reduction in germination and this was not reflected in the final yield. At Broom's Barn, however, there were far more marked effects on the crop in 1963 and recovery from the 3.80 lb/ac rate was not complete. It was notable, however, that the yield on these plots was significantly lower than the plots treated with lower doses but higher than the control plots. This was almost undoubtedly due to severe weed competition on the control plots.

In the 1964 experiments, for which yield results are not yet available, damage to the crop was caused by the top dose at Sprowston and Kirton but recovery appeared to be complete by July.

Results of soil incorporated applications - effect on weeds

At both sites the uracil had very little effect on *Avena fatua* although propham had a marked effect on this weed. Activity against dicotyledonous weeds was much higher at Paston than Tilbury but at both sites the uracil was much more effective than propham.

Over 80% control of all species was achieved at Paston by the mixture of 2.0 lb/ac of propham and 0.5 lb/ac of uracil whilst at Tilbury the mixture of 2.0 lb/ac of propham with 2.0 lb/ac of uracil was necessary for adequate weed control.

Results of soil incorporated application - effect on sugar beet

No effects on the crop were noted at Tilbury by any treatment but at Paston there was a check to the crop by the mixture of 2.0 lb/ac of propham with 2.0 lb/ac of uracil although the germination counts were not significantly different from those of the control plots.

Results of the experiment comparing surface with soil incorporated applications - sugar beet and weeds

It can be seen from Tables 7 and 8 that the selectivity in this experiment followed the pattern established in previous experiments and that no difference in selectivity was caused by the different methods of application.

Activity was, however, appreciably higher from applications worked into the seedbed despite the fact that post-drilling applications were made to a moist seedbed and were followed by apparently adequate rainfall.

1964 - Results of soil incorporated applications

Table 5

Effect on weeds (counts as % control)

Dose lb/acre a.i.	PASTON Avena fatua	PASTON Total dicot. weeds	TILBURY Avena fatua	TILBURY Total dicot. weeds
Propham Uracil				
4.0 + Nil	11	54	42	82
2.0 + 0.5	12	17	39	47
2.0 + 1.0	8	10	31	39
2.0 + 2.0	5	11	22	28
Nil + 2.0	99	25	88	50
Control	100	100	100	100
	19 plants /sq.yd.	43 plants /sq.yd.	15 plants /sq.yd.	74 plants /sq.yd.

Table 6

Effect on sugar beet

Dose lb/acre a.i.	PASTON Germination as % control	PASTON Seedling vigour	PASTON Final population per acre	TILBURY Germination as % control
Propham Uracil				
4.0 + Nil	104	8.5	30,700	131
2.0 + 0.5	101	9.0	30,900	114
2.0 + 1.0	104	7.0	30,600	107
2.0 + 2.0	88	6.5	28,700	111
Nil + 2.0	95	8.0	29,200	104
Control	100	10.0	30,000	100
	45 seedlings /100"			29 seedlings /100"
S.E.as % G.M.	12.0			18.6
Sig.diff. 5%	N.S.			N.S.

1964 - Comparison between surface and soil incorporated applications

Table 7

Effect on weeds (counts as % control)

Dose of uracil lb/acre a.i.	Chenopodium album	Polygonum spp.	Veronica spp.	Capsella bursa pastoris	Viola tricolor	Other dicot. weeds
Soil incorporated treatments						
0.5	4.7	20	49	Nil	58	4
1.0	1.5	6	18	Nil	32	3
2.0	Nil	2	10	Nil	12	2
Surface applications						
1.0	1.9	11	26	Nil	42	2
2.0	0.4	6	7	Nil	34	1
Control	100	100	100	100	100	100
	118 plants /sq.yd.	60 plants /sq.yd.	41 plants /sq.yd.	21 plants /sq.yd.	21 plants /sq.yd.	97 plants /sq.yd.

Table 8

Effect on sugar beet

Dose of uracil lb/acre a.i.	Germination as % control	Seedling vigour	Final population per acre
Soil incorporated treatments			
0.5	108	8	30,200
1.0	88	7	27,800
2.0	61	5	24,800
Surface applications			
1.0	100	8	31,000
2.0	68	7	27,500
Control	100	10	27,200
S.E. as % G.M.	16.7		9.7
Sig. diff. 5%	18		3,300
1%	24		4,500

DISCUSSION

These results appear to show a consistent degree of selectivity by 3-cyclohexyl-5, 6-trimethylene uracil, although the degree of activity has varied from site to site.

Most of the experiments described were conducted on light sandy loam soils except that in 1964 the Kirton experiment was sited on a silt soil and the Tilbury experiment on a heavy soil derived from boulder clay. Activity was lower at both these sites than at comparable light land sites, this being most marked in the case of the Tilbury experiment.

Applications of 3-cyclohexyl-5, 6-trimethylene uracil to experiments of this series have all been followed by amounts of rainfall which have seemed adequate to ensure their activity. It was noted, however, that at Salhouse applications were made to a dry seedbed rather late in the season and activity at this site was very low. This loss of activity cannot be attributed to soil type or to resistant weed species so the possibility remains that this herbicide is more than usually sensitive to soil moisture conditions. This would apparently be supported by the fact that in the 1964 Broom's Barn experiment soil incorporation increased activity of the herbicide even under conditions apparently favourable to the activity of surface applications.

In each of these experiments useful selectivity was recorded but activity varied from site to site so that the problem of devising suitable dose rates remains. More work is needed on the effects of soil conditions upon the activity of this herbicide and a further programme of work will be initiated with this in view.

Acknowledgements

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A PROGRESS REPORT ON WEED CONTROL IN TRANSPLANTED AND DIRECT SOWN BRASSICA CROPS

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Summary Experiments are described in which desmetryne and prometryne and a mixture of desmetryne and 3,6-dichloro 2-methoxy benzoic acid were applied to transplanted cabbage, broccoli and Brussels sprouts and in which trifluralin was applied pre-emergence and desmetryne and prometryne post-emergence to direct sown cabbage at the 3 - 4 true leaf stage. Desmetryne and prometryne scorched broccoli at doses of 8 oz/ac and above but did not damage cabbage. At these doses both herbicides gave a good and similar weed control but desmetryne was more effective against Senecio vulgaris. At a dose of 6 oz/ac weed control was disappointing. The addition of 3,6-dichloro 2-methoxy benzoic acid to desmetryne increased the damage to broccoli and provided a marginal but in some cases a statistically significant improvement in weed control.

INTRODUCTION

During the past two years work at Loughgall (Anon. 1962, 1963) has shown that two substituted triazine herbicides - desmetryne and prometryne - can provide a promising control of certain common annual weeds under Northern Ireland conditions when applied as post planting treatments to Brussels sprouts. Although doses of 8 oz/ac and above caused some transient foliar scorch, crop yields were not affected. The use of these herbicides enabled post-planting cultivation to be eliminated.

Following these results, it was decided to extend this work in 1964 to examine the effect of these herbicides on other brassica crops. This report is a preliminary account of the value of these herbicides when applied to transplanted cabbage, broccoli and Brussels sprout crops and as post-emergence treatments to direct sown cabbage with and without a pre-emergence application of trifluralin.

METHOD AND MATERIALS

Desmetryne and prometryne were applied in a spray volume of 50 gal/ac to transplanted cabbage (Var. Greyhound) three days and three weeks after planting and to direct sown cabbage (Var. Winnigstadt) at the 3 - 4 true leaf stage. Trifluralin was also applied as a pre-emergence treatment to the direct sown crop.

Desmetryne with and without the addition of 3,6-dichloro 2-methoxy benzoic acid and prometryne were applied to three varieties of Brussels sprouts (Irish Elegance, Market Rearguard and Harrisons XXX) and to two varieties of broccoli (April Glory and May Glory) three weeks after planting.

Factorial designs were used for all except the broccoli experiments in which randomised block designs were employed. The standard plot size was 2 x 6 yd.

Weed density was assessed by counts in each of three 12 in. quadrats thrown at random in each plot. Crops were scored for phytotoxicity as necessary and the fresh weight of mature cabbage was recorded. Crop yields are not available from the other crops but height measurements of Brussels sprout plants were recorded.

RESULTS

Experiment 1

This experiment was designed to compare the effect on cabbage of applying the herbicides shortly after planting, when the plants were still in a wilting condition, with the more normally accepted time of application when the plants have fully recovered from the post planting wilt. The results are summarised in Tables 1, 2 and 3. Weeds were absent at the first treatment but at the second seedling weeds were numerous over the entire area.

Table 1

Mean fresh weight of cabbage (var. Greyhound) following post planting applications of two triazines

Date of planting 15.5.64 / Date of recording 27.7.64	Weight of cabbage (lb/plant)
Herbicide	
1. No herbicide	2.29
2. Desmetryne 8 oz/ac	2.37
3. Desmetryne 12 oz/ac	2.18
4. Prometryne 8 oz/ac	2.28
5. Prometryne 12 oz/ac	1.74
L.S.D. (P = 0.05)	0.38
Time of herbicide application	
1. Three days after planting	2.23
2. Three weeks after planting	2.04
L.S.D. (P = 0.05)	NS

Table 2

Mean weed counts per yd^2 following post planting applications of two triazines to cabbage (var. Greyhound)
Main effects

Date of planting 15.5.64 / Date of recording 15.7.64	Total weed	Poa annua	Chenopodium album	Stellaria media	Lamium purpureum	Veronica persica	Senecio vulgaris
Herbicide							
1. No herbicide	64.92	23.96	4.47	6.35	11.98	8.59	3.36
2. Desmetryne 8 oz/ac	29.58	11.22	2.24	1.48	6.72	4.09	1.48
3. Desmetryne 12 oz/ac	18.72	6.34	1.85	0.37	7.09	1.11	-
4. Prometryne 8 oz/ac	29.97	9.35	3.36	1.11	8.97	2.22	2.98
5. Prometryne 12 oz/ac	16.86	2.59	1.49	1.48	7.12	2.23	1.12
L.S.D. (P = 0.05)	15.03	10.14	NS	3.91	NS	4.65	NS
Time of herbicide application							
1. Three days after planting	44.70	14.51	3.87	2.83	13.62	4.32	2.38
2. Three weeks after planting	19.32	6.87	1.49	1.49	3.13	2.98	1.19
L.S.D. (P = 0.05)	9.51	6.41	2.01	NS	4.00	NS	NS

Table 3

Mean weed count per yd^2 following post planting applications of two triazines to cabbage (var. Greyhound)
Interactions (Herbicide x time of application)

Date of planting 15.5.64 Date of recording 15.7.64	Total weed		Poa annua		Chenopodium album		Stellaria media		Lamium purpureum		Veronica persica		Senecio vulgaris	
Time of herbicide* application	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Herbicide														
1. No herbicide	62.39	67.45	23.22	24.70	1.48	7.47	6.72	5.98	14.98	8.98	6.70	10.48	3.73	2.99
2. Desmetryne 8 oz/ac	45.46	12.71	19.46	2.99	4.47	-	2.22	0.74	11.97	1.48	5.22	2.97	0.74	2.22
3. Desmetryne 12 oz/ac	29.94	7.49	9.72	2.97	3.71	-	0.74	-	11.20	2.99	1.48	0.74	-	-
4. Prometryne 8 oz/ac	52.47	7.47	15.72	2.97	6.72	-	2.22	-	15.72	2.22	3.71	0.74	5.22	0.74
5. Prometryne 12 oz/ac	32.24	1.48	4.45	0.74	2.99	-	2.22	0.74	14.24	-	4.47	-	2.25	-
L.S.D. (P = 0.05)	21.25		NS		4.51		NS		NS		NS		NS	

*Time 1 = Three days after planting. Time 2 = Three weeks after planting

No cultivation was practised throughout the life of this crop. Weed counts which were taken shortly before harvest show that both herbicides provided a similar degree of control and that they were particularly effective when applied 3 weeks after planting.

There was no visible crop damage but prometryne at 12 oz/ac produced a significant reduction in the fresh weight of the cabbage.

Experiments 2 and 3

These experiments were designed to examine the tolerance of two varieties of broccoli (April Glory and May Glory) to post planting applications of desmetryne with and without the addition of 3,6-dichloro 2-methoxy benzoic acid and prometryne. At the time of treatment there was a dense uniform stand of seedling weeds. Tables 4 and 5 show that all treatments caused some crop injury. This was most severe where treatments containing desmetryne were applied. All herbicides gave a very good control of *Stellaria media* within one week of application. Desmetryne provided a good control of *Senecio vulgaris* but prometryne gave only a moderate control of this weed. No herbicide controlled *Poa annua* adequately. The addition of 3,6-dichloro 2-methoxy benzoic acid to desmetryne slightly increased the degree of weed control and led to a more rapid result.

Table 4

Mean weed counts per yd^2 and mean crop damage scores following a post-planting herbicide application to broccoli (var. April Glory)

Date of planting 21.8.64	Senecio vulgaris		Stellaria media		Poa annua		Crop damage**
Date of herbicide application 3.9.64	Weed count 11.9.64	Log x*	Weed count 11.9.64	Log x*	Weed count 11.9.64	Log x*	scores 22.9.64
Herbicide							
1. No herbicide	185.22	2.27	60.75	1.78	29.97	1.44	0
2. Desmetryne 8 oz/ac	7.47	0.73	0.76	0.12	18.00	0.98	2.50
3. Desmetryne 12 oz/ac	5.96	0.60	0.76	0.12	11.97	0.94	3.00
4. Desmetryne 8 oz/ac + 3,6-dichloro 2-methoxy benzoic acid 1 oz/ac	-	-	-	-	11.22	1.02	3.75
5. Prometryne 8 oz/ac	78.72	1.87	0.76	0.12	22.47	1.27	2.00
6. Prometryne 12 oz/ac	71.97	1.80	-	-	16.44	1.16	2.25
L.S.D. (P = 0.05)	-	0.15	-	0.08	-	NS	-

Table 5

Mean weed counts per yd^2 and mean crop damage scores following a post-planting herbicide application to broccoli (var. May Glory)

Date of planting 21.8.64 / Date of herbicide application 3.9.64	Senecio vulgaris Weed count 11.9.64	Senecio vulgaris Log x*	Stellaria media Weed count 11.9.64	Stellaria media Log x*	Poa annua Weed count 11.9.64	Poa annua Log x*	Crop damage** scores 22.9.64
Herbicide							
1. No herbicide	255.22	2.34	113.22	1.94	29.20	1.40	0
2. Desmetryne 8 oz/ac	8.98	0.60	0.74	0.12	26.21	1.29	2.00
3. Desmetryne 12 oz/ac	-	-	-	-	20.22	1.05	2.50
4. Desmetryne 8 oz/ac + 3,6-dichloro 2-methoxy benzoic acid 1 oz/ac	-	-	-	-	18.69	1.14	3.00
5. Prometryne 8 oz/ac	62.98	1.79	1.48	0.24	38.97	1.57	1.50
6. Prometryne 12 oz/ac	24.73	1.24	0.74	0.12	17.95	1.16	1.75
L.S.D. (P = 0.05)	-	0.51	-	0.11	-	NS	-

*Log x was calculated from the logarithms of the original observations
**Crop damage scores 0 - 5 (0 = no damage. 5 = very severe damage from which complete kill can be expected)

Experiment 4

The object of this experiment was to examine the tolerance of three varieties of Brussels sprouts to desmetryne and prometryne applied at a dose which was just below the level at which damage had been recorded in previous years. The effect of the addition of 3,6-dichloro 2-methoxy benzoic acid to desmetryne was also examined. Weeds were not numerous on this site but counts of the main weeds and a total weed count are given in Table 6 together with the height of the Brussels sprout plants at the end of August.

Plant height measurements showed that none of the treatments influenced the growth of Brussels sprouts. In addition no foliar scorch was seen at any stage of the crop. The weed control was poor although a slight reduction in Senecio vulgaris and Stellaria media was achieved with all herbicides.

Table 6

Mean weed count per yd^2 and Brussels sprout plant height following post-planting herbicide treatments

Date of planting 12.5.64 Date of herbicide application 5.6.64		Total weed 22.7.64	Senecio vulgaris 22.7.64	Stellaria media 22.7.64	Plant height (in.) 31.8.64
Herbicide					
1. No herbicide		23.55	6.72	7.23	26.19
2. Desmetryne	6 oz/ac	23.21	5.33	1.79	26.15
3. Desmetryne + 3,6-dichloro 2-methoxy benzoic acid	6 oz/ac 1 oz/ac	12.52	3.22	4.23	24.95
4. Prometryne	6 oz/ac	18.04	3.49	1.98	24.97
L.S.D. (P = 0.05)		6.22	NS	NS	NS
Varieties					
1. Irish Elegance		17.91	3.54	2.05	25.90
2. Market Rearguard		16.81	4.66	3.35	25.21
3. Harrisons XXX		23.20	5.87	6.02	25.50
L.S.D. (P = 0.05)		NS	NS	NS	NS

Experiment 5

This experiment was designed as an initial investigation into weed control in direct sown cabbage. Table 7 shows that no treatment affected the fresh weight of cabbage but that trifluralin significantly reduced the number of mature plants.

The weed population on this site was low and variable the predominant weeds being Senecio vulgaris and Stellaria media. The total weed count in Table 7 shows that all post-emergence treatments gave some general weed reduction but the only significant reduction was due to the pre-emergence application of trifluralin.

Table 7

Mean number of mature cabbage plants, mean fresh weight of cabbage and mean weed count per yd^2 following pre and post emergence herbicide applications to direct sown cabbage (var. Winnigstadt)

Date of sowing 8.4.64		Number of mature plants 22.7.64	Yield of cabbage (lb per plant) 22.7.64	Total weed 15.7.64
Pre-emergence herbicide (Applied 16.4.64)				
1. No herbicide		15.33	4.74	23.42
2. Trifluralin	64 oz/ac	10.75	5.42	8.20
L.S.D. (P = 0.05)		3.46	NS	12.01
Post-emergence herbicide (Applied) 11.6.64				
1. No herbicide		13.16	4.36	23.44
2. Desmetryne	6 oz/ac	13.50	6.18	12.45
3. Desmetryne	6 oz/ac	11.66	4.43	15.43
+ 3,6-dichloro 2-methoxy benzoic acid	1 oz/ac			
4. Prometryne	6 oz/ac	13.83	5.33	11.92
L.S.D. (P = 0.05)		NS	NS	NS

DISCUSSION

The results of the experiments reported in this paper suggest that desmetryne and prometryne can be applied to cabbage at doses up to 12 oz/ac without crop damage irrespective of whether the plants are in a wilting condition or not. Broccoli, however, is more susceptible. At doses of 8 oz/ac and above desmetryne and prometryne damaged both varieties of broccoli. In all cases desmetryne caused the most severe damage. Where 3,6-dichloro 2-methoxy benzoic acid was applied as an additive to desmetryne damage was increased.

Data in Tables 1 and 2 indicate that desmetryne and prometryne can provide a good and similar control of a number of common annual weeds at doses of 8 oz/ac and above. Under certain conditions however as shown in Tables 4 and 5 - desmetryne can provide a significantly better control of Senecio vulgaris than prometryne. Neither herbicide will adequately control Poa annua. Both herbicides provide the most satisfactory weed control if they are applied when seedling weeds are present and not when weeds are completely absent. This suggests that their contact action is more important than their residual effect.

Indications are that doses of 6 oz/ac provide a less reliable weed control than higher doses but that crop damage is less likely.

The addition of 3,6-dichloro 2-methoxy benzoic acid to desmetryne can marginally improve the weed control and provides a slightly more rapid kill but due to the crop damage which can follow its use in certain crops it must be considered unsuitable for general use in this way.

Desmetryne and prometryne can be applied to direct sown cabbage at the 3-4 true leaf stage but it appears that doses higher than that used in experiment 5 i.e. 6 oz/ac would be necessary to ensure an adequate weed control. Whilst this might be possible in cabbage it would probably be less satisfactory in other crops such as cauliflower or broccoli. The combination of a pre-emergence herbicide treatment followed by a post-emergence application of a relatively low dose of desmetryne or prometryne might provide a satisfactory solution to weed control in direct sown brassicas. This problem, however, will be investigated further during 1965.

Acknowledgments

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References

ANONYMOUS (1962) Annual Report, Horticultural Centre, Loughgall.
ANONYMOUS (1963) Annual Report, Horticultural Centre, Loughgall.

FURTHER EXPERIENCE IN THE USE OF DESMETRYNE ON KALE AND OTHER BRASSICAS

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Summary The use of desmetryne on brassica crops other than fodder kale was explored in 14 trials carried out in 1964. Brussels sprouts and cabbages tolerated high doses of the herbicide but cauliflowers and broccoli appeared less resistant. Weed control data from these trials and from 8 trials on kale showed that a number of weeds in addition to Chenopodium album are sensitive to desmetryne at least in the seedling stage. Yields of kale are given for 5 weed-infested trials and 6 weed-free trials.

INTRODUCTION

The effectiveness of desmetryne for the control of Chenopodium album in fodder kale was reported in 1962 by Elliott & Cox, Baker et al and Powell and these investigations led to the introduction of desmetryne for use on this one weed and crop.

More recent work has however shown that this triazine can safely be used on a number of other brassica crops and also that under favourable conditions good control can be obtained of a number of weeds other than Chenopodium album. The present paper describes experimental work on these aspects and also includes a brief summary of results obtained on mixtures of desmetryne with dicamba.

METHODS AND MATERIALS

Since the experiments varied in layout and the treatments used, only a general description can be given here. Further details will be given under the appropriate headings.

Chemical: a wettable powder formulation containing 25% desmetryne.

Dosage range: 4 to 12 oz desmetryne per acre. Plots were sprayed at a constant dosage.

Spray volume: 20 gal/ac except in a few trials where 10 or 40 gal/ac was used.

Layout: all experiments were replicated. The number of replications varied from 2 to 6, but in most trials there were at least four.

RESULTS

EXPERIMENTS ON OTHER BRASSICAS

1. Weed-infested crops

In 1964 experiments were carried out on 5 crops of brussels sprouts, 3 of cabbages, 1 of spring greens, and 4 of cauliflowers, all sprayed at 4, 6 and 10 oz desmetryne per acre. The location of the trials, dates of spraying and growth stages of the crop are shown in Table 1.

Table 1

Crops sprayed and growth stages at spraying

Location	Crop	Spraying Date	Crop stage when sprayed
Lincoln 1	Brussels sprouts, Atlas, direct drilled	8th June	6 leaves, 6 in.
Lincoln 2	Brussels sprouts, direct drilled	12th June	6 leaves, 6 in.
Lincoln 3	Brussels sprouts, direct drilled	4th July	6-8 leaves, 7 in.
Kent 1	Brussels sprouts, Bedfordshire Bystander, direct drilled	3rd July	7-8 leaves, 10 in.
Kent 2	Brussels sprouts, Elegance, transplanted	24th July	8-10 leaves, 12 in.
Kent 3	Cabbage, Winnigstadt, transplanted	12th Aug.	4-5 leaves, 5-6 in.
Kent 4	Cabbage, January King, transplanted	12th Aug.	4-5 leaves, 5-6 in.
East Lothian	Cabbage Dutch, transplanted	1st July	8-10 leaves, 12 in.
Kent 5	Cauliflower, Conquest, transplanted	11th Aug.	4-6 leaves, 6-9 in.
Kent 6	Cauliflower, Invicta, transplanted	11th Aug.	4-5 leaves, 5-7 in.
Kent 7	Cauliflower, Canberra, transplanted	11th Aug.	4-5 leaves, 5-6 in.
Kent 8	Cauliflower, Snowcap, transplanted	11th Aug.	4-5 leaves, 3-4 in.
Kent 9	Spring greens, Early Offenham, direct drilled	21st Sept.	4-5 leaves, 4 in.

a) Weed control The final assessment on control of weeds was taken 6 - 8 weeks after spraying, and is shown in Table 2. The weeds included in this table occurred on 2 or more sites and the degree of control shown is the average of at least 2 trials and of 4 replications in each trial.

In this table it will be seen that the 4 oz dose gave good control on a small number of weeds only - *Fumaria officinalis*, *Stellaria media* and *Urtica urens* - whereas the 6 oz dose gave considerably better weed control. It should be noted that these experiments were sprayed after prolonged dry weather.

Table 2

Weed control assessed 6 - 8 weeks after spraying

Weed	Growth stage when sprayed	Average control obtained by 4 oz	6 oz	10 oz
Atriplex patula	3-5 leaves, 2-5 in.	50%	80%	90%
Chenopodium album	3-5 leaves, 2-5 in.	60%	85%	95%
Cirsium arvense	Up to 3 in.	No effect	Slight check	Slight check
Fumaria officinalis	Variable, 2-5 in.	80%	95%	95%
Galeopsis tetrahit	2-4 leaves, 3-5 in.	50% kill, rest checked	60% kill, severe check on rest.	70% kill, severe check on rest.
Galium aparine	Cotyledon to 3 in.	No effect	Slight check	Slight check
Poa annua	2-3 leaves, 2 in.	Slight check	Slight check	Moderate check
Polygonum aviculare	Variable 2-4 in.	Slight check	Moderate check	Moderate check
Polygonum convolvulus	6-8 leaves, 5-6 in.	Slight check	Severe check	50% kill, rest checked severely.
Polygonum persicaria	Variable 3-10 in.	Checked	Killed up to 5 in. larger plants checked	Killed up to 5 in. larger plants checked.
Sinapis arvensis	3-4 leaves, 3-5 in.	Slight check	50% kill, rest checked.	60% kill, rest checked
Sonchus oleraceus	Variable, 2-6 in.	Slight check	Moderate check	Moderate check
Stellaria media	Variable, 2-6 in.	90%	95%	95%
Tripleurospermum spp.	4 leaves, 1-2 in.	Slight check	Slight check	Moderate check
Urtica urens	2-4 leaves, 1-3 in.	75%	90%	95%
Veronica spp.	2-4 leaves, 2-3 in.	Slight check	Severe check	Severe check

b) Crop response

These experiments are not yet completed and yields have yet to be taken from all trials when the crops are mature. Observations made on the growth of the crop after spraying show that there is unlikely to be any permanent adverse effect on the crop from any treatment in any trial. Desmetryne at 4 oz/ac had little or no effect and although 6 oz and 10 oz caused some chlorosis of the older leaves, this went within 3-4 after spraying.

2. Weed-free crops: comparison of 12 brassicas

In an experiment at Chesterford Park 12 different brassicas, drilled side by side (2 rows per variety) were sprayed with desmetryne at 6 oz and 12 oz/ac. Spraying was done on 11th June when the stages of growth were as shown in Table 3. The plots were 3 yd wide, running across all varieties and there were 6 replications. The plots were kept weeded so that the crop response could be assessed without the interaction of crop and weed growth.

In early July, the crops on 3 replications were thinned and the thinnings weighed. These weights give an indication of the initial response of the brassicas and they are shown in Table 3.

Table 3

Weight of thinnings as % of untreated

Varieties	Stage of Growth at Spraying	Dose of desmetryne oz/ac 6	12	Sig.Diff P = 0.05
Cabbage, Greyhound	70% 3-4 leaves, 4 in. 30% 2 leaves, 2 in.	109.6	95.7	44.3
Cabbage, Primo	80% 3-4 leaves, 5 in. 20% 2 leaves, 3 in.	93.3	76.5	15.7
Cabbage, Winnigstadt	70% 4-4½ leaves, 6-7 in. 30% 2-3 leaves, 3 in.	99.6	79.9	17.2
Cabbage, Christmas Drumhead	80% 3½-4 leaves, 4 in. 20% 2-3 leaves, 2 in.	92.0	79.9	21.5
Cabbage, January King	90% 3-4 leaves, 6 in. 10% 2-3 leaves, 3 in.	96.8	92.3	23.2
Savoy, Best of All	60% 3-4 leaves, 4 in. 40% 1-2 leaves, 2 in.	88.4	67.3	18.0
Cauliflower, Majestic	25% 3½-4 leaves, 5 in. 50% 2½-3 leaves, 5 in. 25% 2 leaves, 2 in.	84.2	62.7	11.7
Broccoli, Autumn Giant	50% 2½-3 leaves, 4 in. 50% 1½-2 leaves, 2 in.	75.9	67.5	21.9
Sprout, Cambs. No.3.	70% 3-4 leaves, 5 in. 30% 2 leaves, 2 in.	97.6	80.4	25.9
Curly Kale A.1	70% 4 leaves, 4 in. 30% 2 leaves, 1½ in.	81.5	84.7	23.2
Marrowstem Kale	80% 3-4½ leaves, 5 in. 20% 2 leaves, 3 in.	73.4	80.1	14.7
Kohl rabi	70% 4-5 leaves, 4 in. 30% 2-3 leaves, 2½ in.	80.1	69.1	38.9

These figures show that the high rate of desmetryne (3 times the normal recommended rate) caused some initial check to growth on the majority of the varieties. At the 6 oz rate however, a significant growth reduction occurred on cauliflower, broccoli and marrowstem kale only.

These weights were taken during the period of a few weeks after spraying when differences between the treatments were most pronounced. Later in the season most crops recovered from the initial growth check. No yield figures are available but visual assessments made in early October on all six replications indicated that even the more sensitive crops had almost completely recovered, at least from the 6 oz dose. There appeared to be still about 10% depression of growth when 12 oz desmetryne was used on cauliflower and kale. Brocooli however appeared normal even at the higher rate.

EXPERIMENTS ON KALE

These experiments were intended mainly to provide information on the control of weeds other than _Chenopodium_ spp. and the effect of the removal of these weeds on crop growth. However, in order to obtain further information on the direct response of kale to desmetryne, a number of additional experiments were carried out on relatively weed-free sites.

a) Weed control

In 1963 six trials were carried out in Cumberland on fields infested with _Polygonum persicaria_ (redshank) and other weeds. Desmetryne was applied at 4 oz/ac in mid-July and weed control was assessed about 6 weeks later. Details of the trials are shown in Table 4 which gives the percentage control of the main weeds. The figures are means of 2 replications for High Lorton 1; 5 replications for Keswick; 4 replications for the remaining four trials.

Table 4

Percentage control of weeds with desmetryne - 4 oz/ac

Location	Date Sprayed	Weed	Weed Growth Stage at Spraying	% Control
Keswick	16th July	_P.persicaria_	5-6 leaves, 3-4 in. high	93
Threlkeld	16th July	_P.persicaria_	5 leaves, 3-5 in. high	87
High Lorton 1	13th July	_P.persicaria_	5 leaves, 3 branches, 6 in. high	40
High Lorton 2	13th July	_P.persicaria_	3-5 leaves, 3-5 in. high	92
High Lorton 3	16th July	_P.persicaria_	Branched, 6-10 in. high, flower buds present.	90
Penrith	17th July	_P.persicaria_	5 leaves, 5-6 in. high	99
			Mean (P. persicaria)	83
Keswick	16th July	_Stellaria media_	Starting to branch, 3 in. across (variable)	27

Table 4

Percentage control of weeds with desmetryne - 4 oz/ac (cont'd)

Location	Date Sprayed	Weed	Weed Growth Stage at Spraying	% Control
Threlkeld	16th July	Stellaria media	3 branches, 4 in. high	5
Penrith	17th July	Polygonum aviculare	5-6 branches, up to 9 in. high.	20
High Lorton 3	16th July	Galeopsis tetrahit	4 pairs of leaves, 3-6 in. high.	90
Threlkeld	16th July	Spergula arvensis	Up to 15 in. flowering	28

In 1964 two trials were carried out, one on thousand head kale in Berkshire and one on marrowstem kale in Kent. Desmetryne was applied at 4, 6 and 10 oz/ac at the end of June when the kale was in the 3-4 leaf stage and 4-6 in. high. Assessments were made at intervals; the results shown in Table 5 are from the latest assessment made 5 weeks after spraying.

Table 5

Percentage weed control in kale

Means of 4 replications at each site

Weed	Growth Stage at Spraying	Desmetryne dose in oz/ac 4	6	10
Capsella bursa - pastoris	$1\frac{1}{2}$ - 2 in.	Slight check	Slight check	Slight check
Chenopodium album	Mostly 2 in. some 8 in.	95	97	100
Galium aparine	$\frac{1}{2}$ - $1\frac{1}{2}$ in.	No effect	No effect	Slight check
Poa annua	$\frac{1}{2}$ - $1\frac{1}{2}$ in.	No effect	No effect	Slight check
Polygonum aviculare	3 - 4 in.	Slight check	Slight check	Mod. check
Polygonum convolvulus	2 - 3 in.	90	100	100
Polygonum persicaria	2 - 3 in.	90	90	100
Sinapis arvensis	4 - 6 in.	55	70	80
Sonchus oleraceus	1 - 2 in.	80	85	85
Stellaria media	1 - 2 in.	95	100	100
Tripleurospermum maritimum spp. inodorum	$\frac{1}{2}$ - $1\frac{1}{2}$ in.	Slight check	Slight check	Slight check

b) Crop response

In 1963 in addition to the six weed-infested trials in Cumberland, six trials were carried out in East Anglia on fields with very low weed infestations. In three of these trials desmetryne was applied at 6 oz/ac as well as 4 oz. These trials had 4 or 5 replications.

The kale in some of the trials was checked by the desmetryne but in general the affected crops had recovered when observations were made about 2 months after spraying. At this time treated kale on weed-infested fields was already very much larger and more vigorous than the untreated. Yields were taken in November and the figures are shown in Table 6. One experiment (High Lorton 3) was not harvested because of damage by sheep.

Table 6

Yield of kale in tons per acre

Location	Spraying Date	Kale Stage when sprayed	Desmetryne in oz/ac. 0	4	6	Sig.Diff. P = 0.05
1. INFESTED WITH P. PERSICARIA						
Keswick	16th July	4½-5 leaves, 6-9 in. vigorous.	9.3	12.6	-	4.52
Threlkeld	16th July	3-4 leaves, 5-7 in. starved.	2.4	4.4	-	1.91
High Lorton 1	13th July	2½-3 leaves, 4 in. not very vigorous.	2.3	6.4	-	6.38
High Lorton 2	13th July	2½-3 leaves, variable not very vigorous.	8.2	12.6	-	6.00
Penrith	17th July	3½-4 leaves, 9 in. soft and vigorous.	7.3	13.0	-	6.28
2. WEED-FREE						
Chesterford	1st July	3½-4½ leaves, over 6 in. vigorous, hard	37.7	34.3	36.1	3.71
Newmarket	10th July	2-4 leaves, also cotyledons, variable	20.9	19.6	-	2.24
Ellington 1	22nd July	2½-3 leaves, 5 in. fairly soft.	30.0	29.9	-	1.82
Ellington 2	22nd July	2-3 leaves, 6 in. vigorous, soft.	27.0	26.6	-	2.79
Thriplow	7th Aug.	2½-3 leaves, fairly soft.	15.3	13.9	12.8	2.32
Ickleton	22nd Aug.	4-5 leaves, 6 in. Moderately vigorous.	10.5	8.3	7.5	1.63

In the Cumberland trials crop growth was uneven owing to variation in fertility and the statistical significance of the results is therefore low. However, in all these trials the treated plots show substantially higher yields than the untreated and the figures give an indication of the extent to which P. persicaria depresses kale yields.

On weed-free sites there was a tendency for treated yields to be slightly lower than controls. This was statistically significant in one trial (Ickleton) which was sprayed very late. The growth of the kale was markedly checked, and in the slow-growing conditions of autumn the crop did not completely recover before being cut in November.

EXPERIMENTS WITH MIXTURES OF DESMETRYNE AND DICAMBA

In 1963 on kale desmetryne at 4 oz and 6 oz/ac was compared with desmetryne/dicamba mixtures containing the same dose of desmetryne and with dicamba at $\frac{1}{2}$, 1, and 2 oz/ac. In these trials the control of Polygonum persicaria was improved slightly by the dicamba at 2 oz/ac and there were definite indications that the control of Stellaria media, Polygonum aviculare and Spergula arvensis was improved by this mixture. On weed-free sites the kale was checked and there was approximately 10% crop depression.

In 1964 dicamba at $2\frac{1}{4}$ and 3 oz/ac was added to desmetryne at 6 oz/ac and compared with desmetryne alone at 6 oz/ac. The dicamba gave improved control of Polygonum persicaria, Polygonum aviculare, Polygonum convolvulus, Tripleurospermum maritimum ssp. inodorum and Senecio vulgaris. On kale, brussels sprouts and cauliflower there was some cupping of the leaves and the cauliflower plants were checked for a few weeks after spraying. Cabbages and spring greens appeared to be unaffected by the dicamba. Yields are being taken on these trials at normal harvest time.

DISCUSSION

In the 1963 experiments on kale desmetryne at 4 oz/ac gave better control of Polygonum persicaria than was expected from previous results. In 4 of the 6 sites infested with P. persicaria the control was over 90%. The control of Galeopsis tetrahit was also very good but Stellaria media, Polygonum aviculare and Spergula arvensis were not well controlled. One of the factors responsible for this poor result may have been the rather advanced growth stage of these weeds.

In the 1964 kale experiments 4 oz desmetryne gave good control of seedling P. persicaria, P. convolvulus, Chenopodium album, Sonchus oleraceus and Stellaria media. At 6 oz/ac there was a slight improvement in control of these weeds, but 10 oz gave little further improvement. There was no effect on Galium aparine at any of the doses tried and there was only a slight to moderate check on Capsella bursa-pastoris, Polygonum aviculare, and Tripleurospermum maritimum ssp. inodorum.

In the experiments on other brassicas the average weed control from 4 oz/ac desmetryne was not as good as in the kale trials. This may have been to some extent due to the poorer competitive effect which the other brassicas exerted on the weeds in comparison with fairly thick crops of kale. However, it could also have been caused by the later spraying which occurred on many of the trials. Baker et al. (1963) reported on the increased tolerance of Chenopodium album following a long dry period. Owing to the drought which was experienced in 1964 the only weeds which were reasonably well controlled by 4 oz/ac desmetryne were Stellaria media, Urtica urens and Fumaria officinalis. The increased dose of 6 oz/ac gave improved control of these weeds and also reasonable control of Atriplex patula and Chenopodium album. This dose also gave good control of P. persicaria plants below 5 in. and moderate control of Galeopsis tetrahit and Sinapis arvensis. Weeds where the control was poor included Galium aparine, Poa annua, Tripleurospermum maritimum ssp. inodorum and Senecio vulgaris. The 10 oz/ac dose gave slightly improved weed control over 6 oz /ac but it would appear that this increased dose would not bring the level of weed control up to that from 6 oz/ac in more normal conditions or even from 4 oz/ac in moist growing conditions.

The addition of dicamba at 2 - 3 oz/ac gave improved control of the Polygonum spp., Stellaria media, Spergula arvensis, Tripleurospermum spp. and Senecio vulgaris. However as the dicamba tended to check the crop it remains to be seen whether this is reflected in the crop yields and therefore whether the improved weed control is worthwhile.

Where kale was free of weeds there was a tendency for 4 - 6 oz/ac desmetryne to slightly depress the yield, but where the crop was heavily infested there were substantial yield increases. Although kale was the first crop on which extensive trials were carried out with desmetryne it now seems that some other brassica crops are more resistant to the chemical. Certainly brussels sprouts, cabbages and spring greens were unaffected by 4 oz and the slight check by 6 oz and 10 oz/ac was very temporary. This is also borne out by the yields from the brassica thinnings experiment in which the crops most affected by 6 oz/ac desmetryne were kale and broccoli.

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References

Baker, C., Holmes, H.M., and Pfeiffer, R.K., (1962). Selective control of Chenopodium album in kale with methylmercapto triazines. Proc. 6th Brit. Weed Control Conf., 763 - 765.

Baker, C., Holmes, H.M., and Pfeiffer, R.K., (1963). Selective control of Chenopodium album in kale with methylmercapto triazines. Weed Res. 3, 109 - 127.

References (cont'd)

Elliott, J.G., and Cox, T.I., (1962). The control of weeds in agricultural kale. Proc. 6th Brit. Weed Control Conf., 759 - 761.

Powell, T.R.W., (1962). The control of weeds in kale and other brassicae with certain methylmercapto triazines. Proc. 6th Brit. Weed Control Conf., 767 - 787.

Research Summary

THE CONTROL OF WEEDS IN BRASSICAE WITH POST EMERGENCE APPLICATIONS OF 2,4-DICHLOROPHENYL 4-NITROPHENYL ETHER

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Summary Post-emergence applications of 2,4-dichlorophenyl 4-nitrophenyl ether, 'FW925', at rates of $\frac{3}{4}$ lb - 1$\frac{1}{2}$ lb a.i./ac plus $\frac{1}{2}$ lb a.i. chlorpropham onto cabbage, kale, brussels sprout, turnip and swede crops during 1963-64 showed that 1 lb a.i. 'FW925'/ac + $\frac{1}{2}$ lb a.i. chlorpropham, if applied at any stage of crop growth from emergence to 3-4 true leaf stage, gave no reduction in yield. Weeds controlled by contact action included Chenopodium album, Polygonum spp., Poa annua, Stellaria media, Urtica urens and Veronica spp. These last two were also controlled by residual action; weeds were more tolerant of the mixture if they were over 1 in. tall. Senecio vulgaris Capsella bursa-pastoris, Tripleurospermum maritimum and Thlaspi arvense were not well controlled at any stage of growth.

INTRODUCTION

Following the trials using 2,4-dichlorophenyl 4-nitrophenyl ether, coded as 'FW925' for pre-emergence weed control in Brassicae reported at the 6th British Weed Control Conference (Tyson & Wood, 1962) it was decided to examine the use of this herbicide when applied post-emergence to both crop and weeds. Crops would include cabbage, brussels sprout, cauliflower, kale, turnip and swede. The investigation had to determine the effect of 'FW925' on crop yield together with the susceptibility of weed species to economic doses. Comparison of two application timings were thought necessary, the first application to be given at the stage of maximum weed germination irrespective of crop growth, and the second when the crop had reached the 3-4 true leaf stage. The latter stage was similar to that recommended for the use of desmetryne, marketed in the United Kingdom during 1963 for post-emergence weed control in kale and certain other Brassicae and therefore taken as the standard material.

It was apparent from the work of Tyson & Wood that 'FW925' had no effect against Stellaria media when applied pre-emergence and in the post-emergence trials it was decided to include chlorpropham at $\frac{1}{2}$ lb a.i./ac. Although this dose had given good control of emerged S. media in glass-house trials reports of its effect on Brassicae were limited and conflicting - referring in the main to effect upon cabbage transplants (Anon. 1960).

'FW925' is a product of Rohm & Haas Co., Philadelphia, U.S.A., and marketed by them elsewhere as 'TOK E-25'.

METHODS AND MATERIALS

'FW925'	:	2,4-dichlorophenyl 4-nitrophenyl ether as an emulsifiable concentrate containing 2.4 lb a.i. per Imp. gal.
desmetryne	:	as 'Semeron', a wettable powder containing 25% a.i.
chlorpropham	:	During 1963 as 'TriCIPC', an emulsifiable concentrate containing 4 lb a.i. per Imp. gal; during 1964 as 'Murphy CIPC' containing the same a.i. rate.

Two types of trial were employed; the first being replicated (3- or 4-fold) small plot trials giving mainly weed response and the second, larger field trials for crop yield evaluation. These trials were carried out in various areas of the country to give 3 different soil types - highly organic, light sandy and medium to heavy loams. The small plot trials had split plots to show the effect of a treatment upon crop(s) which were manually hoed and upon normal weed growth.

Materials were applied through an Oxford Precision Sprayer or a logarithmic sprayer giving finite rates. Comparison was made between 2 spray volumes, 50 gal and 20 gal/ac.

RESULTS

1963

Small plot applications of $\frac{3}{4}$ lb, $1\frac{1}{2}$ lb and 2 lb a.i./ac 'FW925' with or without $\frac{1}{2}$ lb a.i. chlorpropham at 50 gal/ac onto marrow-stem kale and spring cabbage indicated that the addition of chlorpropham did not aggravate any check to growth found with 'FW925' alone. Both crops tolerated the $1\frac{1}{2}$ lb 'FW925' dose, made either at full seed leaf or 3-4 true leaf stage, and quickly recovered so that yields taken 3 months after sowing showed no depression in treated crops.

Desmetryne at $\frac{1}{4}$ lb a.i./ac applied at full seed leaf stage severely checked the cabbage and yields were at both stages significantly depressed. $\frac{3}{4}$ lb or $1\frac{1}{2}$ lb 'FW925' plus $\frac{1}{2}$ lb chlorpropham controlled emerged S. media, Urtica urens, Veronica spp., Poa annua, Chenopodium album, Polygonum spp., Solanum nigrum. Senecio vulgaris, Capsella bursa-pastoris, Tripleurospermum maritimum and Thlaspi arvense were not affected. Weeds over 1 in. high were not well controlled (U. urens and Veronica spp. being the exceptions).

1964

Spring applications of 1 or 1½ lb a.i./ac 'FW925' plus ½ lb a.i. chlorpropham were made onto plots sown to marrow-stem kale, summer cabbage, brussels sprout, and swede or turnip. Weed control was adequate with either rate of 'FW925' and compared well with desmetryne as the correct crop stage of growth was reached later than the susceptible growth stage of the major weed species. The higher dose of 'FW925' checked crop growth and these effects persisted. All crops tolerated the lower dose and showed no permanent growth depression. The 1 lb rate gave some residual control of germinating U. urens, Veronica spp. and Polygonum persicaria.

Field scale trials with 1 lb a.i. 'FW925'/ac plus ½ lb a.i. chlorpropham on cabbage, marrow stem kale, turnips and swedes indicate that yields are not depressed by this dose applied any time up to the crop reaching the 3-4 true leaf stage. Desmetryne depressed yields of turnips and swedes significantly. The degree of weed control was better with 50 gal/ac volume than with 20 gal.

DISCUSSION

The standard post-emergence herbicide used in Brassicae at present is desmetryne. This material is not suggested for use before the crop reaches the 3-4 true leaf stage as some depression of growth may be experienced, also certain Brassicae such as swedes and turnips do not tolerate desmetryne at any early stage of growth. It would therefore seem that 1 lb a.i. 'FW925'/ac plus ½ lb a.i. chlorpropham may be an acceptable alternative to desmetryne in certain Brassicae where weed competition is severe during the period from germination of the crop until it reaches a stage where desmetryne, if it may be used, is tolerated. Such a herbicide would be most valuable, even in such crops as kale where the crop's rapid growth can smother weeds, for early weed competition (up to 4 weeks after germination) can reduce crop yields significantly (Shadbolt & Holm, 1956; Hammerton, 1963).

References

ANON (1960) Rep. Luddington Exp. Hort. Sta. for 1959. 40 - 41.

HAMMERTON, J.L. (1963) Control of weeds in marrow stem kale by EPTC and some other herbicides. Weed Res., 3, 138.

SHADBOLT, C.A. & HOLM, L.G. (1956) Some quantitative aspects of weed competition in vegetable crops. Weeds 4, 111 - 123

TYSON, D. & WOOD, C.H.P. (1962) 2,4-Dichlorophenyl 4-nitrophenyl ether; A new residual herbicide. Proc. 6th Brit. Weed Control Conf. 805 - 816.

HERBICIDE TRIALS WITH CARROTS AND RED BEET AT MYLNEFIELD, 1963-4

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Summary Trials with Chantenay Red Cored carrots in two seasons and on two sites are described, in which prometryne, linuron, chlorpropham and chlorpropham + linuron were compared with a post-emergence application of mineral oil. On very light sandy soil, pre-emergence applications of linuron and prometryne stunted the carrot plants, and neither herbicide completely controlled annual weeds when applied pre- or post-emergence. The best treatment tried was a combination of chlorpropham and linuron applied at pre-emergence in 1964. On the light sandy loam at Mylnefield it provided weed control as good as that from mineral oil.

A trial with red beet, variety Formanova, showed that when an early and rapid weed germination is achieved, application of a paraquat/diquat mixture immediately prior to crop emergence can give results as good as those from soil-acting residual herbicides based on endothal, diuron, propham and PCA.

INTRODUCTION

In previously-reported trials at Mylnefield and North Berwick (Stephens, 1962), a number of soil-acting herbicides were compared with mineral oil for weed control in Chantenay Red Cored carrots. This work has been continued with more recently developed herbicides, including linuron and prometryne, applied both before and after emergence.

As a result of some local interest in red beet for processing, preliminary trials conducted in 1963 and not reported here in detail showed that either pre-emergence contact herbicides or a mixture of endothal and propham could reduce the time on hand hoeing, although none of the treatments alone approached an acceptable commercial level of weed control. In 1964 a replicated trial at Mylnefield was used to compare contact pre-emergence and soil-acting herbicides in red beet of the var. Formanova.

METHODS AND MATERIALS

Replicated field trials with carrots, variety Chantenay Red Cored, were sown on a very light sand at North Berwick and on a free-draining sandy loam at Mylnefield in 1963 and at Mylnefield in 1964. The trials in 1963 were arranged in six randomised blocks, each unit plot consisting of a 15 ft section of carrot bed on which were drilled seven rows each 6 in apart, using a hand-pushed seeder. In 1964 the unit plots contained four rows 21 ft long and 1 ft apart, and the carrots were thinned to approximately 2 in apart at the second rough leaf stage.

The layout of the red beet trial was similar to the 1964 carrot trial described above. The plants were singled to approximately 4 in apart some 7 weeks after drilling.

All the herbicides were applied with an Oxford Precision Sprayer, the mineral oil at a volume rate of 80 gal/ac, and the other treatments at 40 gal/ac.

In both years the plots were hand-cleaned when post-spraying weed assessments had been made, except that in 1964 one complete replicate in each trial was left uncultivated to allow a better assessment to be made of the long-term effects of the treatments on the weeds.

RESULTS

a) Carrots, 1963

None of the materials used gave complete weed control at either centre, though the plots receiving the higher rate of linuron applied pre-emergence at North Berwick were almost weed free at the time of the second application of herbicide. Emerged seedlings of Capsella bursa-pastoris were scorched by the mineral oil but their growth was only checked. Fumaria officinalis was not controlled by post-emergence application of linuron and only partially controlled when the herbicide was applied pre-emergence. Prometryne gave results generally similar to those from linuron, but whereas it controlled fumitory, it gave only poor control of Poa annua. Chlorpropham controlled all weeds well except Senecio vulgaris.

Pre-emergence application of both prometryne and linuron on the light sandy soil at North Berwick caused some scorching of the foliage. The post-emergence application of mineral oil caused a slight reduction in intensity of the green colour of the foliage, from which the plants appeared to recover quickly. The other treatments were without obvious effect on the crop.

b) Carrots, 1964

Neither prometryne (1.0 lb/ac) nor linuron (0.75 lb/ac) when applied at pre-emergence gave good control of Poa annua, Polygonum aviculare or Stellaria media. The post-emergence treatments were somewhat better, but the only treatments to give a commercially acceptable weed control until lifting in August were the post-emergence mineral oil application and the pre-emergence mixture of chlorpropham and linuron.

c) Red beet, 1964

There was a rapid emergence of weeds after drilling of the red beet in 1964, and the mixture of paraquat and diquat sprayed immediately before emergence of the beet provided an almost complete kill of these seedlings. Further weed germination was slow, and the plots which received the paraquat/diquat mixture remained almost weed free until lifting time in August. None of the soil-acting herbicides were equal to this mixture in the degree of weed control they gave.

Table 1.

Carrot trial 1963: Root yields (North Berwick and Mylnefield)

Treatment	Rate/ac Time of application 1	2	3	Yield tons/ac Mylnefield	North Berwick
Hand weeded				15.5	-
Mineral oil		80 gal		18.6	19.1
Chlorpropham	2.0 lb			19.2	20.2
Linuron	2.0 lb		1.0 lb	18.6	16.2
Linuron		2.0 lb	1.0 lb	18.1	14.5
Linuron		1.0 lb	0.5 lb	17.1	16.5
Prometryne	2.0 lb		1.0 lb	18.9	14.8
Prometryne		2.0 lb	1.0 lb	17.1	13.8
Prometryne		1.0 lb	0.5 lb	17.1	14.5
Standard error of difference between two means				-[1]	1.0
Significance of F test				-	0.1%

Time of application: 1. at drilling
2. at two rough leaves
3 two months after drilling

[1] Not analysed because lifted with heavy soil tare

Key to weed species in Table 2 and Table 3:-

A <u>Capsella bursa-pastoris</u>

B <u>Chenopodium album</u>

C <u>Fumaria officinalis</u>

D <u>Poa annua</u>

E <u>Polygonum aviculare</u>

F <u>Senecio vulgaris</u>

G <u>Stellaria media</u>

H <u>Veronica hederifolia</u>

Table 2.

Carrot trial 1964: Root yields, weed nos. and dominant surviving species

Treatment	Rate/ac Time of application 1	2	Yield tons/ac	Weeds weeds/sq.ft.	species
Hand weeded			7.48	19.1	A-H
Mineral oil	80 gal		7.22		DG
Chlorpropham	1.5 lb				
Linuron	0.5 lb		9.02	2.4	CF
Linuron	1.0 lb		8.63	7.8	CDE
Linuron	0.75 lb		8.16	10.2	BCD
Linuron		1.0 lb	7.69		DEFG
Linuron		0.75 lb	7.78		CDEG
Prometryne	1.0 lb		8.21	18.1	A-E
Prometryne		1.0 lb	7.08		BD
Standard error of difference between two means			0.9		
Significance of F test			N.S.		

Time of application: 1. at drilling
2. at two rough leaves

Table 3.

Red beet trial, 1964: Yield, weed numbers and main surviving species

Treatment	Rate/ac	Yield tons/ac	Weeds weeds sq.ft.	species
Hand weeded		12.9	16.1	A-EGH
PCA	3.0 lb	13.7	9.9	CDGH
PCA	4.0 lb	12.9	10.8	CDEGH
Diuron/propham (DIPRO)	10.0 lb (product)	11.8	5.3	CDH
Diuron/propham (DIPRO)	14.0 lb (product)	11.9	3.5	CH
Endothal/propham (MURBETEX)	14.0 pt (product)	12.7	5.5	C
Endothal/propham (MURBETEX)	28.0 pt (product)	13.8	5.5	BG
Diquat/paraquat (PREEGLONE EXTRA)	2.0 pt	14.6	2.8	GH
Standard error of difference between two means		2.0		
Significance of F test		N.S.		

DISCUSSION

Before prometryne and linuron became commercially available, the principal herbicide used in the carrot crop grown in Scotland for canning was tractor vapourising oil (T.V.O.). This is a notoriously variable commodity, and crops are sometimes rejected on the grounds of taint attributed to T.V.O. spray. Neither T.V.O. nor the considerably more expensive officially approved mineral oil herbicide used as a standard in these trials can be applied until some time after germination of the crop, and the weed competition during this period can be severe. In addition, T.V.O. sometimes causes tainting of the crop and neither T.V.O. nor mineral oil is able to control a sufficiently wide spectrum of weeds to eliminate the need for some hand weeding.

Linuron was commercially introduced in 1963 as a pre-emergence herbicide recommended for carrots, and subsequently its use as a post-emergence spray was also advised. Prometryne, introduced commercially a year later, is only recommended for use as a post-emergence spray. Chlorpropham is tentatively recommended for carrots in the Weed Control Handbook as a pre-emergence herbicide, with reservations concerning soil type and depth of drilling. Contact pre-emergence sprays are also recommended, but their effective use depends on a rapid weed emergence before the emergence of the crop, and this is unlikely to occur without the use of a stale seed bed, which has certain known disadvantages.

Prometryne - and even more so linuron which can be applied either pre- or post-emergence - appeared in these trials to have some advantages over T.V.O. and mineral oil, their greatest weaknesses being their poor control of certain weed species. Mixtures therefore suggest themselves as one way of achieving a complete chemical weed control. Both prometryne and linuron have been shown in these trials to be capable of reducing the harvested crop of carrots when used on very light soils. A possible advantage of mixtures containing either of these herbicides would be that less of the active ingredient of either might be sufficient for an adequate level of weed control, thereby reducing the danger of damage to the crop.

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References

STEPHENS, R. J. (1962) Trials of soil-acting herbicides in carrots and other vegetables. Proc. 6th Brit. Weed Control Conf. 507-513

EXPERIMENTS WITH PRE-EMERGENCE TREATMENTS FOR WEED CONTROL IN CARROTS, PARSLEY AND PARSNIPS

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Summary Field experiments were carried out during 1961-63 on a sandy loam to evaluate propazine, prometryne and linuron as pre-emergence treatments for weed control in carrots, parsley and parsnips. Propazine at 0.5 lb/ac gave excellent weed control but sometimes caused significant reductions in the stand of carrots. Prometryne proved to be variable in the degree of weed control obtained, and in one experiment the stand of carrots was reduced by 1 lb/ac. Linuron gave consistently good weed control, with the exception of *Fumaria officinalis*, and at 1 lb/ac did not affect either the stand or yield of carrots. Both parsley and parsnips appeared to be more tolerant than carrots to all three herbicides.

INTRODUCTION

Previous work has demonstrated the comparatively high degree of tolerance shown by carrots, parsley and parsnips to propazine, and in preliminary field experiments on a sandy loam it was found that 0.5 lb/ac as a pre-emergence spray gave good weed control with only slight crop damage (Roberts & Wilson, 1960). Two other herbicides which have been reported as showing selectivity in umbelliferous crops are prometryne (Gysin & Knüsli, 1958; Knüsli, 1961) and linuron (Soyez, 1961; Hill *et al.*, 1962; Farbwerke Hoechst, 1962). During 1961-63 these were compared with propazine in field experiments with carrots, parsley and parsnips, and the results obtained are summarized in this report.

METHODS AND MATERIALS

The experiments were all carried out at Wellesbourne on a sandy loam of the Newport series, relatively low in organic matter. Except where stated, a randomized block design was used with three or four replicates and a plot size of 6-8 yd^2. Wettable powder formulations were applied as aqueous suspensions at a volume of 100 gal/ac within a few days after drilling and all doses are given as lb/ac a.i. Weed kill was assessed by counting survivors in a number of random quadrats on each plot about one month after spraying, and all plots were then weeded by hand so that yields could be determined in the absence of any appreciable weed competition. The numbers and weights of carrot roots were determined at harvest; with parsley the numbers and weights of whole plants were recorded. The parsnips were thinned to 6 in. within the rows at the time of weeding, and the data thus refer to the thinned crop. Stands and yields are presented in the tables as percentages of the control values and depressions statistically significant at $P < 0.05$ are indicated by asterisks. The experimental crops all grew well, and the standard errors for individual plots were usually about 10% of the means.

RESULTS

Several unreplicated field tests were made to determine the comparative response of small-seeded vegetable crops to pre-emergence applications of prometryne and linuron. The results from one of these, in which more than 1 in. of rain fell during the day after spraying, are shown in Table 1. Under these conditions four of the seven crops were killed or severely injured by all the treatments, but carrots, parsley and parsnips appeared to show a high degree of inherent tolerance to both compounds.

Table 1.

Comparative susceptibility of vegetable crops to prometryne and linuron, 1961.

	Crop injury (0 = no effect; 10 = complete kill)					
	Prometryne			Linuron		
Dose, lb/ac	0.5	1	2	0.5	1	2
Parsley	0	0	2	0	0	0
Parsnip	0	3	0	0	0	0
Carrot	0	0	2	0	1	5
Onion	4	7	10	9	9	10
Lettuce	8	10	10	10	10	10
Cabbage	9	9	10	10	10	10
Red beet	9	10	10	10	10	10

1961 experiments

Propazine and prometryne were compared in experiments with each of the three crops. The main weed species present were *Fumaria officinalis*, *Polygonum aviculare*, *Thlaspi arvense* and *Veronica persica*, and the results are summarized in Table 2.

Table 2.

Comparison of pre-emergence applications of propazine and prometryne on carrots, parsley and parsnips, 1961.

	Carrot Early Market			Parsley Imperial Curled			Parsnip Offenham		
	% weed kill	No.	Wt.	% weed kill	No.	Wt.	% weed kill	No.	Wt.
Propazine									
0.5 lb/ac	99	82*	97	67	100	93	96	98	102
1 "	99	62*	85	95	72*	63*	100	109	105
Prometryne									
0.5 lb/ac	56	94	93	44	97	91	62	106	105
1 "	77	90	93	70	97	105	82	105	107

Both the carrots and the parsnips received heavy rain within a week after spraying; the parsley was sown later during a dry period and received only

0.5 in. irrigation during the first three weeks after spraying. Propazine gave almost complete kill of weeds in the carrots and parsnips but in the parsley, 0.5 lb/ac gave only moderate control. The stand of carrots was significantly reduced by both doses and that of parsley was reduced by 1 lb/ac. Propazine at 0.5 lb/ac caused a temporary check to parsley, but there were no visible effects on the parsnips with either dose. Prometryne was consistently less effective than propazine against the weeds, but at neither dose was there any adverse effect on the growth, stand or yield of the three crops.

1962 experiments

- Linuron was compared with prometryne and propazine in experiments with each of the three crops. The main weed species present included *Fumaria officinalis*, *Thlaspi arvense*, *Chenopodium album*, *Polygonum aviculare*, *Poa annua* and *Trifolium repens*, and the results are shown in Table 3.

Table 3.

Comparison of pre-emergence applications of linuron, prometryne and propazine on carrots, parsley and parsnips, 1962.

	Carrot New Stump-rooted			Parsley New Dark Green Winter			Parsnip Offenham		
	% weed kill	No.	Wt.	% weed kill	No.	Wt.	% weed kill	No.	Wt.
Linuron									
1 lb/ac	92	87	102	95	111	129	96	105	113
2 "	97	66*	92	100	94	105	91	104	105
4 "	100	9*	35*	100	59*	103	100	100	97
Prometryne									
0.5 lb/ac	90	88	98	60	109	117	91	101	104
1 "	98	78*	88	90	113	115	97	103	103
2 "	99	59*	91	99	107	119	100	94	99
Propazine									
0.5 lb/ac	99	63*	95	100	86	114	97	104	102

The carrots and parsnips both received 0.46 in. rain four days after spraying and in addition, 0.3 in. irrigation was applied at about the time of emergence. The parsley received 0.3 in. irrigation two days after spraying. Conditions were thus favourable to the action of residual herbicides, and with the exception of prometryne 0.5 lb/ac in the parsley experiment, all treatments gave more than 90% weed kill. Some injury to the carrots was caused by all the treatments, but with linuron 1 lb/ac and prometryne 0.5 lb/ac there was no significant reduction in stand. Prometryne appeared to be rather more injurious than linuron at the same doses. Stand counts of the parsnips prior to thinning showed that under the same conditions none of the treatments caused any reduction, nor was there any adverse effect on final yield. Propazine 0.5 lb/ac caused slight damage to parsley, but the only treatment resulting in significant stand reduction was linuron 4 lb/ac. In this experiment the weeds were rather large at the time of weeding and some competition occurred; it is also possible that some crop seedlings were inadvertently removed from the control plots during weeding.

1963 experiments

Experiments with the three crops were made concurrently in 1963, when more than 0.5 in. rain fell during each of the three weeks following spraying. The weeds present included *Fumaria officinalis*, *Thlaspi arvense*, *Chenopodium album*, *Polygonum aviculare*, *Poa annua*, *Trifolium repens*, *Veronica persica* and *Stellaria media*, and the results are summarized in Table 4.

Table 4.

Comparison of pre-emergence applications of linuron, prometryne and propazine on carrots, parsley and parsnips, 1963.

	Carrot New Stump-rooted			Parsley Cluseed Exhibition			Parsnip Offenham		
	% weed kill	No.	Wt.	% weed kill	No.	Wt.	% weed kill	No.	Wt.
Linuron									
0.5 lb/ac	85	109	103	79	111	118	88	102	99
1 "	88	103	100	81	121	114	87	94	96
Prometryne									
0.5 lb/ac	14	107	99	21	99	107	37	100	104
1 "	67	112	100	54	110	116	58	100	99
Propazine									
0.5 lb/ac	81	106	101	79	118	117	82	100	106

The emergence of weeds took place only slowly, and the degree of kill obtained was somewhat lower than in previous years. Nevertheless, both linuron and propazine gave good results and at the same dose were approximately equal in performance. Prometryne in these experiments gave only poor results, and at 1 lb/ac was inferior to linuron at 0.5 lb/ac. None of the treatments affected crop growth and there was no significant reduction in crop stand or yield.

DISCUSSION

The experiments confirmed the relative tolerance of carrots, parsley and parsnips to propazine, which gave consistently good control of the mixed weed populations present. It must be admitted, however, that because the primary aim of the experiments was to examine crop tolerance, irrigation was applied in the absence of rainfall; without this the results might have been less good. In two out of the three experiments with carrots (Tables 2 and 3) and in others not reported here, propazine at 0.5 lb/ac caused significant reductions in crop stand and it is clear that at this rate of application the use of propazine on a light soil would be unsafe.

Prometryne was always less effective than propazine at the same rates from the point of view of weed control, and in 1963 (Table 4) gave very poor results in comparison with those obtained in 1962 (Table 3). This variable performance of prometryne when used as a pre-emergence treatment was also noted in experiments with other crops and is in accord with general experience in the U.K. (Abel, 1963). Only in 1962 (Table 3) was there any significant reduction in the stand of carrots with 1 lb/ac, and as with propazine, both parsley and parsnips appeared to be more tolerant than carrots.

The preliminary tests in 1961 demonstrated the marked tolerance shown by carrots, and especially parsley and parsnips, to linuron (Table 1). In 1962 (Table 3), the stand of carrots was reduced by 2 lb/ac but at 1 lb there was no significant reduction in stand or yield with any of the three crops. Linuron gave excellent control of the main weed species encountered in the experiments with the exception of Fumaria officinalis which was not affected by doses of 2 lb/ac or less. In contrast with prometryne, linuron gave good results in 1963 when weed emergence was slow, and in these experiments (Table 4) there was little to choose between 0.5 and 1 lb/ac.

Taking into account both weed control and crop damage, linuron at doses of not more than 1 lb/ac gave the most satisfactory results in these experiments. In other experiments not reported here, good results were obtained in carrots, parsley and parsnips with post-emergence applications of both prometryne and linuron. It thus appears that a combination of linuron pre-emergence followed by a post-emergence spray of either linuron or prometryne offers a means of obtaining weed control for as long as is normally required. Fumaria officinalis was found to be susceptible to prometryne even when the plants had passed the seedling stage, and a pre-emergence spray of linuron 0.75 lb/ac followed by post-emergence treatment with prometryne 1 lb/ac has been adopted as a standard procedure for carrot, parsley and parsnip crops at Wellesbourne, with excellent results.

Acknowledgments

We are grateful to Fisons Pest Control Limited and Du Pont Company (United Kingdom) Limited for providing the herbicides used in this work.

References

ABEL, A.L. (1963) A new chemical weedkiller for carrots. Agric. vet. Chemic. 4, 147.

FARBWERKE HOECHST A.G. (1962) Afalon and Aresin. Tech. Bull. 1/1962.

GYSIN, H. & KNÜSLI, E. (1958) Activity and mode of action of triazine herbicides. Proc. 4th Brit. Weed Control Conf. 225-233.

HILL, G.D., EVANS, A.W. & VARNER, R.W. (1962) Selective weed control in crops with a new substituted urea herbicide. Proc. 15th Southern Weed Conf. 49-59.

KNÜSLI, E. (1961) Advances in the field of triazine herbicides. Proc. EWRC/COLUMA Symp. on Herbicides, 46-51.

ROBERTS, H.A. & WILSON, B.J. (1960) The response of vegetable crops to pre-emergence application of some substituted triazines. Proc. 5th Brit. Weed Control Conf. 409-412.

SOYEZ, J.L. (1961) 3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea. EWRC/COLUMA Symp. on Herbicides, 207-208.

N'-4-(p-METHOXY-PHENOXY)-PHENYL-NN-DIMETHYLUREA, A NEW SELECTIVE HERBICIDE IN ONIONS

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Summary N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea (Ref. No. C-3470) is a selective herbicide for controlling important annual weeds in sown and planted onions (*Allium cepa*). The application is done from the late whip stage onward in seeded onions and after emergence of the weeds in planted onions. Optimal weed control is obtained with applications in the cotyledon till 6-leaf stage of the weeds. The recommended rate is 4-6 kg/ha (3.6-5.3 lb/ac) of the formulated product. C-3470 applied according to recommendations does not depress yields, even at high rates.

INTRODUCTION

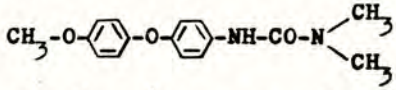
The most difficult problem in the cultivation of sown onions is a satisfactory weed control. An improvement has been reached in the last years due to the use of chemical products. However, in some regions certain resistant weed species were favored by a continuous application for several years; this caused new problems of weed control. Therefore, in the long run successful weed control can only be obtained by the alternate use of several products with a different weed spectrum.

CIBA Limited has tested during the last years the product C-3470 (N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea) for weed control in onions.

The most important results are reported here.

IMPORTANT CHEMICAL AND PHYSICAL PROPERTIES

Structure:



Chemical name: N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea

Solubility in water: 20 ppm

Formulation: 50% wettable powder

Toxicity

Acute oral toxicity:	Mouse LD_{50}	>1000 mg/kg
	Rat LD_{50}	>1000 mg/kg
Irritation:	In rabbits no irritation on eyes up to a 10% solution.	
Danger to bees:	LD_{50} in 24 hours: 200 γ p.o., i.e. not dangerous.	

Toxicity to fish and to the organisms on which they feed

Limit of lethal doses: *	Rainbow trout (Salmo irideus)	10 ppm
	Freshwater shrimp (Gammarus pulex)	20 ppm
	Tube worms (Tubifex spp.)	>20 ppm

* In conformity with Liebmann, H., 1962.
Handbuch der Frischwasser- und Abwasserbiologie,
Band II, Verlag Oldenburg, München.

BIOLOGICAL PROPERTIES

C-3470 was tested on onions in various countries in and outside Europe in 1963 and 1964. The principal objectives of the trials conducted in Switzerland in 1964 were to clarify the following questions:

1. Herbicidal effect in relation to the developmental stage of the weeds.
2. Tolerance of sown onions in various developmental stages.
3. Yield as affected by C-3470.
4. Susceptibility of different varieties.

The rates given in the following text refer to the formulated preparation with 50% active ingredients.

1. Herbicidal Effect in Relation to the Developmental Stage of the Weeds

The greatest susceptibility of the weeds to C-3470 ranges from the cotyledon to the four-leaf stage. In this case the required rate amounts to 4-6 kg/ha (3.6-5.3 lb/ac). In some trials good results were obtained with 6 kg/ha applied before emergence of the weeds. The susceptibility of important weed species is given in Table 1.

Table 1.

Susceptibility of Important Weed Species to C-3470 Applied in the Cotyledon till 4-Leaf Stage

Amaranthus retroflexus	S	Poa annua	MR
Artemisia vulgaris	R	Panicum crus-galli	R
Capsella bursa-pastoris	S	Portulaca oleracea	MR
Chenopodium album	S	Rumex acetosella	S
Galinsoga parviflora	S	Sonchus spp.	MR
Galeopsis tetrahit	MS	Stellaria media	MS
Fumaria officinalis	MS	Senecio vulgaris	S
Lamium purpureum	S	Sinapis arvensis	MS
Galium aparine	MR	Setaria spp.	R
Matricaria recutita	S	Solanum nigrum	S
Polygonum persicaria	MS	Urtica urens	S

S = very susceptible
MS = susceptible; sufficient injury
MR = little susceptibility; temporary injury
R = resistant.

MS and MR signify that these species are better controlled at the higher rate and in the cotyledon stage.

2. Tolerance of Sown Onions in Various Developmental Stages

The tolerance of sown onions to C-3470 as affected by developmental stage is presented in Table 2. The onions are very susceptible in the loop till whip stage, while after the whip stage all rates are well tolerated.

Table 2.

Degree of Crop Injury in Sown Onions as Affected by Rate of C-3470 and Developmental Stage of Onions

Rate kg/ha	Rate lb/ac	Pre-emergent trials 1	2	3	4	Loop-whip trials 1	2	3	4	After whip trials 1	2	3	4
4	3.6	-	2	1	1	4	5	2	3	1	1	1	1
6	5.3	-	2	1	2	4	6	3	4	1	1	1	1
8	7.1	-	-	1	-	5	-	4	4	2	-	1	1

1 = no injury
9 = 100% injury
- = no treatment

3. Yield Trials

3.1 Yield Trials in Sown Onions

In yield trial in sown onions C-3470 was compared to an uncultivated weedy control, and a control weeded mechanically according to common methods.

Time of application: A = Onions in whip stage.
Weeds in 4- till 6-leaf stage.

B = Onions after whip stage, about 8-10 cm (3.2-4.0 in.) high. Weeds about 5-8 cm (2.0-3.2 in.) high.

Rates of application: C-3470 4.0 kg/ha (3.6 lb/ac)
6.0 kg/ha (5.3 lb/ac)
8.0 kg/ha (7.1 lb/ac)

Reference compound
Chloro-JPC 5.0 l/ha (3.5 Imp.pints/ac)

Variety: Gelbe Kugel

Rate of sowing: 14 kg/ha (12.5 lb/ac)

Amount of water: 500 l/ha (Imp.gal/ac)

Table 3.

Yield Trial with C-3470 in Sown Onions

Time of application	A				B		
Rate in kg/ha	4.0	6.0	8.0	R.C.*	4.0	6.0	8.0
Weed control	3	3	2	6	3	3	2
Crop injury	3	4	5	1	1	1	2

* Reference Compound

Yields (Mean of 4 replications)					
Treatments		Time of appli-cation	weight of 100 onions kg	metric tons/ha	English tons/ac
Control not weeded		-	1.16	4.75	1.89
Control weeded		-	6.32	32.75	13.00
C-3470	4.0 kg	A	6.36	29.12	11.56
	6.0 kg	A	6.08	28.02	11.12
	8.0 kg	A	6.36	25.52*	10.13
Reference compound	5.0 l	A	6.83	35.65	14.15
C-3470	4.0 kg	B	7.22	33.30	13.22
	6.0 kg	B	6.80	39.55*	15.70
	8.0 kg	B	7.30	35.22	13.98

Assessment of weed control: 1 = 100% control
9 = no control

Assessment of crop injury: 1 = no injury
9 = 100% killed

* Significant at the 5% level
with reference to the handweeded control plot.

C-3470 applied at the whip stage caused market yield depressions particularly at the higher rates. Applied after the whip stage C-3470 showed good selectivity and good weed control. In this case the yields were, despite no cultivation whatever, similar or higher than the weeded control.

3.2 Yield Trials in Planted Onions

In the corresponding manner as in Section 3.1 C-3470 and Chloroxuron were compared to an uncultivated and a cultivated control.

Time of application: A = Planted onions 8-12 cm (3.2-4.8 in.) high. Weeds: 2-leaf stage.

B = Onions: 20-25 cm (8-10 in.) high. Weeds: 6-leaf stage.

Rates of application: C-3470 4.0 6.0 (B only) 8.0 12.0 kg/ha
3.6 5.3 7.1 10.7 lb/ac.

Reference compound
Chloroxuron as Tenoran®
7.5 kg/ha (6.7 lb/ac).

Variety: Stuttgarter Riesen.

Table 4.

Yield Trial with C-3470 in Planted Onions

Time of application	A				B			
Rate in kg/ha	4.0	8.0	12.0	Chlor-oxuron	4.0	6.0	8.0	12.0
Weed control	4	2	1	1	3	1	1	1
Crop injury	1	2	2	2	1	2	3	4

Yields (Mean of 4 replications)

Treatments		Time of application	metric tons/ha	English tons/ac
Control not weeded		-	26.5	10.52
Control weeded		-	44.1	17.50
C-3470	4.0 kg	A	53.4**	21.20
	8.0 kg	A	51.0*	20.25
	12.0 kg	A	48.0	19.06
Chloroxuron	7.5 kg	A	47.3	18.78
C-3470	4.0 kg	B	47.8	18.98
	6.0 kg	B	47.8	18.98
	8.0 kg	B	47.8	18.98
	12.0 kg	B	49.8	19.77

** Highly significant at the 5% level with reference to the handweeded control plot

* significant at the 5% level with reference to the handweeded control plot.

According to Table 4 the application of C-3470 at 8 and 12 kg/ha to planted onions, 20-25 cm high, caused slight crop injury. However, these injuries did not adversely affect the yield.

4. Investigations on the Susceptibility of Various Varieties

The test on possible differential susceptibility of varieties was conducted with 6 kg/ha (5.3 lb/ac) of C-3470. The following varieties were tested in two stages of development: Satelit, Superba, Stuttgarter Riesen, Zittauer, Vertus, Gelbe Kugel, Ideal, Presto, Savoyer, and Ebenezer.

Developmental stage of the onions: A = whip stage
B = late whip stage 6-8 cm (2.4-3.2 in.) high

Table 5.

Susceptibility of the Listed Varieties of Seeded Onions to C-3470

Variety	Stage A	Stage B
Zittauer	2	1
Vertus	2	1
Gelbe Kugel	2	1
Ideal	2	1
Presto	2	1
Savoyer	2	1
Ebenezer	2	1
Satelit	3	1
Stuttgarter Riesen	3	2
Superba	4	3

All varieties exhibited greater susceptibility in the developmental stage A than stage B. The variety Superba showed considerable susceptibility in both stages.

Residue Analysis

Samples were taken from all 1964-trials and treatments for residue analysis of the harvested crop. The results are not available, yet, but the results from the trials in 1963 give some indications:

Table 6.

Residues of C-3470 in Onions (Harvest 1963)

Crop	Planting or Sowing	Date of appli-cation	Rate kg a.i./ha	Harvest after ...days	Residues ppm
Onions sets	7.5.63	8.5.63	4	106	0
			4	106	0
Sown onions	7.5.63	5.6.63	2	78	0
			2	78	0
			4	78	0
			4	78	0

DISCUSSION

Nine important onion varieties were found tolerant to C-3470, while the variety Superba was susceptible.

Under conditions of fast weed development it is occasionally not possible to apply C-3470 at the optimal time because of the developmental stage of the onions. In this case it is advantageous to apply a contact herbicide (Paraquat or Diquat) before emergence of the onions in order to control early-emerged weeds. The additional application of C-3470 after the whip stage of the onions on the later-emerged weeds guarantees a particularly long-lasting effect.

The onions contain no residues of C-3470 at the time of harvest.

Tenoran® = Registered Trade Mark of CIBA Limited

EXPERIMENTS WITH POST-EMERGENCE TREATMENTS FOR WEED CONTROL IN DRILLED ONIONS

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Summary In field experiments on a sandy loam, N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea, prometryne and linuron were applied as post-emergence treatments on drilled onions, either alone or following various pre-emergence treatments. All three herbicides gave selective control of susceptible weed species provided that spraying was done after the crop had developed one true leaf and no uptake through the roots occurred. When heavy rain followed application, N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea 3 lb/ac, prometryne 1 lb/ac and linuron 0.75 lb/ac caused severe damage, with linuron consistently more damaging than prometryne. It is concluded that on light soils these treatments would not be feasible, although they may prove to be sufficiently safe on more organic soils.

INTRODUCTION

The onion crop presents difficult problems from the point of view of weed control. Germination, emergence and early growth are relatively slow and at no time is a complete canopy formed, so that the crop is susceptible to weed competition throughout its life. The main chemical methods of weed control at present employed in Britain are contact pre-emergence treatments, residual pre-emergence sprays based on chlorpropham and post-emergence sprays of sodium monochloroacetate (Woodford & Evans, 1962). None of these is entirely satisfactory, and there is a pressing need for more effective and reliable herbicides.

One approach which seemed worthy of examination was the post-emergence use of herbicides which act both through the foliage and through the soil. If materials of this kind were sufficiently selective, they could be applied after contact pre-emergence treatment to kill late-germinating weeds and to give some measure of residual control. In 1963, tests were made with an experimental herbicide N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea (C.3470), which was reported to have shown promise in onions (CIBA Laboratories Ltd., 1963). These were extended in 1964, and on the basis of earlier tests, linuron and several triazines were also examined. The results obtained are summarized in this report.

METHODS AND MATERIALS

The experiments were all carried out at Wellesbourne on a sandy loam of the Newport series, relatively low in organic matter. Except where stated, a randomized block design with 2-4 replicates was used, with small plots of 3-8 yd^2. The sprays were applied in a volume of 100 gal/ac and all doses are given as lb/ac a.i. Weed kill was assessed by counting survivors in a number of random quadrats on each plot, and the plots were then weeded by hand so that the effects of the treatments on crop yield could be determined in the absence of any appreciable weed competition. Visual assessments were made of crop injury, stand counts were made, and the yields of either dry bulbs or bunching onions were recorded. Stands and yields are presented in the tables as percentages of the control values, and depressions statistically significant at $P < 0.05$ are indicated by asterisks.

RESULTS

The effects on onions of N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea were examined in three experiments during 1963. In the first, the crop was sprayed at the early crook stage and at the early 1-leaf stage with 2 and 4 lb/ac, and the results are shown in Table 1.

Table 1.

Effect of N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea on weeds and on Bedfordshire Champion onions, 1963

	% weed kill						Onions	
	Poa ann.	Poly. avic.	Stell. media	Veron. per.	Anag. arv.	other spp.	no.	wt.
early crook stage								
2 lb/ac	9	7	93	99	97	60	99	116
4 "	0	24	99	99	97	75	92	107
early 1-leaf stage								
2 lb/ac	18	25	72	100	93	76	106	108
4 "	24	25	95	100	96	83	107	115

At both doses and on both occasions, excellent kills of Stellaria media, Veronica persica, Anagallis arvensis and also of Thlaspi arvense were obtained, but there was little effect on Poa annua or Polygonum aviculare, both of which had three leaves at the first spraying occasion. Some plants of Fumaria officinalis also survived, especially at the lower dose. Onions treated with 2 lb/ac at the early crook stage showed slight damage, and at 4 lb/ac there was quite severe leaf injury and death of a few plants was observed. The crop recovered and there was no significant depression of stand or yield of dry bulbs. When sprayed at the later stage of growth, the onions showed no injury.

In a second experiment with bulb onions, doses up to 8 lb/ac were applied either at the late crook or the late 1-leaf stages and the results are shown in Table 2. The crop suffered some leaf injury, especially at the higher doses, but none of the treatments resulted in any significant depression of stand or yield. In both this and the previous experiment initial crop growth was very slow and the weeds were therefore relatively large at spraying. Some competition occurred on the control plots and on those sprayed with the low dose prior to weeding.

Later in the season, the same treatments were applied to White Lisbon onions, and the results are also shown in Table 2. At the early crook stage all doses caused injury and significantly reduced both stand and yield, whereas application at the 1-leaf stage caused no visible injury. The crop damage that occurred at the earlier stage was much greater than that observed in the two previous experiments, and may have been associated with the heavy rainfall which followed spraying. During the two weeks after the first application 1.7 in. rain fell, whereas the second was followed by a dry period. In this experiment the weeds emerged slightly later than the crop, and excellent kills were obtained of Veronica persica, Capsella bursa-pastoris, Senecio vulgaris and several other species. At the lowest dose some Poa annua was killed; at higher doses there was appreciable kill of this species.

Table 2.

Effect of N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea on onions, 1963

	Elsom's Maincrop, sown 26.4.63				White Lisbon, sown 8.8.63			
	late crook		late 1-leaf		early crook		1-leaf	
	no.	wt.	no.	wt.	no.	wt.	no.	wt.
2 lb/ac	87	86	93	92	86*	72*	98	106
4 "	98	104	102	103	44*	26*	103	95
6 "	123	115	100	114	15*	8*	94	84*
8 "	93	113	99	108	7*	5*	108	91

In spring 1964, an experiment was carried out in which onions were sprayed on six occasions, from immediately after sowing until the 2-leaf stage. The results are summarized in Table 3.

Table 3.

Effect of N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea on weeds and on Giant Zittau onions, 1964

			onions					
Time of application	% weed kill		injury 0 - 10		stand as % of control		yield as % of control	
	2 lb	4 lb	2 lb	4 lb	2 lb	4 lb	2 lb	4 lb
After sowing	53	81	1.0	4.0	95	85	102	99
Before emergence	86	97	5.0	7.3	66*	48*	85	71*
Loop stage	89	97	7.3	8.7	42*	24*	75*	50*
Crook stage	84	96	5.7	7.7	64*	46*	92	48*
1-leaf stage	—	—	1.3	1.0	93	95	90	106
2-leaf stage	—	—	0.0	1.3	110	98	110	89

The application made after sowing was followed by more than 2.5 in. rain during the next two weeks and gave fairly good weed control, with Atriplex patula, Fumaria officinalis and Polygonum aviculare as the main survivors. Later, Anagallis arvensis became established on these plots, especially where the lower dose had been used. At 4 lb/ac some crop injury and kill of a few plants occurred, but neither stand nor yield was reduced by a significant amount. The applications just before emergence and at the loop and crook stages all gave excellent kills of Stellaria media, Trifolium repens, Thlaspi arvense, Capsella bursa-pastoris, Spergula arvensis and Anagallis arvensis, but some plants of Atriplex patula, Fumaria officinalis and Polygonum aviculare survived, especially at the lower dose. During the period following each of these applications measurable amounts of rain fell on most days and both doses at all three stages caused serious injury and significantly reduced crop stand. The plants which were not killed recovered, so that the depressions in yield were less than those in stand. The applications made at the 1-leaf and 2-leaf stages were followed by drier weather and had little visible effect on the crop with no depression of either stand or yield.

Tests during 1961 showed that although onions were very susceptible to pre-emergence applications of prometryne and linuron, the crop assumed some degree of tolerance to both herbicides after the 1-leaf stage. This was confirmed in an experiment begun in March, 1964. At the early 1-leaf stage, both stands and yields were reduced by doses of 0.5 and 1 lb/ac, but at the early 2-leaf stage only linuron 1 lb/ac caused any reduction. Desmetryne at 0.25 and 0.5 lb/ac was also included in this experiment, and again there was no adverse effect on stand or yield from application at the second stage of growth. Both applications were followed by only light rainfall but at the end of May and the beginning of June there was heavy rain. When the plots were examined in mid-June, slight injury was seen in plants which had received 1 lb/ac prometryne at the later stage and this injury was more marked on the corresponding linuron plots.

In a later experiment the rains occurred shortly after application and even at the 2-leaf stage 1 lb/ac linuron, prometryne and desmetryne all caused appreciable reductions in stand, most marked with linuron. Simetryne, however, caused much less injury and did not reduce stand at 1 lb/ac.

Prometryne, desmetryne, simetryne and linuron were compared with N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea in an experiment with White Lisbon onions sprayed at the 1-leaf stage on 13th July, 1964. The rainfall amounted to only 0.32 in. during the three weeks after spraying and 0.5 in. was applied as irrigation during this period. The results are shown in Table 4.

Table 4.

Effect of various post-emergence treatments on the stand and yield of White Lisbon onions, 1964

		Stand as % of control	Wt. as % of control
N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea	2 lb/ac	92	99
	4 "	84*	81*
Prometryne	0.5 "	108	102
"	1 "	45*	65*
Desmetryne	0.5 "	109	100
"	1 "	84*	80*
Simetryne	1 "	100	95
"	2 "	97	78*
Linuron	0.5 "	86	84
"	1 "	11*	10*

At the lower doses used, there were no significant reductions in crop stand or yield, although with linuron 0.5 lb/ac these approached significance at $P = 0.05$. The higher doses all reduced both stand and yield except for simetryne 2 lb/ac which did not reduce stand. Prometryne was rather more damaging than desmetryne and as in previous experiments, linuron caused more damage than prometryne at the same rates of application.

Two attempts were made in 1964 to control weeds chemically in onions by combinations of pre- and post-emergence treatments. Sets of plots received three different pre-emergence treatments and subsequently four post-emergence treatments were applied, to give twelve combinations as shown in Table 5.

Table 5

Effect of combined pre- and post-emergence treatments on onion stand, 1964

	Onion stand as % of control					
	Giant Zittau, sown 5.3.64			Giant Zittau, sown 14.4.64		
Post-emergence spray	pre-emergence spray			pre-emergence spray		
	A	B	C	A	B	C
N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea 3 lb/ac	36*	82	107	50*	44*	78*
Prometryne 1 lb/ac	16*	81	87	18*	5*	20*
Chlorpropham 1 lb/ac	31*	98	94	51*	70*	65*
Linuron 0.75 lb/ac	11*	60*	91	10*	5*	18*

A = chlorpropham 0.75 lb + diuron 0.15 lb/ac after sowing
B = N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea 3 lb/ac after sowing
C = diquat + paraquat just before crop emergence

None of the sprayed plots in these experiments was weeded, but hand-weeded control plots were included in the design.

In the first experiment, begun in early March, the pre-emergence sprays of residual herbicides were followed by heavy rain. On the plots which had received chlorpropham + diuron more than 60% of the onions failed to emerge, an effect attributable to the chlorpropham. Where N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea was applied pre-emergence there was slight crop damage, while the contact pre-emergence spray of diquat + paraquat had no adverse effect.

The post-emergence sprays were applied on 15th May at the early 2-leaf stage. During the following two weeks there was little rain and none of these sprays had any visible effect on the crop. At the end of May and the beginning of June, however, there was heavy rain and injury symptoms then began to appear on the plots which had received prometryne and linuron. These were especially severe with linuron, and on some plots a proportion of the crop was killed. Those plants not killed recovered, and when stand counts were made in mid-July (Table 5) there was a significant reduction where linuron had followed pre-emergence treatment B but not where it had followed C.

The main weed species in this experiment were Atriplex patula, Fumaria officinalis, Polygonum aviculare and some Thlaspi arvense and Stellaria media. Trifolium repens emerged later, after the contact pre-emergence treatment had been applied. Some weed species were killed by all the treatment combinations; others, as indicated in Table 6, survived particular combinations, depending on susceptibility and time of emergence. Taking into account both weed control and lack of crop damage, the best result was given by contact pre-emergence treatment followed by prometryne, where only a few plants of Polygonum aviculare remained.

Table 6.

Effect of combined pre- and post-emergence treatments on weeds, 1964

Post-emergence spray	Main surviving weed species					
	crop sown 5.3.64			crop sown 14.4.64		
	pre-emergence spray			pre-emergence spray		
	A	B	C	A	B	C
N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea 3 lb/ac	AFP	AFP	AFP	F	FP	CFPT
Prometryne 1 lb/ac	-	AP	P	P	P	PT
Chlorpropham 1 lb/ac	T	AFP	AFPT	CFT	FP	CFT
Linuron 0.75 lb/ac	F	FP	AFP	F	F	F

A = *Atriplex patula*, C = *Chenopodium album*, F = *Fumaria officinalis*, P = *Polygonum aviculare*, T = *Trifolium repens*

Pre-emergence treatments as in Table 5.

The second experiment was begun in mid-April at a time when there was rain on most days but not in large amounts. The pre-emergence treatments appeared to have no adverse effect on the crop and the post-emergence sprays were applied on 27th May at the early 2-leaf stage. During the next 10 days more than 2.5 in. rain fell and by the end of this time all the sprayed plots except those which received chlorpropham showed severe damage. Most of the plants on the plots which had post-emergence linuron and prometryne subsequently died, as did many of those treated with N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea. Chlorpropham had a progressive stunting effect on the crop and the stand was eventually reduced (Table 5). Hence, in this experiment there was a significant stand reduction on all the sprayed plots, and no combination of treatments could be considered satisfactory.

As in the previous experiment, different weeds survived the various treatments (Table 6). The cleanest plots were again those which received prometryne, where only a very few plants of *Polygonum aviculare* remained.

DISCUSSION

The experiments in 1963 with N'-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea showed that at a dose of 2 lb/ac excellent kill of several weed species could be obtained. In the first two experiments (Tables 1 and 2), there were only slight effects on the crop, with indications that the earlier the crop was sprayed the greater the injury. In the third experiment (Table 2) the lowest dose used, 2 lb/ac, caused severe damage when spraying at the early crook stage was followed by heavy rain. Similar results were obtained in 1964 (Table 3) when spraying at the loop and crook stages was followed by rain, and in this experiment there was also injury from treatments applied just prior to crop emergence. In the absence of appreciable rainfall, spraying at the 1-leaf stage had little effect on the crop (Tables 2 and 3), but when heavy rain fell, application of 3 lb/ac at the early 2-leaf stage significantly depressed stand (Table 5). It thus appears that if applied after the 1-leaf stage, and provided no uptake through the roots occurs, this herbicide can give selective control of a number of weed species in onions. On a light soil, however, there would seem to be a risk that crop damage might occur if heavy rain should follow spraying. At 2 lb/ac applied after sowing (Table 3) there was fairly good weed control and small seedlings of most species were well controlled. There may thus be a place for this herbicide as a follow-up after pre-emergence treatment with a contact herbicide, especially on heavier or more organic soils and where the relatively tolerant species Poa annua, Polygonum aviculare and Fumaria officinalis are not prominent.

Tests made in 1961 with pre-emergence applications of prometryne and linuron (Roberts & Wilson, 1964) showed that onions were susceptible and that linuron was more damaging than prometryne. Patterson (1962) has also reported that onions were killed after a pre-emergence spray of 0.5 lb/ac prometryne. Although it seemed worthwhile to examine the possibility of using these herbicides as post-emergence sprays, it was therefore not unexpected that damage might occur if conditions for root uptake were favourable. This took place with treatments made just before heavy rainfall (Table 5) and it is thought that this same rainfall was responsible for the injury observed in plants sprayed several weeks beforehand.

In the absence of root uptake, and provided that application was made after the 1-leaf stage, prometryne 1 lb/ac proved a successful treatment and gave the cleanest plots when used after a contact pre-emergence spray (Tables 5 and 6). Prometryne thus appears to show a foliar selectivity in onions, but in the absence of any high degree of inherent tolerance to the herbicide when taken up through the roots, treatment would not be safe on light soils. Prometryne, and also desmetryne (Table 4), might well be worth pursuing as post-emergence sprays for use on highly organic soils, especially when the main weeds present are susceptible species. Simetryne was appreciably less injurious than prometryne to onions, as noted in the pre-emergence tests of Scudder (1962) and Thompson (1962), but simetryne is also less effective against weeds. Linuron was consistently more injurious to onions than prometryne and at 0.75 lb/ac caused greater stand reductions than 1 lb/ac prometryne.

It is concluded that all the herbicides examined showed foliar selectivity in onions when applied after the 1-leaf stage, but that on this light soil damage can occur as a result of root uptake. There is a definite need for a herbicide which can be applied at this stage of growth after a pre-emergence treatment, and the possibility of using these herbicides on more organic soils remains to be determined. It may be that on light soils herbicides with little residual activity might offer more promise. One herbicide of this kind to which onions have been reported to show tolerance is ioxynil (Holly & Holroyd, 1963). Experiments at Wellesbourne have shown that if applied at 4 - 12 oz/ac after the 1-leaf stage, ioxynil caused only transient injury, with no adverse effect on stand or yield.

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References

CIBA LABORATORIES LIMITED (1963) Selective herbicide C. 3470. Data sheet.

HOLLY, K. & HOLROYD, J. (1963) 3,5-diiodo-4-hydroxybenzonitrile. A progress report on experimental work by the A.R.C. Weed Research Organisation May-October, 1963. W.R.O. tech. Rep. no. 2.

PATTERSON, T. M. (1962) Weed control in peas, carrots and onions. Proc. 15th N. Z. Weed Control Conf. 138-144.

ROBERTS, H. A. & WILSON, B. J. (1964) Experiments with pre-emergence treatments for weed control in carrots, parsley and parsnips. Proc. 7th Brit. Weed Control Conf.

SCUDDER, W. T. (1962) Response of several vegetable crops to 21 triazines on organic soil. Proc. 15th Southern Weed Conf. 112-113.

THOMPSON, A. (1962) Weed control in carrot, onion and brassica crops. Proc. 15th N. Z. Weed Control Conf. 145-151.

WOODFORD, E.K. & EVANS, S.A. (eds.) (1963) Weed Control Handbook. Oxford, Blackwell Scientific Publications.

TRIALS WITH HERBICIDES IN ONIONS GROWN FROM SEED AND SETS

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Summary In trials with herbicides on onions grown from sets PCA + BiPC applied pre-emergence gave highly promising results. Prometryne caused crop injury when used pre-emergence on onion sets but results suggest that this herbicide was promising for post-emergence application. In onions grown from seed PCA + BiPC gave satisfactory weed control with high crop tolerance when applied after sowing or immediately prior to crop emergence.

INTRODUCTION

Chlorpropham at 2 - 3 lb/ac has been widely accepted in Ireland for weed control in onion sets. Chlorpropham + diuron is also used to a lesser extent. Weed control with these herbicides is not always satisfactory because of the tolerance of Senecio vulgaris (groundsel), one of the most prevalent weeds in vegetable growing areas. The available residual herbicides for weed control in onions grown from seed are not entirely safe. This applies particularly to light sandy soils where the greater percentage of onions are grown in Ireland. The difficulty of handweeding onions and the decreased availability of labour has resulted in an urgent need for a residual herbicide with prolonged activity and high crop tolerance. A chemical even with short-lived activity but which could be applied at the loop or crook stage when onions are susceptible to herbicides such as sulphuric acid and sodium monochloroacetate would be of considerable value.

METHOD AND MATERIALS

Onions grown from sets

Each of the thirteen herbicide treatments in this trial was applied pre and post-emergence. Plot size was 6 x 16 ft and each plot was divided into sub-plots 6 x 8 ft. Treatments were applied pre-emergence to half of each plot and post-emergence to the other half. All treatments were replicated four times in a randomised block design. The herbicides used are shown in Table 1. The trial was sited on a loam soil with a clay percentage of 25.6 and an organic matter percentage of 3.9. All treatments were applied in a volume of 70 gal/ac with an Oxford Precision Sprayer.

The variety Rijnsburger was planted in shallow drills, 2 in. deep, and covered with soil on 11 April, 1964. Pre-emergence applications were carried out on 16 April, except 3.5-diiodo-4-hydroxybenzonitrile, which was applied on 25 April. Soil conditions were fine and damp at the time of spraying. Post-emergence treatments were applied on 16 May when the onions were 4 - 5 in high and the weeds were at the 2 - 4 rough leaf stage. After visual assessments of crop damage and weed control all plots were handweeded on 10 June. The weight of weeds removed from each plot was recorded.

The main weeds in the trial were Fumaria officinalis, Stellaria media, Senecio vulgaris, Chenopodium album, Veronica sp., Polygonum aviculare, and Poa annua.

Onions grown from seed

The herbicides used in this trial are shown in Table 2. Each treatment was replicated 4 times in a randomised block design. Plot size was 6 x 15 ft. Soil organic matter and clay percentage and method of spray application were the same as for onion sets. Seed was sown on 8 April, 1964 at a depth of approximately 1 in. in drills 18 in. apart. The pre-emergence treatments were applied on 14 April and the PCA + BiPC treatments prior to emergence on 25 April. The onions emerged on 27 April. Plots treated with chlorpropham 1.0 + diuron 0.25 lb/ac and dacthal at 7.5 and 11.25 lb/ac were abandoned because of poor weed control. Plots treated with N'-4-(p-methoxyphenoxy)-phenyl-NN-dimethylurea (C.3470) at 2, 3, 4 and 6 lb/ac were discarded because of severe crop injury as well as poor weed control. The untreated control plots became so overgrown with weeds that these were also abandoned. The weight of weeds removed from each of the remaining plots was recorded on the 11 June. Handweeded control plots were handweeded twice only. The PCA + BiPC formulation used on both onions grown from seed and sets was a mixture containing 25% PCA + 20% BiPC. In this paper doses of the mixture are referred to in terms of total active ingredient based on 56% PCA +44% BiPC. Doses of the other herbicides used are also given in lb/ac a.i.

RESULTS

Onions grown from sets

Pre-emergence treatment with chlorpropham at 3.0 lb/ac. gave good control of all weeds except Senecio vulgaris. Post-emergence application had no effect on Senecio vulgaris but Stellaria media and Fumaria officinalis were severely checked. No crop damage resulted from either pre- or post-emergence applications.

Pre-emergence treatment with chlorpropham 1.0 + diuron 0.25 lb/ac did not cause any injury to the crop but control of weeds, especially Senecio vulgaris and to a lesser extent Fumaria officinalis was poor. Post-emergence application caused severe leaf scorch and crop yield was significantly reduced in these plots compared with the handweeded control. Weed control was better than with pre-emergence application although Senecio vulgaris was still tolerant.

Linuron at 1.0 lb/ac both pre and post-emergence did not control Fumaria officinalis. This weed became very prevalent in these plots and reduced crop yield. With the exception of slight scorch in the month after spraying neither pre nor post-emergence application of linuron had any apparent adverse effect on the crop.

Linuron 1.0 + chlorpropham 1.0 lb/ac applied post-emergence gave a significant increase in yield over the handweeded control. The addition of chlorpropham greatly improved the control of Fumaria officinalis. The post-emergence treatment caused scorch and a growth check in the month after spraying but this was quickly outgrown. With pre-emergence application less damage occurred but weed control was inferior.

Table 1

Weed control in onions grown from sets
(mean of 4 replicates)

Treatment	Dose lb/ac	Wt. of weeds in tons/ac Pre	Wt. of weeds in tons/ac Post	No. of onions per 16 ft. Pre	No. of onions per 16 ft. Post	Assessments on crop Pre	Assessments on crop Post	Assessments on weeds Pre	Assessments on weeds Post	Yield + tons/ac Pre	Yield + tons/ac Post
1. Chlorpropham	3.0	11.53	8.70	60.3	63.7	8.5	9.0	7.5	4.0	11.66	10.24
2. " + diuron	1.0 0.25	0.67	2.50	62.3	46.0	9.5	5.8	3.8	5.7	11.59	7.12
3. Linuron	1.0	9.13	7.50	47.0	52.7	8.5	8.5	3.5	3.5	8.81	8.94
4. " + chlorpropham	1.0 1.0	4.43	2.30	62.7	81.7	8.2	5.7	6.3	8.2	13.45	15.53
5. Prometryne	1.5	3.53	0.57	58.3	62.7	7.5	8.2	8.8	8.8	12.18	12.83
6. "	3.0	1.70	0.33	39.0	55.7	2.5	6.0	9.2	9.0	8.17	13.77
7. PCA + BiPC	1.8	5.87	8.87	75.3	71.3	9.3	9.5	6.5	2.8	13.74	10.46
8. " "	3.6	1.87	6.10	77.3	70.0	8.8	9.4	9.2	4.7	15.36	11.27
9. * C.3470	2.0	12.53	9.10	51.3	52.7	9.5	9.5	2.0	2.3	6.72	8.20
10. "	4.0	7.67	6.07	65.7	65.7	9.2	9.2	4.0	4.2	11.71	10.77
11. 3,5-diiodo-hydroxybenzonitrile	0.5	11.30	9.57	57.0	47.3	9.5	8.3	2.3	3.2	7.19	7.90
12. "	1.0	9.73	6.93	56.7	53.3	10.0	8.5	1.7	4.0	8.64	7.56
13. "	1.5	8.43	6.90	64.7	48.3	8.7	7.7	4.2	4.7	11.41	8.22
14. Handweeding		0.00	0.00	61.0	56.7	10.0	10.0	10.0	10.0	10.87	11.07
15. Control (untreated)		19.07	14.73	48.3	50.0	10.0	10.0	0.	0.	4.79	4.86
Sig. Diff. P= 0.05		5.25		21.88						4.11	

* C.3470 = N^1-4-(p-methoxy-phenoxy)-phenyl-NN-dimethylurea.

\+ 3 replicates only

Rating scale : Weeds : 0(Dense cover of weeds) - 10 (No weeds)
Crop : 0(Complete kill) - 10 (No damage)

Table 2

Treatment	Doses lb/ac	Time of application
Chlorpropham	2.0	Six days after sowing
Chlorpropham + diuron	1.0 0.25	" " " "
Dacthal	7.5, 11.25, 15.0	" " " "
C 3470	2.0, 3.0, 4.0, 6.0	" " " "
PCA + BiPC	1.8, 2.7, 3.6	" " " "
PCA + BiPC	1.8, 2.7, 3.6	Two days prior to emergence

Table 3

Weed control in onions grown from seed
(mean of 4 replicates)

Treatment	Dose lb/ac	Wt. of Weeds tons/ac	No. of Onions harvested per 26 ft row	Yield tons/ac
Chlorpropham	2.0	15.81	247	4.25
Dacthal	15.0	13.62	224	3.71
PCA + BiPC	1.8	8.24	297	4.76
" "	2.7	5.98	219	8.19
" "	3.6	4.29	226	9.02
* PCA + BiPC	1.8	4.50	291	9.22
* " "	2.7	2.16	289	10.78
* " "	3.6	2.90	270	13.08
Handweeded Control		4.71	228	4.68
Sig. diff. P = 0.05		3.92	105	3.72

* Applied two days prior to emergence

Post-emergence treatment with prometryne was much more selective than pre-emergence and also gave better weed control. Veronica sp. were susceptible to post-emergence and Polygonum aviculare to pre-emergence treatments. Leaf scorch was apparent for about 4 - 6 weeks after all applications but where post-emergence treatment was used the damage was only temporary. Pre-emergence treatment with 3 lb/ac caused an obvious reduction in crop stand and surviving plants were severely scorched.

PCA + BiPC applied both pre and post-emergence at 1.8 and 3.6 lb/ac caused no crop damage and gave good control of a wide spectrum of weeds. Post-emergence applications were not as effective as pre-emergence applications. This was reflected in higher weed weights and lighter crop yields (Table 1). All weed species in the trial plots were susceptible to pre-emergence treatment at 3.6 lb/ac. Slight resistence was shown by Fumaria officinalis and Senecio vulgaris at 1.8 lb/ac. Stellaria media was the only species susceptible to post-emergence applications. Senecio vulgaris, Fumaria officinalis, Polygonum aviculare and Chenopodium album were severely checked but not completely killed.

Crop tolerance of C.3470 was good at 2 and 4 lb/ac both pre and post-emergence but control of weeds, particularly Fumaria officinalis and Polygonum aviculare was unsatisfactory irrespective of time of application.

3,5-diiodo-4-hydroxybenzonitrile at 0.5, 1.0 and 1.5 lb/ac. showed high crop selectivity but the range of weed control was narrow. Fumaria officinalis and Polygonum aviculare were very resistant; Stellaria media, Chenopodium album and Veronica sp. were fairly susceptible but control of these species was not complete even at the highest dose. Post-emergence treatments gave slightly better control than pre-emergence applications.

Onions grown from seed

In plots treated with chlorpropham at 2.0 lb/ac competition from Senecio vulgaris considerably reduced crop yield. This treatment gave good control of other weeds.

Crop tolerance to dacthal at 15 lb/ac was good but this treatment did not control Senecio vulgaris, or completely suppress Fumaria officinalis. Stellaria media and Chenopodium album were susceptible.

PCA + BiPC applied at 1.8, 2.7 and 3.6 lb/ac two days prior to emergence gave better weed control over a longer period than the same doses applied six days after sowing. The treatments applied prior to emergence caused a slightly more severe check to growth in the eight weeks after emergence than the treatments applied six days after sowing. Onions on all plots outgrew this early check and gave higher yields than handweeded control plots (Table 3). Compared with the handweeded controls a significant increase in yield was obtained from plots treated with PCA + BiPC 3.6 lb/ac applied six days after sowing and 1.8, 2.7 and 3.6 lb/ac applied prior to emergence. All weed species in the trial area were susceptible to a dose of 2.7 and 3.6 lb/ac applied two days prior to emergence. Treatment with 3.6 lb/ac six days after sowing and 1.8 lb/ac two days prior to emergence did not completely suppress Fumaria officinalis and Chenopodium album. These species and Senecio vulgaris were not completely controlled at 1.8 and 2.7 lb/ac six days after sowing.

DISCUSSION

The results of the trials reported in this paper suggest that PCA + BiPC is a promising mixture for pre-emergence use in onions grown from seed and sets. It has good crop selectivity and at 2.7 and 3.6 lb/ac controlled a wide range of weeds over a period of eight weeks. Observations made in other trials during the season indicated that the onion showed good tolerance to PCA and BiPC applied at the loop and crook stage. This result suggests that under similar conditions the repeated use of low doses of the mixture (around 1.5 - 2.5 lb/ac) applied pre and post-emergence as necessary may be a safe, economical and effective treatment in onions grown from seed.

Prometryne, linuron and linuron + chlorpropham show promise as post-emergence applications in onion sets. However, as these are the results of one year's work only, there is need for further trials on a range of soil types and under different climatic conditions before firm recommendations can be made.

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EXPERIMENTS ON THE CONTROL OF BROAD-LEAVED WEEDS IN PEAS. ~~A PROGRESS~~ REPORT 1963-64

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Summary The results of a series of trials carried out by the P.G.R.O. in 1963 and 1964 are reported, in which nine herbicides were assessed on a range of soil types.

Pre-emergence materials which showed promise were chloroxuron on the light soils and prometryne on the medium and heavy soils. These materials were capable of giving excellent weed control. The post-emergence application of dinoseb-acetate also proved to be of interest on account of its higher crop safety when compared to dinoseb-amine. This could be a useful alternative for those vining pea varieties which are susceptible to dinoseb-amine. Dinoseb in oil applied pre-emergence gave only moderate weed control but proved safe even on light soils. Linuron, on the other hand effectively controlled weeds but induced crop damage on light soils. The use of chlorpropham in mixtures with diuron, linuron or solan did not prove successful. Chlorpropham damage occurred at rates as low as 0.5 lb/ac and weed control was not always satisfactory.

INTRODUCTION

At the last British Weed Control Conference the results of two years work were reported in which fourteen herbicides were examined for the control of broad-leaved weeds in peas (King & Hancock, 1962). This series of experiments was continued in 1963 and 1964, and the present report deals with results obtained from eight main yield trials in which a further five herbicides were assessed together with four previously reported on. In addition to an untreated control plot dinoseb-amine applied post-emergence at 1.35 lb/ac was included each year as the standard herbicide used in the pea crop at present. The materials and rates used in these trials were taken from preliminary screening trials which contained approximately fourteen materials per year, each applied at varying doses using a logarithmic sprayer. The preliminary screening trials were laid down on at least three different soil types each year.

METHOD AND MATERIALS

In all trials applications were made with an Oxford Precision Sprayer using Allman '0' jets at a volume of 50 gal/ac. All doses referred to herein are active ingredient. Plot size in 1963 was 1/200th acre and in 1964 1/400th acre and four-fold replication was employed. The pre-emergence herbicides were applied when the peas had germinated, radicle and plumule being present in most cases, this being taken as a guide to the commencement of weed growth.

The post-emergence applications were made at a stage when it was considered that optimum conditions of weed growth had been reached at each site. Where weather conditions allowed, these applications were made when the weeds were still at the seedling stage.

At sites where a suitable weed pattern existed detailed weed counts were made and at seven sites pea emergence was also recorded by counts. Treatments were assessed visually for weed control and crop vigour and trials were taken to yields.

Chemicals used in the two seasons were as follows:-

Material	Formulation	1963	1964
chlorpropham plus diuron	20% wt./vol. combined emulsifiable 8% " concentrate	PR	-
chlorpropham plus linuron	8% " combined emulsifiable 8% " concentrate	-	PR
chlorpropham plus solan	20% " combined emulsifiable 20% " concentrate	-	PR
chloroxuron	50% wettable powder	PR	-
dinoseb in oil	9% as emulsifiable oil solution	-	PR
linuron	50% wettable powder	PR	-
prometryne	50% wettable powder	PR	PR
dinoseb-acetate	40% wettable powder	PO	PO
dinoseb-amine	18.5% wt./vol. alkanolamine salt	PO	PO

PR pre-emergence; PO post-emergence.

1963-1964 Site details

1963 Sites	A	B	C	D
Soil type	Very fine sandy loam	Fine sandy loam	Loamy very fine sand	Clay loam
Organic matter (%)	3.8	n.r.	1.8	2.9
Silt; Clay (%)	18; 13	20; 15	11; 21	18; 36
Date: drilled	23 March	24 April	22 March	26 March
pre-emerg.spray	1 April	2 May	3 April	4 April
pea emergence	14 April	7 May	10 April	18 April
post-emerg.spray	8 May	31 May	8 May	21 May
Harvested	Green	Green	Green	Dry
Rain: (in.)				
14 days before	1.13	0.75	n.r.	n.r.
14 days after pre-emerg.spray	1.61	1.07	"	"
1964 Sites	**E**	**F**	**G**	**H**
Soil type	Loamy fine sand	Silty clay loam	Peaty loam	Fine sandy loam
Organic matter (%)	2.6	2.6	17.8	2.2
Silt; Clay (%)	12; 14	30; 15	n.r.	18; 26
Date: drilled	2 March	14 April	9 March	12 March
pre-emerg.spray	23 March	22 April	7 April	1 April
pea emergence	28 March	26 April	10 April	5 April
post-emerg.spray	12 May	20 May	5 May	12 May
Harvested	Green	Green	Green	Green
Rain: (in.)				
7 days before	2.20	1.13	0.12	0.69
7 days after pre-emerg.spray	2.75	0.60	Nil	0.20

n.r. not recorded

Table 1

Percentage weed control at sites A, C and D - 1963

(Figures are based on five counts per plot, and expressed as the percentage control of the weed population on the untreated plots)

Material	lb/ac	Site	Annual nettle	Black bindweed	Chickweed	Cleavers	Fools parsley	Fumitory	Knotgrass	Mayweed	Shepherd's purse	Speedwell	Total weeds
			Predominant weed species										
chlorpropham plus diuron	1.0	A	–	73	97	0	–	–	82	100	–	90	84
	+0.4	C	100	100	100	–	–	77	99	100	100	96	96
	"	D	–	85	100	0	25	–	74	–	–	50	62
chloroxuron	4.5	A	–	91	100	72	–	–	91	86	–	95	92
	"	C	98	100	94	–	–	44	90	99	98	94	91
	"	D	–	71	74	75	0	–	48	–	–	64	47
linuron	1.0	A	–	91	100	28	–	–	91	100	–	99	93
	"	C	100	100	100	–	–	8	98	99	100	91	87
	1.25	D	–	86	96	0	39	–	69	–	–	32	62
prometryne	1.87	A	–	100	100	33	–	–	91	100	–	95	92
	"	C	100	100	100	–	–	100	100	100	100	96	99
	2.25	D	–	97	100	62	67	–	96	–	–	93	88
dinoseb-acetate	3.0	A	–	100	100	94	–	–	82	100	–	93	91
	"	C	94	100	100	–	–	99	62	90	100	98	91
	"	D	–	86	96	100	47	–	0	–	–	57	49
dinoseb-amine	1.85	A	–	100	100	88	–	–	82	44	–	91	88
	"	C	51	100	65	–	–	91	41	41	91	93	70
	"	D	–	94	96	88	33	–	28	–	–	86	63

Table 2

Percentage weed control at sites E, F and G - 1964

(Figures are based on three counts per plot at sites E and F, and on two counts at site G; they are expressed as the percentage control of the weed population on the untreated plots)

Material	lb/ac	Site	Annual nettle	Annual grasses	Black bindweed	Charlock	Chickweed	Fat hen	Knotgrass	Mayweed	Shepherd's purse	Speedwell	Total weeds
			Predominant weed species										
chlorpropham	0.5	E	92	–	–	–	–	–	48	100	–	73	83
plus linuron	+0.5	F	–	63	–	–	88	100	–	–	100	30	78
	"	G	–	–	0	100	43	8	–	–	–	10	38
chlorpropham	0.75	E	60	–	–	–	–	–	16	44	–	73	47
plus solan	+0.75	F	–	25	–	–	76	61	–	–	76	43	55
	"	G	–	–	0	80	52	0	–	–	–	20	11
dinoseb in oil	2.5	E	53	–	–	–	–	–	0	95	–	82	50
	"	F	–	47	–	–	46	76	–	–	83	0	46
	"	G	–	–	0	100	13	75	–	–	–	50	42
prometryne	1.5	E	99	–	–	–	–	–	91	100	–	90	98
	"	F	–	87	–	–	98	92	–	–	100	81	94
	"	G	–	–	87	100	96	42	–	–	–	50	82
dinoseb-acetate	2.4	E	83	–	–	–	–	–	66	35	–	55	55
	"	F	–	0	–	–	100	100	–	–	100	87	74
	"	G	–	–	n.r.	n.r.	n.r.	n.r.	–	–	–	n.r.	n.r.
dinoseb-amine	1.85	E	69	–	–	–	–	–	39	78	–	100	65
	"	F	–	0	–	–	95	100	–	–	100	94	74
	"	G	–	–	n.r.	n.r.	n.r.	n.r.	–	–	–	n.r.	n.r.

Table 3

Pea yields expressed as percentage of the untreated control - 1963

Material	lb/ac	Site A	Site B	Site C	Site D
chlorpropham plus diuron	1.0 +0.4	109	108	75	118
chloroxuron	4.5	112	93	96	100
linuron	0.75	-	98	-	-
"	1.0	121	-	83	-
"	1.25	-	-	-	100
prometryne	1.5	-	95	-	-
"	1.87	106	-	99	-
"	2.25	-	-	-	123
dinoseb-acetate	1.5	-	99	-	-
" "	3.0	113	-	87	97
dinoseb-amine	0.9	-	107	-	-
" "	1.85	107	-	95	104
S.E. per plot (% of mean)		17.6	9.4	24.5	n.a.

n.a. not analysed

Table 4

Pea yields expressed as percentage of the untreated control - 1964

Material	lb/ac	Site E	Site F	Site G	Site H
chlorpropham plus linuron	0.5 +0.5	125	93	128*	99
chlorpropham plus solan	0.75 +0.75	102	98	110	94
dinoseb in oil	2.5	110	103	115	100
prometryne	1.5	138	97	123*	101
dinoseb-acetate	2.4	123	108	118*	99
dinoseb-amine	1.85	124	121*	119*	96
S.E. per plot (% of mean)		20.4	9.5	8.9	4.1

* significant difference from untreated control at P = 0.05

RESULTS

1963

Site A - Very fine sandy loam.

Conditions were ideal for pre-emergence applications and all materials gave excellent weed control. However, on this free-draining soil, with over 1½ in. of rain in the fourteen days after applications, prometryne and to a lesser extent linuron caused chlorosis. This initial damage was soon outgrown and both treatments outyielded the control. Chloroxuron and chlorpropham plus diuron gave very good weed control without visible damage. The dinoseb-acetate, applied post-emergence, proved slightly more effective than dinoseb-amine, particularly in the control of Tripleurospermum maritimum ssp. inodorum (scentless mayweed), and this resulted in a higher yield than dinoseb-amine.

Site B - Fine sandy loam.

Pre-emergence applications were made on a very wet seedbed. As at the previous site crop damage resulted from the prometryne and linuron treatments, with the latter giving the more severe effect in this case. Chloroxuron gave almost complete weed control, but slight chlorosis was seen, and yield was slightly reduced. In the case of prometryne and linuron control of a low weed population did not compensate for initial crop damage. Chlorpropham plus diuron did not cause visible crop damage and yields were satisfactory. The temperature was high when the two post-emergence treatments were applied and the rates were reduced in consequence. This did not prove successful and very poor weed control was given by both materials.

Site C - Loamy very fine sand.

This site was on a light free-draining soil low in organic matter and the applications of linuron and prometryne caused appreciable chlorosis whilst chlorpropham plus diuron delayed emergence and stunted the crop. Weed control from the pre-emergence materials was generally good but apart from prometryne all the treatments reduced the yield below the untreated control. The yield from chlorpropham plus diuron was particularly low. Linuron gave virtually no control of Fumaria officinalis (fumitory) and the control from chloroxuron was only moderate. The dinoseb-acetate and dinoseb-amine treatments failed to increase the yields in spite of satisfactory weed control. At this site dinoseb-acetate gave a better control of scentless mayweed and Polygonum aviculare (knotgrass) than dinoseb-amine.

Site D - Clay loam.

The soil was rather cloddy but moist when the pre-emergence sprays were applied. On this heavy soil no crop damage was recorded and weed control, except with prometryne, was moderate. Chlorpropham plus diuron and linuron failed to control Galium aparine (cleavers) and none of the pre- or post-emergence treatments, again with the exception of prometryne, satisfactorily controlled Aethusa cynapium (fools parsley). The value of the trial was reduced by a heavy infestation of Avena fatua (wild oat) which seriously affected yields and prevented the harvest of two of the four replicates. The only materials to control this weed were prometryne, and chlorpropham plus diuron, both of which increased the yield over the untreated control by approximately 20%.

The post-emergence applications were made when the weeds were past the seedling stage and weed control was only moderately successful. This illustrated the need to apply contact herbicides at an early stage of weed development, particularly with more resistant weeds such as knotgrass.

1964

Site E - Loamy fine sand.

Heavy rain fell the day after the pre-emergence applications had been made and both chlorpropham mixtures caused delayed emergence, basal branching and stunting. The effects were outgrown later but chlorpropham plus solan gave only slightly higher yields than the control. Chlorpropham plus linuron, which gave a better weed control, substantially increased yields. There was no visual crop damage from dinoseb in oil but weed control was only moderate. This material, together with chlorpropham plus solan failed to give adequate control of knotgrass. Weed control by prometryne was excellent and produced the highest yield at this site, outyielding dinoseb-amine.

As at Site D in 1963 the weeds had passed the optimum stage for spraying when the post-emergence treatments were applied and once again weed control was poor. Dinoseb-acetate failed to control scentless mayweed and Veronica sp. (speedwell). Although dinoseb-amine controlled both these weeds it did not control knotgrass to the same degree as the dinoseb-acetate. In spite of this both treatments increased yields over the control.

Site F - Fine sandy loam.

Pre-emergence applications were made on a seedbed still wet from rain the previous day and there was also rain after the applications. Very little crop damage was noted, there being slight chlorosis from prometryne which was only transitory. This treatment gave excellent weed control, as did chlorpropham plus linuron, but yields from both were below the untreated control. There may well have been more effect on the crop from these treatments than was apparent. Chlorpropham plus solan and dinoseb in oil failed to give 'commercial' control at this site. The applications of dinoseb-acetate and dinoseb-amine resulted in adequate control of the predominant weeds and increased yields. The increase from dinoseb-amine reached a significant level.

Site G - Peaty loam.

The weed population was low, the dominant species being Sinapis arvensis (charlock). The increases in yield resulting from the pre-emergence treatments were directly related to the control of this weed. (see Tables 2 and 4). Weeds which were inadequately controlled by the chlorpropham mixtures were Chenopodium album (fat hen), Veronica sp. (speedwell) and Polygonum convolvulus (black bindweed). Dinoseb in oil also failed to control black bindweed. The post-emergence applications produced very useful control and both significantly increased yields.

Site H - Fine sandy loam.

Virtually no weed growth took place at this site and weed assessment and counts could not be made. The pre-emergence materials did not cause crop damage and there were no significant reductions in yield. The post-emergence applications were made in an effort to discover possible effects on the crop in the absence of weed competition, but again there were no significant yield reductions.

The effect on plant populations.

None of the pre-emergence treatments caused significant reductions in plant numbers in either year.

The effect on crop maturity.

The treatments did not materially affect maturity, as measured by the tenderometer, in either year.

DISCUSSION

The results closely follow the trends reported in the previous paper (King & Hancock 1962). The relatively insoluble material chloroxuron achieved excellent weed control on light non-retentive soils and had a high degree of crop safety. Control on heavy soils was not good. It is unfortunate that the high cost of this treatment makes it uneconomic in the pea crop, as it could otherwise be a valuable material for use on light free-draining soils low in humus and clay. On the heavier soils, possibly including the less organic peats, the most promising material in these trials was the more soluble prometryne. This material gave outstanding weed control on a wide range of soil types. The material does not appear, however, to possess sufficient selectivity on the free-draining soils particularly when applied under moist conditions. Initial chlorosis was noted in these instances although it was soon outgrown and yields were rarely affected. The cost of prometryne is likely to be higher than the post-emergence application of dinoseb-amine, but its ability to control weeds which are resistant, or moderately resistant, to dinoseb-amine may justify its use.

The selectivity of linuron was suspect on light soils and in 1964 the material was tested in mixture with chlorpropham at relatively low rates. It was hoped that this would prevent crop damage and also widen the range of weeds controlled. This was only partially achieved, there being no signs of linuron damage but quite appreciable chlorpropham damage occurred on a light soil under wet conditions. It is too early to say whether this mixture will be suitable for use in peas.

The mixture of chlorpropham and solan used in 1964 proved less efficient than that containing linuron and whilst chlorpropham plus diuron gave useful control on the lighter soils it was relatively ineffective on a clay loam. This series of trials has illustrated the effect on peas of applying chlorpropham on non-retentive soils. Rates as low as 0.5 lb/ac have caused quite appreciable damage and this raises doubts as to the reliability of the material in the crop, in relation to soil and weather conditions.

Tested at four sites in 1964, dinoseb in oil proved only moderately successful. Weed control was not good but there was no crop damage and yields were generally increased. The material does not possess long residual activity and it is likely to be less active on soils containing more clay than those reported herein.

The post-emergence application of dinoseb-acetate was worthy of note. Used at 3.0 lb/ac in 1963 it was slightly more effective than the normal rate of dinoseb-amine. The reduced rate used in 1964 did not, however, give comparable weed control to dinoseb-amine. The material's main attribute is its lower crop toxicity and this could prove useful particularly for the more tender vining pea varieties. More work is required on the influence of climatic conditions and stage of growth.

Dinoseb-amine applied post-emergence again provided the most consistent results. For maximum weed control the material should be applied when the weeds are still at the seedling stage, particularly when the more resistant weed species are present.

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References

KING, J.M. & HANCOCK, D.H. (1962) Experiments on the control of broad-leaved weeds in peas - a progress report 1961-62. Proc. 6th Brit. Weed Control Conf., 491-505.

CONTROL OF WILD OATS (AVENA FATUA) IN PEAS - A PROGRESS REPORT 1963-64

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Summary Trials undertaken in 1963 and 1964 are reported, this being a continuation of work carried out since 1954. The purpose of this latest series of trials has been to evaluate the newer material tri-allate, in comparison with those herbicides which have already been recommended. Results obtained indicate that pre-sowing applications of tri-allate are superior to the treatments previously recommended.

INTRODUCTION

Work on the control of wild oats in the pea crop has been carried out by the Pea Growing Research Organisation since 1954, that which took place up to 1962 having been reported at previous Weed Control Conferences (see references).

A booklet setting out practical recommendations was issued by the P.G.R.O. in January 1963; barban, di-allate, propham and TCA were the materials suggested and indications were given as to which should be used according to conditions imposed by soil type, likely wild oat density, the type of pea crop and the date of sowing.

The following studies have been made in the last two seasons:-

1. 1963. Trials to compare tri-allate with the four materials already recommended.

2. 1963. Trials to determine the susceptibility of crops treated with wild oat herbicides pre-sowing to subsequent treatments with (a) barban, (b) dinoseb-amine and (c) both barban and dinoseb-amine.

3. 1964. Strip trials with tri-allate to further assess the efficiency of the material in a range of conditions and to obtain the reaction of growers.

Part 1

METHOD AND MATERIALS

At four centres replicated trials were carried out to compare di-allate and tri-allate, both applied pre-sowing and post-sowing at 1.5 lb a.i./ac, propham at 3 lb a.i./ac and TCA at 7.0 lb a.i./ac pre-sowing and barban at 0.5 lb a.i./ac post-emergence. Barban was applied in 20 gal/ac and the remainder in 50 gal/ac by O.P.S. in this and in all 1963 trials reported herein.

Soil types and varieties on which trials were carried out included peaty loam (Big Ben), silty loam (Minerva), silty clay loam (Harrison's Glory) and clay loam (Atlanta).

RESULTS

Table 1

Treatments	Means of four centres			Yield at clay loam centre	
	Pea stand per yd^2	% Kill wild oats	% Wild oat panicle reduction	cwt/ac	Yield as % control
Di-allate pre-sowing	39	80	63	27.6	155
Di-allate post-sowing	38	64	55	26.5	149
Tri-allate pre-sowing	41	87	76	29.1	164
Tri-allate post-sowing	39	68	68	25.9	146
Propham pre-sowing	39	72	58	22.5	143
TCA pre-sowing	39	70	61	25.5	143
Barban post-emergence	-	-	59	20.5	115
Untreated control	39	-	-	17.8	100
	Level of significance			1.0%	
	Sig. diff. P = 0.05			5.1	
	C. of V.			14.3%	

Pre-sowing applications of di-allate and tri-allate gave excellent control at all centres and significantly increased yields at the clay loam centre. Post-drilling applications of these materials gave poorer control and yield was lower than when treatments were carried out pre-sowing.

Propham gave satisfactory control except at the peaty loam centre.

TCA treatments resulted in crop damage at all centres and in some cases this was evident for some considerable time.

The post-emergence application of barban checked wild oat development and caused little crop damage. Control with this material was excellent at the peaty loam centre, where wild oat growth and development was excessive.

Taint tests were carried out at Chipping Campden on the canned produce from the clay loam centre and no taints were detected in any of the samples.

Part 2

Trial A

METHOD AND MATERIALS

In a replicated trial, TCA was applied at 7.0 lb a.i./ac, tri-allate at 1.5 lb a.i./ac, di-allate at 1.5 lb a.i./ac, all pre-sowing, and barban at 0.5 lb a.i./ac was applied post-emergence.

Half plots of each treatment were subsequently treated with dinoseb-amine at 1.4 lb a.i./ac.

Thomas Laxton peas were used in this work, being a variety susceptible to damage from dinoseb-amine, and the whole trial was kept hand weeded.

RESULTS

Table 2

Treatments	Pre-dinoseb scorings*	Post dinoseb scorings*	Yield ≠ cwt/ac	Yield as % untreated control
TCA	8.1	8.0	16.5	62
TCA, dinoseb-amine	8.1	7.2	11.4	43
Tri-allate	9.4	9.9	27.1	101
Tri-allate, dinoseb-amine	9.4	9.4	26.4	99
Di-allate	8.5	8.8	21.8	81
Di-allate, dinoseb-amine	8.5	8.0	19.6	73
Barban	8.9	9.6	25.5	95
Barban, dinoseb-amine	8.9	9.4	24.4	91
Untreated control	10.0	10.0	26.8	100
Control, dinoseb-amine	10.0	9.6	24.9	93
		Level of significance	0.1%	
		Sig. diff. P = 0.05	3.9	
		C. of V.	12.0%	

* Scorings for effects of treatment on crop:-

0 = complete kill 7.5 = appreciable damage
5 = severe damage 10.0 = no apparent damage

≠ Yields are means of four replicates.

The application and incorporation of the pre-sowing treatments the day before drilling tended to emphasize crop damage. This was particularly noticeable with TCA, which caused severe loss of bloom and bunching. Di-allate and tri-allate both caused slight leaf wrinkle on individual plants, but this was less marked with the latter. The post-emergence barban treatment had little effect on the crop except for slight chlorosis.

The application of dinoseb-amine after wild oat herbicides resulted in depressions of yield proportional to the amount of damage already present at the time of dinoseb application. Thus the greatest reduction was after TCA, followed to a lessening degree by di-allate, barban and tri-allate.

Trial B

METHOD AND MATERIALS

In a replicated trial TCA at 7 lb a.i./ac, tri-allate at 1.5 lb a.i./ac, di-allate at 1.5 lb a.i./ac and propham at 3.0 lb a.i./ac were applied pre-sowing.

Half plots of each treatment were subsequently treated with barban at 0.5 lb a.i./ac when the peas were 1½ in. in height, and the whole trial was treated with dinoseb-amine at 1.4 lb a.i./ac eleven days after the application of barban. The variety Thomas Laxton was used in this trial, which was kept weed free by hand.

RESULTS

Table 3

Treatments	Pre-dinoseb scorings*	Post-dinoseb scorings*	Yield ≠ cwt/ac	Yield as % control ø
TCA, dinoseb-amine	8.2	7.6	14.0	52
TCA, barban, dinoseb-amine	7.5	7.6	12.3	46
Propham, dinoseb-amine	9.6	9.4	25.5	94
Propham, barban, dinoseb-amine	9.1	9.0	23.7	88
Tri-allate, dinoseb-amine	9.7	9.5	26.8	99
Tri-allate, barban, dinoseb-amine	9.1	9.3	26.9	100
Di-allate, dinoseb-amine	8.6	8.5	26.2	97
Di-allate, barban, dinoseb-amine	8.2	8.0	24.4	90
Control, dinoseb-amine ø	10.0	9.6	27.0	100
Control, barban, dinoseb-amine	9.4	9.4	26.4	98
	Level of significance		0.1%	
	Sig. diff. P = 0.05		5.7	
	C. of V.		17.0%	

* Scorings for effects of treatments on crop:-
0 = complete kill — 7.5 = appreciable damage
5 = severe damage — 10.0 = no apparent damage

≠ Yields are means of four replications.

The effect of applying barban after previous treatments with wild oat herbicides followed a similar trend to that given in Trial A when dinoseb-amine was used. The greatest reduction in yield was caused by barban after TCA, propham and di-allate, in that order, while the adverse effect after tri-allate was negligible. The application of dinoseb-amine at 1.4 lb a.i./ac after these dual treatments was found to be practicable, without undue yield reduction.

It should be remembered that both trials were hand weeded, thus eliminating weed competition and that in practice most of the yield reductions caused by treatments would be compensated for by the weed control achieved.

Part 3

Strip trials A to H

METHOD AND MATERIALS

Eight farmers kindly co-operated in these tests by applying tri-allate pre-sowing at 1.25 lb a.i./ac, to one acre strips of peas, on a range of soil types; plant counts and other observations were subsequently made.

RESULTS

(see Table 4)

Pea counts at each site revealed that no undue loss of plants resulted from this treatment; no form of damage was observed during growth, but excellent control of wild oats was achieved.

The results at site B emphasise the considerable reduction in the efficiency of this treatment which occurs when it is not followed by immediate and thorough incorporation.

DISCUSSION

Tri-allate gave control of wild oats which was superior to that given by di-allate, propham and TCA on the peaty loam, silty loam and clay loam soils in 1963. Tri-allate, di-allate and propham resulted in negligible crop damage, while TCA produced damage at all centres. Barban gave the best reduction of wild oat panicles on the peaty loam, where wild oat population was high and where pre-sowing chemicals were less effective.

In the susceptibility trials, tri-allate again proved to be the least damaging of the materials and it did not appear to increase the susceptibility of the crop to dinoseb-amine.

Useful results were obtained from the strip trials with tri-allate and farmer reaction was generally very favourable.

Tri-allate would appear to be the most effective herbicide for wild oat control on all soil types and at the same time seems the least likely to cause crop damage. No pre-sowing chemical, however, appears to give consistent results on very peaty soils.

There is still a strong case for the use of propham on light soils where wild oat populations are not likely to be too excessive, and where the additional control of broad-leaved weeds, particularly knotgrass, which this material offers often makes further weed control unnecessary.

Pre-sowing treatments are to be preferred for the control of wild oats in peas; the post-emergence application of barban should be contemplated only when high populations of wild oats appear unexpectedly or where a pre-sowing treatment has given completely inadequate control.

Table 4

Site	Soil Type and Organic matter. %	Volume used. Interval between spraying and drilling.	Intensity of cultivations after spraying.	% Wild oat control and W.O. population sq. yd.	Remarks
A	Clay loam 2.6	60 gal/ac 1 day	Heavy to depth 4 in.	99.4 164 sq yd	Excellent control. In spite of heavy population at this site, hand weeding of remaining wild oats on treated strip when in ear would have been practical.
B	Organic silty clay loam 8.4	25 gal/ac 4 days	Nil, except for harrows behind drill	17.5 10 sq yd	Lack of cultivations after application should mainly account for poor control.
C	Silty clay loam 3.2	20 gal/ac 3 days	Medium to depth 4 in.	87.3 8 sq yd	Wild oats very patchy, and control not too impressive when wild oats in ear.
D	Organic silty loam 7.6	20 gal/ac 23 days	Medium to depth 4 in.	78.3 4 sq yd	Control good in spite of long delay between application and drilling.
E	Peaty loam 15.6	25-30 gal/ac 5 days	Heavy to depth 3-4 in.	68.2 28 sq yd	Control not impressive possibly due to high organic content.
F	Clay loam 2.9	20 gal/ac 5 days	Medium to depth 3 in.	-	Remainder of field treated propham and no untreated area left. Superior control by tri-allate over propham.
G	Sandy clay loam 2.9	20 gal/ac 5 days	Medium to depth 3 in.	90-95 10-20 sq yd (Visual assessment)	Control very impressive when oats in ear.
H	Silty loam	20 gal/ac 6 days	Heavy to depth 3 in.	79.3 7 sq yd	Wild oats very patchy and counts difficult. Control on sprayed strip seen to be excellent when wild oats in ear.

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References

ARMSBY, W.A. & GANE, A.J. (1962) Control of wild oats in peas: progress report 1961-62. Proc. 6th Brit. Weed Control Conf., 329-343.

ARMSBY, W.A. & GANE, A.J. (1963) The control of wild oats in peas. P.G.R.O. Adv. Bull.

ARMSBY, W.A. & REYNOLDS, J.D. (1960) Experiments on the control of wild oats in peas: progress report 1959-60. Proc. 5th Brit. Weed Control Conf., 521-530.

GREGORY, P., REYNOLDS, J.D. & PROCTOR, J.M. (1955) Preliminary experiments on chemical control of wild oats in peas. Proc. 2nd Brit. Weed Control Conf., 177-184.

HOLMES, H.M., GREGORY, P. & PROCTOR, J.M. (1957) Experiments with TCA for the control of wild oats in peas: progress report 1955. Proc. 3rd Brit. Weed Control Conf., 65-63.

PROCTOR, J.M. & ARMSBY, W.A. (1957) Further experiments on the control of wild oats in peas: progress report 1956. Proc. 3rd Brit. Weed Control Conf., 69-78.

TRIALS WITH HERBICIDES IN FRENCH BEANS

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Summary Eight herbicides were compared as pre-emergence treatments on French beans at three sites. Three chemicals, monolinuron linuron + monolinuron and N-(p-bromophenyl)- N^1- methyl - N^1- methoxyurea showed considerable promise because of high crop tolerance and wide range of weed control. Linuron, linuron + chlorpropham and prometryne also gave good results. In general these herbicides were superior to dinoseb (amine and ammonium formulations) except at one centre.

INTRODUCTION

In Ireland the pre-emergence application of dinoseb amine (Roberts, 1959) has become accepted for weed control in French beans. This treatment has usually a short residual effect, entailing the need for one or two handweedings before harvesting. With the introduction of mechanical harvesting, the need for satisfactory prolonged weed control is becoming increasingly important. A comparison of five makes of French bean harvester in 1964 showed that the presence of weeds at harvest time impaired the efficiency of all machines by as much as 50% (Downes 1964). Preliminary trials in 1963 (Cassidy 1964, Thomas 1964) indicated that linuron, linuron + chlorpropham and prometryne were herbicides worthy of further investigation in this crop.

METHOD AND MATERIALS

Experiments were conducted at three different sites, one being at the Research Station, Kinsealy and the others in Co. Carlow and Co. Laois. Twenty treatments, each replicated four times, were applied to plots 2 yd x 5 yd in a randomised block layout. The herbicides tested are shown in Table 3. All herbicides were applied pre-emergence in 70 gal/ac with an Oxford Precision Sprayer. Visual assessments of treatment effect on crop and weeds were made during the season (Table 3). A plant and weed count was taken at Kinsealy (Table 4). Site details, rainfall and dates of application are given in Table 1. No cultivation or handweeding was carried out at any site except on handweeded control plots. To simulate mechanical harvesting, plots at Sites B and C were harvested once only. Two pickings were carried out at Site A.

RESULTS

Site A

Monolinuron gave excellent weed control at doses of 1.5 lb and 3 lb/ac. No crop damage was apparent at the lower dose; at 3 lb/ac slight temporary growth check occurred but this had no effect on final yield. Excellent weed control was also obtained with N-(p-bromophenyl)- N^1-methyl - N^1-methoxyurea (C3126) at 3 lb and 4 lb/ac. At the lowest dose used (2 lb/ac) weed control was only slightly inferior, Fumaria officinalis and Veronica sp not being completely controlled. No crop damage was apparent at 2 lb and 3 lb/ac and only slight initial reduction in vigour occurred at 4 lb/ac. That this was only of a temporary nature is reflected in the high yields obtained with this treatment (Table 5). Monolinuron + linuron also gave very promising results.

Table 1

Site Details

	SITE A Kinsealy, Co. Dublin	SITE B Sugar Co. Farm Carlow	SITE C Ballickmoyler Co. Laois.
Soil Type	Loam	Silty Loam	Silty Loam
Organic Matter (per cent)	3.9	1.7	1.2
* Clay (per cent)	25.6	9.0	21.1
Variety	Elsom's 839	Processor	Harvester
Seed bed conditions	Dry : fine	Dry:fairly fine	Damp:cloddy
Date of drilling	15th June	8th June	5th June
Date of spraying	18th June	11th June	10th June
Rainfall in inches			
14 days before spraying	1.44	2.18	-
14 days after spraying	0.16	.88	-
28 days after spraying	0.7	1.24	-

* Particle size of clay $<$ .002 mm.

Table 2

Most prevalent weeds at different sites

SITE A	SITE B	SITE C
Capsella bursa-pastoris	Senecio vulgaris	Polygonum persicaria
Poa Annua	Lamium purpureum	Poa annua
Stellaria media	Fumaria officinalis	Stellaria media
Fumaria officinalis	Veronica sp.	Polygonum aviculare
Polygonum aviculare	Chenopodium album	Agropyron repens
Veronica sp.		

Weed control at 1.5 lb + 0.5 lb/ac was equal to that obtained with monolinuron at 3 lb/ac and N-(p-bromophenyl)- N^1-methyl- N^1-methoxyurea (C3126) at 3 lb/ac. The mixture caused a slight check to growth but this was quickly outgrown as indicated by the high yields obtained. At the lower dose of 0.75 lb + 0.25 lb/ac, weed control was good but Fumaria officinalis was not completely suppressed. More weeds tended to become established in these plots towards harvest.

Linuron at 0.75 lb and 1 lb/ac caused no crop damage and gave good weed control of all species present except Fumaria officinalis. Slight veinal chlorosis of the lower leaves was evident where a dose of 1.5 lb/ac was used alone and in combination with 1 lb chlorpropham. The addition of chlorpropham to all doses of linuron resulted in improved control of Fumaria officinalis and Polygonum aviculare. Prometryne at 1 lb/ac gave fair weed control and no crop damage. At higher doses, weed control was satisfactory but veinal chlorosis occurred. This damage was particularly evident where a dose of 2 lb/ac was used, but crop yield was not reduced. Dinoseb-amine and dinoseb-ammonium gave relatively poor control, weeds becoming established in these plots three to four weeks after spraying. These treatments gave the lowest yields in the trial, except for the untreated control plots. Three handweedings were given to the handweeded controls at this site.

Site B

Excellent weed control was given by all treatments. All chemicals caused initial crop check in varying degrees, but this was soon outgrown and there was no significant reduction in yield. During the month after emergence most severe check was caused by prometryne, 2 lb/ac, N-(p-bromophenyl)-N^1-methyl-N^1-methoxyurea (C3126) 4 lb and linuron 1.5 lb + chlorpropham 1 lb. Prometryne 1 lb, linuron 0.75 lb, monolinuron + linuron 0.75 lb + 0.25 lb and 1.5 lb + 0.5 lb/ac both formulations of dinoseb and monolinuron 1.5 lb, caused least check. Other treatments were intermediate in their effect on the crop. At this site handweeded controls were weeded once only, eight weeks after sowing. By this time a severe weed problem had developed which accounts for the relatively low yields obtained. Weed control with dinoseb (amine and ammonium) was much better than at Site A. Crop growth was exceptionally strong at Site B due to high soil fertility and to the vigorous nature of the variety Processor. The initial weed control provided by both formulations of dinoseb, coupled with the smothering effect of the crop, resulted in season-long weed control.

Site C

Crop emergence was irregular, due to cloddy seed-bed conditions and uneven sowing. All treatments gave good control of weeds except Agropyron repens (couch), which was prevalent throughout the experimental area. Prometryne at 1.5 lb. and 2 lb/ac caused a check to crop growth and veinal chlorosis for about a month after emergence. The crop made good recovery and yield was not reduced. Weed control and crop yield in plots treated with linuron + chlorpropham were better than in plots treated with linuron alone, but differences were not significant. Results with monolinuron, N-(p-bromophenyl)-N^1- methyl-N^1-methoxyurea (C3126) and monolinuron + linuron were similar to those obtained at Site A. Plots treated with monolinuron 1.5 lb and N-(p-bromophenyl)-N^1-methyl-N^1-methoxyurea (C3126) 3 lb/ac were outstanding, both for complete freedom from weeds and excellent crop vigour. Weed

Table 3

Assessments on crop and weeds
(mean of 4 replicates)

Treatment	Dose lb/ac	SITE A 7th July Crop	SITE A 7th July Weeds	SITE A 20th July Crop	SITE A 20th July Weeds	SITE A 22nd August Crop	SITE A 22nd August Weeds	SITE B 3rd July Crop	SITE B 3rd July Weeds	SITE C 2nd July Crop	SITE C 2nd July Weeds
1. Linuron	0.75	9.5	9.1	9.4	7.8	9.9	7.4	9.4	9.9	9.3	9.9
2. "	1.0	9.6	8.7	9.5	8.6	9.8	7.1	8.3	9.9	9.0	9.9
3. "	1.5	9.1	8.9	8.8	9.3	9.6	8.4	8.6	10.0	8.8	9.9
4. Linuron + chlorpropham	0.75 1.0	9.5	9.3	9.4	9.1	9.9	7.5	8.3	10.0	8.6	10.0
5. Linuron + chlorpropham	1.0 1.0	9.5	9.4	9.1	9.2	9.3	8.3	8.4	10.0	8.6	10.0
6. Linuron + chlorpropham	1.5 1.0	9.5	9.7	9.5	9.6	9.1	8.9	7.6	10.0	8.4	10.0
7. Prometryne	1.0	8.7	8.7	9.5	7.0	9.8	5.3	9.8	10.0	9.5	9.9
8. "	1.5	9.5	9.0	9.4	8.4	9.8	7.8	8.0	10.0	6.5	10.0
9. "	2.0	9.4	9.2	8.6	9.6	9.4	8.2	6.5	10.0	6.3	9.9
10. * C3126	2.0	9.3	9.3	9.3	9.4	9.6	8.5	8.6	10.0	8.6	10.0
11. "	3.0	9.0	9.4	9.5	9.6	9.5	9.0	8.6	10.0	9.0	10.0
12. "	4.0	9.6	9.8	8.9	9.8	9.3	9.8	7.6	10.0	8.0	10.0
13. Monolinuron	1.5	9.4	9.3	9.1	9.1	9.3	9.1	9.0	10.0	9.5	10.0
14. "	3.0	9.3	9.4	8.8	9.8	8.9	9.8	8.1	10.0	-	-
15. Monolinuron + linuron	0.75 0.25	9.5	8.5	9.3	8.5	9.5	7.9	9.3	9.9	-	-
16. Monolinuron + linuron	1.5 0.5	9.6	9.7	9.5	9.6	9.4	9.4	9.1	10.0	9.3	10.0
17. Dinoseb-ammonium	4.0	9.1	7.6	9.3	6.1	9.4	5.3	9.1	10.0	8.8	10.0
18. Dinoseb-amine	4.0	9.4	6.5	9.6	5.6	9.6	5.0	9.3	10.0	9.4	10.0
19. Handweeding		9.8	2.4	10.0	10.0	10.0	10.0	10.0	0	10.0	0
20. Control		10.0	3.4	10.0	0	10.0	0	10.0	0	10.0	0
Sig. Diff. P = 0.05		.56	.87	.90	1.1	.51	1.3	.99	.06	1.66	0.14

* N(p-bromophenyl)-N^1-methyl-N^1-methoxyurea.

Rating Scale : Weeds : 0 (Dense cover of weeds)-10(no weeds)

Crop : 0 (Complete kill) - 10(no damage)

Table 4

Treatment effects on bean and weed populations

Site A (25 Aug.)

(mean of 4 replicates)

Treatments	Dose lb/ac	Weeds per 4 ft^2 Fumitory	Chickweed	Knotgrass	Annual meadowgrass	Shepherd's purse	Total	No. of Bean Plants/30ft row
1. Linuron	0.75	6.0	2.8	0.5	1.3	0.0	10.5	114
2. "	1.0	4.0	2.3	0.3	0.0	0.3	6.8	115
3. "	1.5	3.3	1.0	0.0	0.8	0.0	5.0	117
4. Linuron+ chlorpropham	0.75 1.0	5.0	0.8	0.0	0.3	0.0	6.0	110
5. Linuron + chlorpropham	1.0 1.0	2.3	3.3	0.0	0.3	0.0	5.8	109
6. Linuron + chlorpropham	1.5 1.0	2.8	1.3	0.0	0.0	0.0	4.0	110
7. Prometryne	1.0	2.3	1.0	0.8	2.3	1.5	7.8	106
8. "	1.5	1.8	1.5	0.8	1.0	0.0	5.0	129
9. "	2.0	1.5	0.0	0.3	1.3	1.0	4.0	95
10. * C3126	2.0	1.8	3.0	0.3	0.0	0.0	5.0	121
11. "	3.0	1.8	2.3	0.3	0.0	0.0	4.3	101
12. "	4.0	1.5	1.3	0.0	0.0	0.0	2.0	124
13. Monolinuron	1.5	2.3	3.3	1.0	0.3	0.0	6.8	109
14. "	3.0	0.0	2.0	0.0	0.0	0.0	2.0	116
15. Monolinuron + linuron	0.75 0.25	2.3	3.3	0.3	0.5	0.0	6.3	102
16. Monolinuron + linuron	1.5 0.5	0.8	1.0	0.3	1.0	0.0	3.0	106
17. Dinoseb-ammonium	4.0	2.0	3.0	1.3	4.5	0.3	11.0	111
18. Dinoseb-amine	4.0	4.5	3.8	1.0	1.5	1.3	12.0	109
19. Handweeding		1.3	1.8	0.8	1.8	2.8	8.3	108
20. Control (untreated)		1.8	2.3	1.3	3.8	7.3	16.3	105
Sig. Diff. P = 0.05		2.3	2.1	1.2	2.0	1.8	4.1	21

* N(p-bromophenyl)-N^1-methyl-N^1-methoxyurea

Table 5

Effect of treatments on yield in tons per acre

Treatment	Dose lb/ac	Site A First Pick	Site A Second Pick	Site A Total	Site B	Site C
1. Linuron	0.75	3.66	2.80	6.46	4.68	1.57
2. "	1.0	3.37	2.88	6.25	3.47	1.76
3. "	1.5	3.66	3.12	6.78	4.29	1.79
4. Linuron + chlorpropham	0.75 1.0	3.81	2.83	6.64	4.57	1.59
5. Linuron + chlorpropham	1.0 1.0	3.76	2.90	6.67	3.91	2.12
6. Linuron + chlorpropham	1.5 1.0	4.00	3.22	7.22	4.26	2.31
7. Prometryne	1.0	3.00	2.44	5.44	4.46	2.20
8. "	1.5	3.15	2.26	5.41	4.70	2.53
9. "	2.0	3.59	3.05	6.63	4.73	2.01
10. C 3126 *	2.0	3.22	3.53	6.75	4.35	1.51
11. "	3.0	3.76	3.43	7.19	4.70	2.81
12. "	4.0	3.77	3.70	7.47	4.51	2.59
13. Monolinuron	1.5	3.81	3.44	7.26	4.95	3.25
14. "	3.0	3.86	3.27	7.14	4.51	-
15. Monolinuron + linuron	0.75 0.25	3.51	3.20	6.71	5.20	-
16. Monolinuron + linuron	1.5 0.5	4.45	3.21	7.67	5.12	2.72
17. Dinoseb-ammonium	4.0	3.09	2.12	5.21	4.79	1.93
18. Dinoseb-amine	4.0	2.70	1.97	4.67	5.17	1.84
19. Handweeded		3.24	2.78	6.02	3.38	1.35
20. Control (untreated)		2.32	1.25	3.57	2.70	0.80
Significant diff. P= 0.05		0.79	0.76	1.21	1.27	1.01

* N-(p-bromophenyl) - N^1-methyl - N^1 - methoxyurea.

control with both formulations of dinoseb was inferior to that of the other treatments. Polygonum persicaria and Poa annua became established in plots where these treatments were applied. As in Site B, handweeded controls were weeded once only, eight weeks after spraying.

DISCUSSION

The widely accepted herbicide (dinoseb-amine) for use in French beans has not proved entirely satisfactory under Irish conditions. The results of the trials reported in this paper suggest that other herbicides, now available offer an alternative to dinoseb-amine. The absence of commercially significant injury to the crop at doses twice that needed for good weed control indicates that monolinuron and N-(p-bromophenyl)-N^1-methyl-N^1-methoxyurea) (C3126) in particular hold promise for use in this crop. Although excellent selective weed control was achieved the results have been obtained in one season only, a year in which little rain fell for four weeks after treatment. Whilst the selectivity of monolinuron, and N-(p-bromophenyl) N^1-methyl-N^1-methoxyurea (C3126) appears to be adequate, further trials will be necessary before recommendations can be made. At Site A 0.75 lb monolinuron + 0.25 lb/ac linuron did not have sufficient residual activity to maintain weed free conditions up to harvesting. The selectivity of linuron at doses up to 1.5 lb/ac would appear to be adequate but the failure of this herbicide to control Fumaria officinalis a common weed in Irish soils, is a serious drawback. The addition of 1 lb/ac chlorpropham to linuron gave good control of Fumaria officinalis without any increase in crop injury, but further work would be necessary to determine selectivity of this mixture under a range of soil and climatic conditions. It would appear that there is only a narrow margin of crop safety with prometryne at doses required to give weed control comparable to monolinuron and N-(p-bromophenyl)-N^1-methyl -N^1- methoxyurea (C3126). Although the results at Site B show that amine and ammonium formulations of dinoseb can give good weed control where conditions favour rapid crop development, the results from other sites indicate that consistent results cannot be expected. It would seem that a more promising approach to the problem of weed control in French beans lies in the use of a herbicide with greater residual action, although the risk of damage to succeeding crops would need to be borne in mind.

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References

CASSIDY, J.C. (1964) Research Report 1963, Horticulture and Forestry Division, Agricultural Institute, Ireland.

DOWNES, M. (1964) Irish Sugar Co; private communications.

ROBERTS, H.A. (1959) Rep. nat. Veg. Res. Station, Wellesbourne for 1958 40 - 42.

THOMAS, T.M. (1964) Research Report 1963, Plant Sciences and Crop Husbandry Division, Agricultural Institute, Ireland.

CDEC - ITS EFFICACY IN VEGETABLES - A REVIEW

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Summary - CDEC has been marketed commercially for several years in the U.S.A. for weed control in vegetables. Although essentially a grass-killer, CDEC controls certain broad-leaved species. Conditions of soil and climate significantly affect efficacy, with performance being acceptable in southern climes and Mediterranean climates. Performance has been inconsistent in northern climes of western Canada, England and northern Europe. The addition of chlorpropham to CDEC has enhanced activity on broad-leaved weeds and consistency of performance in England. This mixture may be effective in other areas of northern and southern latitudes.

INTRODUCTION

It is the purpose of this paper to briefly review the performance of CDEC (VEGADEX*) for vegetables in North America and Europe and indicate means by which the product may contribute to vegetable production in Europe.

Commercial Use in the U.S.A.

CDEC (2-Chloroallyl diethyl dithiocarbamate) has been a successful commercial herbicide for several years in the United States on many thousands of acres of vegetable crops. Selective in a wide range of crops represented by the families Cucurbitaceae Leguminosae, Cruciferae and Solanaceae, CDEC is mainly a grass-killer with activity also on certain broad-leaved species.

The most important crops in which CDEC is used commercially in the U.S.A. are as follows: lettuce, spinach, tomatoes, celery, red beets, maize, cucurbits and cabbage. Mixtures of CDEC and CDAA have been effective in eastern U.S.A. for weed control in potatoes (Sweet et al., 1961) and are presently used commercially for this purpose.

Characteristics of CDEC

CDEC is available as a 480g/l emulsifiable concentrate or a 20% granular formulation. Pre-emergence soil applications are made without soil incorporation. CDEC is registered as "moderately irritating" to skin and eyes and "slightly toxic" to man from the standpoint of oral ingestion. The LD50 in rats is 850mg/kg and MLD in rabbits 1,500mg/kg.

Environment is important in relation to efficacy, with soil moisture being an important factor (Althaus & Gleason, 1960). Performance is best in soils that are low in clay, or on muck

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* Registered trademark of Monsanto Company, St. Louis, Mo.

soils where rainfall is good or irrigation is practised. Efficacy is reduced if air temperatures at the time of application exceed 20°C. The above factors limit the effective use of CDEC to certain geographical locations. For example, the product has not provided consistent efficacy in western Canada. In addition, CDEC is not sufficiently effective if resistant broad-leaved weeds are predominant, as is often the case in Great Britain and Europe.

Performance in Europe

CDEC has been effective in southern Europe, particularly for salads. Two years of testing in France have demonstrated adequate efficacy at a rate of 12 l/ha total product, and adequate selectivity in various salads, escaroles, cabbage, turnip and melon (Waffelaert, 1964). This rate falls within the 4 to 6 lb/ac range which is used in the U.S.A. Performance was also good in 1964 (Poignant, 1964). The annual weed species *Portulaca oleracea*, *Stellaria media*, *Senecio vulgaris*, *Chenopodium* sp., *Sonchus* sp., *Solanum nigrum*, *Poa annua*, *Setaria* spp. and *Digitaria* sp. are reported to be susceptible to CDEC, with *Urtica urens* and *Artemisia* sp. somewhat more tolerant (Waffelaert, 1964). *Raphanus* sp. was also susceptible (Poignant, 1964). Persistence in the soil usually lasts 5 weeks in the U.S.A. (Althaus *et al*., 1960). In France, the product was effective for 4 weeks when applied in early September, 6 weeks when applied at the end of September, and 8 to 10 weeks when applied at the end of October (Waffelaert, 1964). This duration of activity negates any possibility of persistence in soil which could be hazardous to a sensitive crop planted the following season.

In preliminary experiments, similar results have been obtained in Spain and Italy. *Portulaca* and *Cyperus olivarus* were adequately controlled with CDEC at 11 l/ha without injury to tomatoes in southern Spain (Garcia, 1964). In Italy, 8.0 l/ha of CDEC was effective on *Poa* spp. and *Stellaria media*, in chicory, lettuce and spinach (Chiapparini, 1961). In 1964, CDEC at 12 l/ha provided 82% weed control in chicory. The 16 l/ha rate controlled 90% of the weeds but some phytotoxic effects were also visible (Antonelli, 1964).

Certain phytotoxicological effects have occurred with lettuce in France which were most severe when seeding and emergence occurred at temperatures exceeding 20°C. As a general rule, germination of lettuce plants was reduced by 5 to 10% and emergence delayed for 2 or 3 days at a rate of 12 l/ha. Germination was reduced by 28% at a rate of 20 l/ha. Occasionally, the first leaves of emerging plants appeared abnormally crisp, resulting in some plant deformation in early stages of development. At harvest, however, stands were normal and deformations not apparent (Waffelaert, 1964). Similar phytotoxic effects to lettuce have occurred in California, necessitating more than usual care in commercial applications in order to avoid crop injury.

Prior to commercial applications in France, a new product must be approved by the official Toxicological and Agronomic Committees. CDEC has been cleared by the French Toxicological Committee and clearance by the Agronomic Committee is expected within the next few months.

Performance in England

Experimental work with CDEC has been conducted in England at Experimental Stations during 1961 - 1962 with varying results, frequently with inadequate control of broad-leaved weeds. The addition of chlorpropham to CDEC, however, in experiments in co-operation with J.M. Stokes since 1962, has controlled most annual broad-leaved weeds, including annual grasses, Senecio vulgaris and Chenopodium album and is particularly effective on Stellaria media and Urtica urens. Fair control of Galium aparine, Solanum nigrum, Sinapis arvensis and Raphanus raphanistrum was obtained under moist conditions but their survival was frequent in dry soil. Deep germinating weed seeds of all species were more difficult to control (Milne & Hyde, 1964). A dose of CDEC at 1.8 lb plus chlorpropham at 0.25 lb/ac has been found satisfactory on light and heavy soils, but efficacy was reduced by organic matter, for example, fields recently treated with farm-yard manure. Although soil moisture is usually adequate for good performance in England, efficacy has been improved by overhead irrigation after application.

The CDEC-chlorpropham mix is registered for cabbage in England and clearance is anticipated for cabbage and kale. The product has become popular for use in July-drilled cabbage during three years of commercial use, and is sold under the trade-name J.M.S. No.6. In some areas severely infested with weeds, it has been necessary to plow in fields planted to cabbage. The use of CDEC and chlorpropham mixture in England has virtually solved this problem, and the cost of hand-weeding in drilled cabbage (for later transplanting) has been reduced as much as 15 to 25 pounds sterling/ac. Field tests have shown swedes, turnips, red-beets and lettuce to be tolerant to this product (Milne & Hyde, 1964). There is every likelihood that a mixture of chlorpropham and CDEC with its increased activity for broad-leaved weeds could make an important contribution also to vegetable production in northern and southern Europe.

References

Antonelli, C. (1964) Sipcam, Milano, Italy. Personal communication.

Althaus, R.E. and L.S. Gleason. (1961) Recent developments in the use of Vegadex. Proc. Northeastern Weed Control Conf., 41-45.

Chiapparini, Luigi. (1961) Il diserbo chimico delle colture ortive ed ornamentali. L'informatore Agrario 7, 135-138.

Garcia, V. (1964) Insecticidas Condor, Bilbao, Spain. Personal communication.

Milne, N.S. and C.L. Hyde. (1964) J.M. Stokes, Ltd., Evesham, England. Personal communication.

Poignant, P.M. (1964) Pechiney-Progil, Lyon, France. Personal communication.

Sweet, R.D., Cialone, J.C. and R. Hagon. (1961) Chemicals for weeding potatoes on muck and upland soils. Paper No. 470, Dept. of Vegetable Crops, Cornell University, Ithaca, N.Y.

Waffelaert, P. (1964) Le désherbage chimique de la salade. Bulletin technique 29, 31-39.

CONTROL OF ANNUAL WEEDS IN SPEARMINT (MENTHA SPICATA)

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Summary Seventeen residual herbicides were tested at three sites in commercial spearmint crops in 1964, and their effect on mint regrowth and weed competition assessed. Chloroxuron at 4 lb/ac a.i. in 100 gallons of water was found to be the most suitable; propham, UCP 49, Tordon, chlorpropham, New Residuren and WL 5792 caused excessive damage to the crop, in the conditions of the tests.

INTRODUCTION

Spearmint is grown as a field crop in several areas in eastern England for processing to produce concentrated mint sauce in bottles. Under conditions of good management it will yield three crops in a season, producing in all 12-15 tons per acre of green material.

The crop is perennial, and may be established either by planting runners during the dormant period, or cuttings during April and May, in ground which is free from perennial weeds. During the early part of the first season, before the crop starts "running", it is possible to treat it as a row crop, but by mid-July such cultivations are no longer desirable and other methods of weed control become necessary. Preliminary experiments in 1962-3 have shown that while several non-persistent herbicides are quite useful, at this stage the crop is rather sensitive to residual herbicides, and we do not generally recommend any during the first season.

METHODS AND MATERIALS

During the spring of 1964 observation plots of seventeen herbicides, believed to have residual effects, were laid down in three commercial crops of spearmint in Norfolk, all in their second year; at Thrigby, a silty loam with a pH value of 6.2 and 2.6% organic matter content; West Dereham, a sandy loam, pH 7.25, organic matter 4.4%, and Methwold, a fen soil, pH 6.6 and organic matter 53.9%.

Methwold had no previous herbicidal treatments, except harrowing which was done about a week before the application of the residuals; West Dereham was sprayed with paraquat and harrowed about ten days beforehand, and the Thrigby site was sprayed with paraquat immediately before application of the residuals.

Individual plot size was 3 yards by 4 yards, and all herbicides except WL 5792 were applied at a standard concentration in 100 gallons of water per acre (1 quart of solution per plot) using a modified Dorman Osprey machine, during the first ten days of April. Weather conditions were fine and dry at all sites, with the first shoots of mint just above ground.

There were three untreated control plots at each site. Table 1 gives details of the herbicides tested.

WL 5792 was applied at the beginning of May, when mint growth was 4-6 inches high. To obtain uniform application the herbicide was mixed with 7 lbs. of dry sand before being broadcast on the plot.

RESULTS

Prior to the first cut the vigour of growth of the mint was assessed on a 0 - 9 scale (0 = no growth), and the suppression of weeds, either by the herbicides or the growth of mint, was estimated as a percentage weed suppression. These results are shown in Table 2. Table 3(a) and (b) gives an assessment of weed species present, their survival of the herbicidal treatments (3a), and reinfestation in mid-July, after the first cut of mint (3b).

DISCUSSION

Previous experiments with chlorpropham have given inconsistent results in England and in U.S.A., where, however, it was found to be effective in mixture with dinoseb (Warren, 1955); the evidence from this series of trials is that chlorpropham, alone or in combination with diuron as 'New Residuren', causes a check to the growth of the crop which is still noticeable at the time of cutting. This was also true of propham, 'UCP 49', 'Tordon' and 'WL 5792', and, at the rates applied in these trials, these herbicides are considered unsuitable.

Linuron gave unsatisfactory control of weeds at Methwold, but appears to have a fairly protracted residual effect and may be worth further trial.

ACP 63-303 gave poor weed control at all sites, but since the trials were laid down it has been shown that this product does not act as a residual herbicide.

The remaining nine herbicides have shown considerable promise at one or all sites. They are listed below, with notes on their behaviour, in order of their relative value as herbicides in spearmint.

Chloroxuron	Did not affect mint growth. Weed control poor at Methwold.
Simazine Diuron	These had the longest residual action, but on the fine sand at West Dereham there was some evidence by the end of July that they were affecting the mint growth.
'Hoechst 2839, 2831'	Both had a good residual effect, the former slightly better, but causing more check to the mint.
Bromacil	Very good control of weeds and residual value, causing slight check to mint at Thrigby.
'Dacthal W75'	Slightly less effective as a weedkiller, and caused serious check to mint growth at Thrigby.

'Alipur' Chloramben	Evidence of slight damage to the mint at all sites. Residual action not as long as the rest.

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REFERENCE

WARREN G.F. et al. (1955) (Weed Control in) other vegetables. Res. Rep. 12th ann. N. centr. Weed Control Conf. 1955. 146 - 50.

Table 1

Residual herbicides tested

Code & name of herbicide		Rate of application a.i. lb/ac
A	Chloroxuron	4.0
B	Propham	3.0
C	Simazine	1.5
D	Bromacil	0.8
E	'Dacthal W 75' (dimethyl ester of tetrachloroterephthalic acid)	9.0
H	Linuron	1.0
J	'UCP 49' (di-isopropyl xanthogen disulphide)	9.0
K	'Hoechst 2839' and	-
L	'Hoechst 2831' (mixtures in unspecified proportions of linuron and monolinuron, applied at 3 lb/ac)	-
M	'Alipur' (OMU + BiPC)	1.25
N	Chloramben	3.0
P	'ACP 63-303' (Lithium salt of ioxynil)	0.8
S	'Tordon' (4-amino - 3,5,6 - trichloropicolinic acid)	0.75
T	Chlorpropham	2.0
U	Diuron	1.6
X	'New Residuren' (Chlorpropham + diuron)	1.4
W	'WL 5792' (2,6 - dichlorothiobenzamide)	2.0

Table 2

Weed suppression and mint establishment & vigour

	W. Dereham			Thrigby			Methwold		
Date & height of crop (in.)	4 June 24			3 June 15			15 May 15		
Herbicide	1	2	3	1	2	3	1	2	3
A Chloroxuron	95	8	9	95	7	8	50	9	7
B Propham	5	5	5	25	5	8	10	8	4
C Simazine	100	6	7	100	3	6	100	8	7
D Bromacil	100	7	8	95	5	8	100	8	9
E 'Dacthal W 75'	90	8	9	10	5	7	100	7	9
H Linuron	95	7	7	100	6	7	20	6	7
J 'UCP 49'	50	8	9	0	6	9	5	8	6
K 'Hoechst 2839'	95	6	7	100	5	6	80	7	9
L 'Hoechst 2831'	95	5	8	95	7	8	100	6	9
M 'Alipur'	90	7	7	50	4	6	100	8	7
N Chloramben	80	8	9	95	4	5	80	7	6
P 'ACP 63-303'	80	7	9	50	4	7	50	7	8
S 'Tordon'	95	0	0	95	0	0	50	1	1
T Chlorpropham	50	7	6	0	4	5	20	8	3
U Diuron	100	8	9	100	4	7	100	6	9
X 'New Residuren'	10	7	5	100	4	6	95	8	5
W 'WL 5792'	90	6	5	95	3	3	10	5	4
Controls	0	7	9	0	5	8	0	7	7
	0	6	7	0	7	9	0	7	9
	0	7	9	0	7	8	0	8	7

1. % annual weed suppression
2. Mint establishment (0 = no mint; 9 = complete ground cover)
3. Mint vigour (0 = no mint; 9 = very strong growth)

Table 3a

Weed species

Survival (mid-June)

Herbicide	W. Dereham	Thrigby	Methwold
A	none	11.	3.9.5.4.6.12.
B	3.2.13.	1.2.9.11.	3.9.
C	3.	none	3.9.
D	none	none	3.
E	none	11.3.2.	9.3.
H	3.	11.2.4.	3.12.
J	3.	1.2.3.4.5.9.11.	3.9.4.12.5.
K	none	none	3.
L	none	11.	3.
M	3.1.13.	11.3.	9.3.
N	3.	11.1.4.	3.
P	3.1.11.13.	11.1.2.3.9.	9.3.1.11.
S	11.	11.12.	9.3.12.13.
T	3.	11.3.2.	3.9.
U	none	11.3.	3.9.
X	3.9.1.6.2.13.	none	none
W	9.1.	2.11.	9.
Controls:	3.1.9.13.	1.2.3.4.5.7.9.11.	3.9.4.2.12.7.5.10.
	3.5.11.9.2.13.	3.2.1.4.11.9.	9.3.1.4.7.
	3.1.9.8.13.	1.2.3.11.9.4.5.	9.3.1.

Weeds listed in order of importance

For key see foot of Table 3b

Table 3b

Weed species

Reinfestation (July)

Herbicide	W. Dereham	Thrigby	Methwold
A	1.3.	1.11.	3.1.4.5.
B	9.3.2.13.	1.2.4.5.6.9.11.	3.4.
C	none	none	3.1.
D	3.	1.3.11.	3.1.
E	3.11.	2.3.11.	3.5.4.
H	3.1.13.	11.	3.5.12.
J	1.2.3.4.11.	1.2.3.4.5.9.11.	9.5.4.3.
K	3.	1.11.	3.
L	3.	3.11.	3.
M	3.	3.11.	3.9.4.
N	3.12.13.	1.2.3.4.5.9.10.11.	3.
P	9.3.1.5.2.13.	1.2.3.9.11.	3.5.4.13.
S	11.3.	11.	11.7.
T	3.12.	2.3.4.11.	5.3.
U	3.	3.11.	3.5.4.
X	3.11.5.9.	3.11.	3.5.12.
W	9.3.13.	2.5.11.	9.4.5.
Controls:	3.1.9.13.	1.2.5.11.	3.4.9.5.13.
	11.3.9.5.13.	1.2.3.4.5.9.11.	3.1.4.5.9.
	9.1.3.11.2.	1.2.3.5.9.11.	4.3.5.10.12.9.

Weeds listed in order of importance.

Key

1. Urtica urens
2. Matricaria spp.
3. Senecio vulgaris
4. Chenopodium album
5. Polygonum spp.
6. Veronica arvensis
7. Capsella bursa-pastoris
8. Fumaria officinalis
9. Stellaria media: Cerastium spp.
10. Sonchus oleraceus
11. Poa annua
12. Other grasses
13. Other weeds