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THE BIOLOGY OF REED (PHRAGMITES COMMUNIS) IN RELATION TO ITS CONTROL

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Summary. Reedswamp and reedmarshes are common in many alluvial and coastal districts of Britain. Reeds (Phragmites communis Trin) are a useful cash crop in themselves, and have considerable amenity value in land use, and scientific value as a refuge for wildlife and as part of a hydrosere. Cutting, grazing and drainage are the best methods of control. Cutting in July, when the cut shoots are not replaced, is best, as half the growing season is then lost to the plant. Phragmites can be lowered from the dominant to a sparse member of a community fairly easily, but it will persist indefinitely except under very severe strain, such as cattle grazing throughout the summer for many years. Involuntary chemical control occurs with salt in sea water, and planned control, for different purposes, with Dalapon and $KClO_3$. Dredging, ploughing and shading are specialised in their application or effects.

INTRODUCTION

Reedbeds are a characteristic part of fens, Broads and similar lowland marshes and valleys, and the species is also common in some lakes, marshes and bogs in highland regions. Reedbeds have obvious amenity value as a landscape feature, and scientific value both as a refuge for animal life, particularly marsh birds, and as part of the hydrosere succession.

Phragmites communis in Britain requires an accessible (liquid) water supply for at least several months of the year, and to be regularly flooded no more than 0.75 - 1.5m deep (the permissible depth being greater the higher the nutrient status). Within this range the species is widespread, except where liable to scour, in very nutrient-poor (particularly calcium-deficient) areas, in nutrient-rich areas permitting the good growth of competitors, in high-salt coastal communities, and - the most frequent - in areas of intensive interference. Control of this important vegetation type may be needed to ensure diversity of habitat in marshland, to allow grazing or cultivation, to prevent the obstruction of ditches and flooded areas, and for other minor purposes (e.g. making paths).

Reedswamp comes between the hydrophyte (e.g. water lily) and carr (typically Salix cinerea) stages in the hydrosere. Schoenoplectus lacustris, and perhaps Typha spp, may be common in the deeper water, but pure stands of dense Phragmites are common in the marsh areas. In lighter shade species such as Iris pseudacorus Carex acutiformis and Salix spp increase in the marshes. On drying, Calamagrostis canescens, or Arrhenatherum elatius, Poa trivialis etc. may become common, and, as bushes increase, so also do Filipendula ulmaria, Urtica dioica etc. Where interference prevents carr development Epilobium hirsutum, Juncus spp etc. may come in as well. In nutrient-poor areas, sparser reeds occur in communities of Carex spp, Cladium mariscus, Erica tetralix, Juncus spp, Molinia caerulea etc. (Haslam 1969 a)

STEM TYPES AND BUD BIOLOGY

All ordinary populations have horizontal and vertical rhizomes and aerial stems (Fig.1). Some also have legehalme (long runners), but these are not essential, and their removal can do no more than retard invasion by an advancing population. Aerial shoots photosynthesise and flower, and their removal prevents photosynthesis and necessitates using rhizome reserves for replacements.

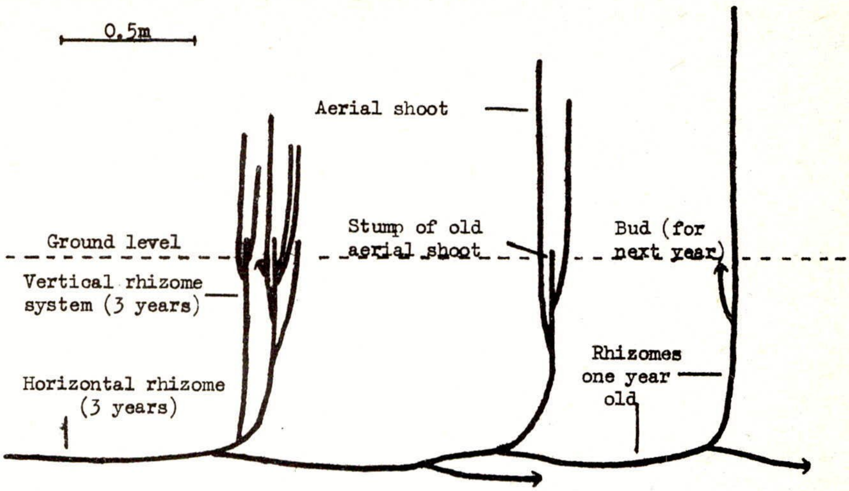

Fig. 1. Diagram to show stem types and variation with age in a sparse marsh Phragmites stand in Britain. In dense stands vertical rhizome systems branch more and lower, forming oblique intermediate rhizomes as well.

Verticals bear the aerial shoots, usually one in the first year, (0 -) 1 - 2 (- 4) in the second, 0 - 6 in the third, and less in subsequent (up to six) years. If removed, they must grow again before aerials can form, and as only one aerial is usually borne on a first year vertical, recolonisation is slow. In one 1 x 1m plot excavated to lower the level by c. 20cm, removing the upper part of the verticals, the density was only two thirds of the original, three seasons later.

Horizontals are the rejuvenating agent and main hormone store of the plant. They are wide, whether they arise from horizontals or from narrow verticals. Each order of branching away from the horizontal is narrower than the last, and so it is horizontals that perpetuate the stand. They cannot, however, bear aerials without first bearing verticals. Stands without horizontals occur, in practice, only when a new stand is started from transplants of verticals bearing aerials, and horizontals then grow well at the end of the first summer. (Haslam 1969 b)

Most axillary buds of Phragmites rhizomes remain dormant throughout their life. Once one is growing upwards, however, it is a potential aerial shoot, and such buds develop during most of the year. In July the main crop of aerial shoots are nearly full grown, and with, presumably, food to spare, new buds start to develop. A few emerge, but more remain dormant near the soil surface. By the beginning of winter about half (in many stands) of the buds for next season's crop are present in the soil. More buds develop slowly in winter, and then more quickly in spring, so that most of the buds (excluding replacements) are formed when the emergence period starts.

During most of the year, newly-formed buds are held dormant near the soil surface. While dormant, their tips (of leaf sheaths), but not their apical meristems, can emerge above ground and grow to c. 20cm in a warm spell. Over-wintering buds, formed when food is abundant, tend to be large (wide), to have grown high in the soil when emergence starts, and to emerge early. Spring-formed ones tend to be small and to emerge late, so that the average size of emergent buds decreases through the emergence period. Up to a third of the population may, however, be composed of "summer shoots" which are large shoots arising late in the season.

In the emergence period pre-formed buds emerge, any large number of new-formed ones do so too, (not many in British stands, usually), and damaged buds or shoots can be replaced. The period starts when internal dormancy ends and when it is warm enough (where investigated in Britain, internal dormancy ends in late February, but emergence is usually delayed 1-2 months longer). It lasts c. 2-12 weeks, usually c.4 in ordinary British stands without much damage and without thick litter. Initially, buds come up rapidly, and then the rate gradually declines. Severe frosts prolong the period to 8 weeks or more, as replacements take about a month to come up. (Haslam 1969 c)

THE EFFECT OF VARIOUS TREATMENTS ON PHRAGMITES

1. Cutting. An annual cut, at the right season, can depress and sometimes eliminate *Phragmites*. Cutting during the early emergence period (April and/or May, in Britain, usually) gives a full replacement crop. That from cutting alone is similar in height and density to the potential original, but if the cut area is also exposed to frost the crop is both shorter and denser. If a June cut is during the main emergence period there will be a good replacement crop, if emergence is declineing replacement will be partial, and if it has ended there will be (almost) none. Different stands vary in their state in June.

In July the emergence period is over in virtually all stands, and since cutting hardly releases internal dormancy the replacement crop is negligible or little. So July cutting eliminates the second half of the growing season, when reserves (used in the emergence period) are normally being replaced, and new rhizome growth made. Cutting in August and September has increasingly less effect, and by the time the aerial shoots are dying and dead their removal has no deleterious effect on the plant, though it does expose the buds to frost, and to increased light in spring.

In the Netherlands, cutting in spring and early autumn kills reeds. In Britain July cutting, sometimes with a cut in early autumn, either depresses or kills reeds, the result depending on the available competitors - low growing species, or those which, like *Phragmites*, are seriously damaged by summer cutting, will allow *Phragmites* to persist, sparsely but indefinitely. (Haslam 1969 a,c,d).

2. Grazing. Grazing is persistent but often incomplete cutting. Cattle graze low, eat indiscriminately, and trample heavily. They are the most efficient animals for depressing reeds, and can turn reedbeds into rough grazing in, occasionally, as little as two years. Short *Phragmites*, however, may remain for many years, and take over if grazing is stopped. Sheep graze low, and heavily in spring but little in summer when more alternatives are available. Spring-grazed shoots, unlike summer-grazed ones, are replaced providing reserves are available. So sheep grazing decreases reeds, but, unlike cattle, normally leaves them conspicuous in the community. Horses, in places like the New Forest, graze and trample but intermittently, and the result is like that of sheep grazing. Cows and sheep tend to eat the whole of short or young shoots, though cows will eat the tops of taller shoots the far side of fences, etc. Horses eat the upper parts of small and medium shoots in the New Forest. Goats, however, commonly eat the tops off taller shoots, and so leave the reeds dominant. (Haslam 1969 a,d).

3. Eating of buds. Coypu (*Myocastor coypu*) cleared reedbeds in Norfolk by eating buds and shoots, and some have not yet recovered. Damaged buds are replaceable to start with, but continuous destruction uses up reserves while not permitting photosynthesis. (Haslam 1969 a).

4. Disturbance of the top soil. Cattle and horses trample, and by moving the top soil, damage the sensitive tops of the vertical rhizomes. So does the passing of tractors, etc. Wet soil is softer than dry, and wet peaty soil can turn liquid

after disturbance, and give no support to the verticals. Bent and harmed verticals do not bear aerial shoots, and new ones form but slowly. (Haslam d, Rudescu et al 1965).

5. Ploughing. This cuts rhizomes, so releasing internal dormancy and allowing new growth (in warm weather). A viable portion must usually be at least 3 nodes and 20 cm long, have adequate water and aeration, and be near ground level. (Haslam 1969 c). Such a portion can develop (20-) 40 - 70(-100) cm of new stem, from one bud or split up among several, and this length must include the early part of the above-ground as well as the below-ground stems. Longer portions can, of course, support longer stems, and bear larger shoots.

Superficial ploughing, e.g. by hand, leaves many superficial rhizome portions and gives a dense but short replacement crop, and is less damaging than July cutting, because the new shoots grow quickly. Deeper ploughing leaves more rhizome unviably deep in the soil. In Malta c.6 (superficial) cultivations a year are needed for satisfactory crop growth, while in Britain 1-2 are adequate. In the Netherlands, ploughing (c.20 cm deep) is used to decrease the reeds in beds already weakened by drainage (D. Bakker). Since the subsequent shoots are short - and the original reeds tall - further control measures are thus rendered easier.

6. Dredging. If vertical rhizomes are removed while dredging dykes etc. recolonisation is slow (see above). If horizontals also are removed, re-invasion depends on the inoculum potential at the edges, and can be slow, or, if this is great, rapid. If the dredging leaves water over c. 1.5m deep, invasion will be postponed until accretion has lessened the depth.

7. Drainage. *Phragmites* requires a wet habitat, though the amount of ground water needed varies with the rainfall, and perhaps with genotype. Draining *Phragmites* lessens its vigour and increases dry-marsh species which, especially in nutrient-rich places, can compete successfully with it. Reeds can persist in marshes too dry for them to invade but sufficient drainage will kill them. Such great drainage is normally impractical for other reasons (e.g. in part of the Fenland). Normal drainage can be considered to depress but not eliminate *Phragmites*. In the new polders in the Netherlands drainage is, naturally, the first step towards removing the reeds when their part in the process is complete (D. Bakker).

8. Succession. Reedbeds are succeeded in the natural hydrosere by carr, which is normally undesirable, since its scientific and amenity value is less than that of marshes. Bush colonisation is very slow in dense reed, but is speeded by temporary clearance, or by weakening the *Phragmites*, e.g. by drainage. Shaded *Phragmites* is flaccid, sterile and sparse, and it decreases and dies with increased shade and drought. (Haslam 1969 a).

9. Competition. The habitat range in which *Phragmites* can suppress its competitors is narrower than the range in which it can potentially dominate, and it can grow sparsely in a yet wider range. Hence competition can reduce *Phragmites* from a dominant to a sparse species, especially in nutrient-rich and dry marshes (so reeds are found in drier parts of nutrient-poor than of nutrient-rich marshes). Advancing margins of e.g. *Glyceria maxima*, *Phalaris arundinacea* can suppress reed, and e.g. *Calamagrostis canescens*, *Arrhenatherum elatius*, and *Juncus subnodulosus* can slowly decrease it in dry areas.

When new polders in the Netherlands are reclaimed, the final stage in the removal of the reeds is to sow a crop with a high competetive power, e.g. winter wheat, spring barley or oats. Provided the field is kept dry, reeds cause no trouble after 3-5 years (D. Bakker).

10. Burning. Burning breaks internal dormancy and allows all pre-formed and about-to-be-formed buds to emerge about a month after the fire, provided the weather is warm enough. A fire in winter produces a very rapid early emergence of buds in spring, which is a competitive advantage to the reed. A spring fire gives a replacement crop, perhaps denser than the original because of the stimulating effect on the dormant axillary buds on the rhizome. A summer fire is less harmful than summer

cutting since, while both remove existing shoots, only the former produces a proper replacement crop. A spring fire, however, may result in late emergence, because of the delay after the fire.

A fire sufficiently severe to badly scorch the surface soil causes up to two months delay in emergence the next spring. These reeds will not complete their growth before the autumn frosts, and so the crop is diminished in the same way as that of crops coming up late after late severe frosts, cutting in late May or June, etc. (Haslam 1969 c, d).

11. Salt. While Phragmites can tolerate up to 1.2% chlorinity (Ranwell et al. 1964), sudden increases are toxic. Liquor from salt pans is lethal. And sea-flooding of a reedbed causes severe damage, the reeds being few, short and weak for the - several - years before the salt is drained or leached out. No chlorinity records are available.

12. Chemical control. To remove reeds between bird hides and ponds in East Anglia, Dalapon has been applied in two consecutive years in dry spells in the leafing season (R. W. Sankey). Salt could presumably be used also. DCP has been used in the Netherlands to spray the regrowth of reeds after new polders have been drained and ploughed (D. Bakker). In Rumania $KClO_3$ (15-30 Kg/ha, from aircraft), is used to defoliate reed, allowing harvesting, for the cellulose industry, in summer. The leaves fall c. 40 days after the May treatment. Because of the interruption to the growing season and the nutrition of the plant, treated areas are not cropped the next year. (Rudescu et al. 1965)

DISCUSSION

Phragmites is almost cosmopolitan, and of wide habitat range, and so it tolerates many variations in environment. It is difficult to eradicate, recuperates remarkably well after strain, and persists, sparse and short, where suppressed as a dominant.

July cutting is the most effective simple method for increasing habitat diversity in a reedmarsh, and for preventing bush colonisation, but it is time-consuming without mechanical aids. Reed can be killed by this if, and only if, effective tall competitors are present, as in some dry and nutrient-rich places. Burning is quicker to achieve than cutting, but is less effective for control as it breaks internal dormancy and allows another crop to arise outside the emergence period.

Control by grazing is easy providing domestic animals are available, the area is suitable, and the ground not too soft. Lowland marshes are usually enclosed, and can be used for rough grazing after an initial burn. In highland regions animals usually roam over unenclosed land, and more local grazing or (in lower parts) better drainage is needed to depress reeds further. Cattle are the most efficient grazing animals in Britain, as they graze low and indiscriminately, damage the upper verticals by trampling - and are usually in small spaces, while sheep are often in large areas and may visit any one place only infrequently. Sheep depress Phragmites, while intensive and continued cattle grazing can kill it.

Lowering the water level decreases the vigour of Phragmites and increases that of its dry-marsh competitors. On reclamation, ploughing, cutting or grazing aid drainage in depressing reed. However, the value of wet marshes, which includes reedbeds, is usually greater than that of dry ones. In lowland areas nettle beds please no one, in highland areas there is sufficient moor anyway, and few herbs other than reed provide tall winter and spring cover for birds. Unless required for farming or forestry, marshland should be kept wet, not dry.

The effectiveness of cultivation in suppressing weed reeds depends on how much of the rhizome is left too deep to be viable - and on the competition offered by the crop. It is usually less harmful than July cutting, because it breaks internal dormancy.

Chemical control of reeds, except for certain limited purposes, is to be deprecated. The chemicals used at present are non-specific, and marshes are one of the few remaining habitats for much wildlife. The eutrophicisation of the valleys is bringing much unwanted change to such areas, and change there should be resisted, not speeded.

In the Netherlands, reeds have been used in the reclamation of new land. They must then be controlled before good crops can be grown. This is done by drainage, cutting, ploughing (perhaps spraying the regrowth) and finally sowing crops which can compete successfully with the reed. In Britain there are no comparable wetland areas being drained so much.

Reeds may need control in three main types of habitat. First when reedbeds cover larger areas in a marsh than are desired. Control methods have been discussed above. Second, where weed reeds occur in crops, as in the Fenland. Eradication is difficult, as further drainage is impractical, cutting impossible because of the requirements of the crop, and ordinary ploughing leaves viable rhizome. And thirdly, where reeds are encroaching on bodies of open water, which is rapid where - and only where - deposition is also rapid (or the habitat is new). In practice, accretion is either so slow than invasion is negligible, as in many areas, or, if it is rapid, as in the Broads, there is no known satisfactory means of control, as cutting and dredging are impractical, and drainage and chemical control undesirable. Ditches, in contrast, can be kept clear by dredging every few years.

Finally, reeds themselves form a valuable crop, yielding a profit of £30 - £50 per acre (D. S. A. Macdougall). The market is now expanding, and reeds for thatching etc. are sold all over Britain from East Anglia. In Rumania, Denmark etc., reeds are exploited on a large scale for the cellulose industry, and a high degree of mechanisation is achieved. Before deciding to kill reeds it is worth pondering whether they themselves may not be the most satisfactory means of land use!

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UPTAKE AND TRANSLOCATION OF HERBICIDES IN SUBMERSED AQUATIC PLANTS

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Summary The uptake of endothal-^{14}C (disodium salt) by excised leaves of Potamogeton nodosus Poir. and Elodea canadensis Michx. was studied in laboratory experiments. Internal concentrations of ^{14}C label equivalent to 12 and 8 times the concentration of the external solution (0.1 ppm a.e.) were obtained in P. nodosus and E. canadensis respectively after 48 hours of absorption. A loss of radioactivity from P. nodosus commenced after 24 hours absorption in 0.1 ppm and 5.0 ppm solutions. Loss of radioactivity from E. canadensis occurred only when the concentration of the external solution was 5.0 ppm.

Gross radioautography studies indicated symplastic translocation of ^{14}C label following leaf treatment of intact plants of P. nodosus with 2,4-D-^{14}C, endothal-^{14}C and fenac-^{14}C. Similar patterns of translocation, presumably ^{14}C labelled photosynthate were obtained when leaves were treated with $Na_2{}^{14}CO_3$. Stem uptake and subsequent translocation of endothal-^{14}C was also demonstrated. A relatively complex system of translocation between primary and secondary plants was observed. A somewhat restricted movement of ^{14}C isotope and subsequent accumulation in meristematic tissues occurred in E. canadensis following leaf and stem applications of endothal-^{14}C and $Na_2{}^{14}CO_3$.

INTRODUCTION

Chemical control of aquatic weeds is a rapidly expanding area of investigation and is already an established practice in many countries (Lawrence, 1962; Little, 1968). There is relatively scant information available at the present time on the uptake, movement and ultimate fate of many herbicides in aquatic plants. It is conceivable that precise information on these aspects would lead to a more rational and effective use of such chemicals in aquatic situations. This paper describes preliminary studies on some aspects of the uptake and translocation of some herbicides in Potamogeton nodosus Poir. and Elodea canadensis Michx.

METHODS AND MATERIALS

Uptake Studies.

The uptake of endothal-^{14}C by excised leaves of Potamogeton nodosus Poir. and Elodea canadensis Michx. was studied in laboratory experiments. Sections, 1.0 cm long, of leaf tissue of P. nodosus and trifoliate nodes of E. canadensis were used as experimental material. A definite number of sections or nodes were taken for each sample, the weight being approximately 150 mg fresh weight. Each sample was

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transferred to 100 ml of experimental solution which consisted of one quarter strength Hoagland's solution containing the desired concentration of *endothal-^{14}C in a 250 ml Erlenmeyer flask. The flasks were placed on a rotary shaker under room (incandescent) light throughout the duration of the experiment. At the end of the absorption period the sample was rinsed for one minute in running tap water and then desorbed for 60 min in an equivalent concentration of the disodium salt of unlabelled endothal. Samples were assayed for radioactivity by a modified Schöniger oxygen flask combustion technique (Wang and Willis, 1965). Each sample was ignited in an atmosphere of pure oxygen within a two litre filter flask. A solution of ethanol/ethanolamine (1 : 2 v/v) was injected into the filter flask and aliquot of the ethanolamine carbonate was then counted in a liquid scintillation spectrometer.

Translocation Studies.

Materials and methods used in translocation studies were the same as described by Thomas and Seaman (1968). Briefly, plants of *P. nodosus* were grown from winter buds in two litre jars of tap or pond water. Plants having 5-7 submersed leaves (no floating leaves) were set up for treatment in 50 x 400 mm test tubes containing approximately 600 ml of quarter strength Hoagland's solution. Leaf, internode and root treatments were made by isolating these portions of intact plants in short pieces of plexiglass tubing or glass test tubes by means of silicone grease seals. 5 ml of one quarter strength Hoagland's solution was added to the test tube or sealed tubing which, together with the plant, was then attached to a supporting glass rod. The radiolabelled chemicals were added using a Hamilton microlitre syringe. At the end of the treatment period the plants were rinsed in running tap water and spread out between mounting paper and clear thin plastic film. They were then frozen by convection in an ice box and freeze dried. Thereafter the techniques described by Crafts and Yamaguchi (1964) were followed for mounting, exposure to X-ray film and development of the film.

Unrooted branched plants of *E. canadensis* were used as experimental material. Methods of treatment and subsequent procedure were the same as described above for *P. nodosus*.

RESULTS

Uptake Studies.

The time course uptake of endothal-^{14}C by *P. nodosus* and *E. canadensis* during a 48 hour experimental period in 0.1 ppm (a.e.) solution is shown in Fig.1a. There was a relatively rapid increase in the amount of ^{14}C isotope absorbed by *P. nodosus* during the first 8 hours. Subsequently the rate decreased but accumulation continued until 36 hours had elapsed. A decrease in the amount of ^{14}C isotope present in the plant tissues occurred between 36 and 48 hours absorption.

The pattern of uptake in *E. canadensis* was approximately quantitatively similar to that in *P. nodosus* for the first 8 hours. Uptake continued from 8 to 48 hours at a reduced but steady rate without evidence of loss of radioactivity from the tissues. Uptake patterns in 1.0 ppm and 5.0 ppm solutions are shown in Figs.1b and 1c respectively. A loss of radioactivity from *P. nodosus* occurred after 24 hours absorption. There was a relatively rapid uptake in *E. canadensis* during the first 12 hours. This was followed by a sharp decline until no further accumulation occurred after 24 hours. A decrease in radioactivity was observed after 36 hours absorption in the 5.0 ppm solution.

*ring-labelled (2,3) endothal-^{14}C; specific activity 1.11 uc/uM

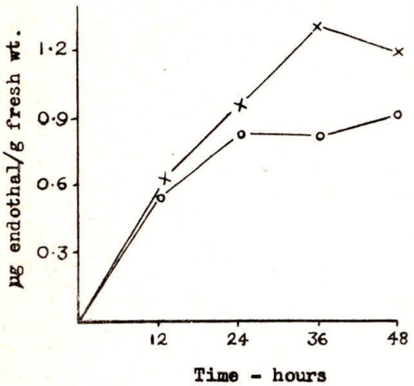

Fig. 1a

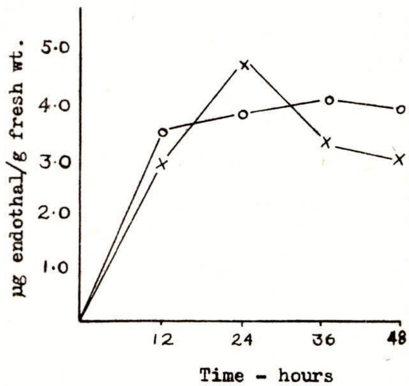

Fig. 1b

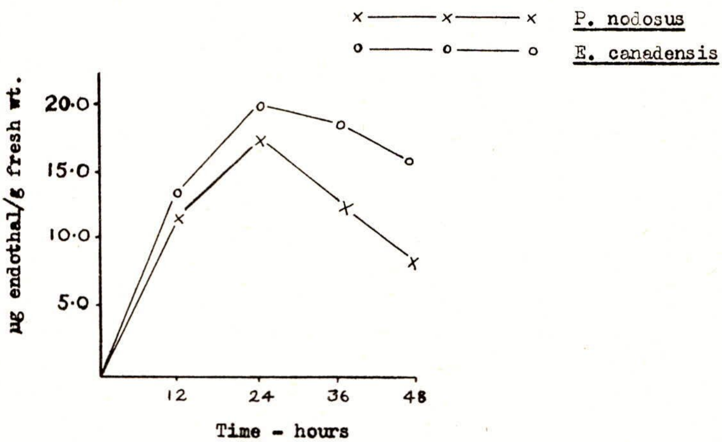

Fig. 1c

Figure 1. Uptake course of endothal-^{14}C in excised leaf tissues of *Potamogeton nodosus* and *Elodea canadensis*.

a = 0.1 ppm endothal-^{14}C

b = 1.0 ppm endothal-^{14}C

c = 5.0 ppm endothal-^{14}C

Translocation Studies.

Gross radioautography studies showed that 2,4-D-^{14}C, endothal-^{14}C and fenac-^{14}C applied to mature exporting leaves of P. nodosus moved into expanding leaves of the primary plant and into meristematic tissues of developing secondary plants. No movement of ^{14}C isotope into mature leaves was obtained. A similar pattern of translocation presumably ^{14}C-labelled photosynthate was observed when leaves were treated with $Na^{14}CO_3$. Atrazine-^{14}C and diuron-^{14}C did not move from the point of application.

Stem uptake and subsequent acropetal and basipetal movement of ^{14}C isotope into expanding leaves and young secondary plants occurred following treatment with endothal-^{14}C and fenac-^{14}C. No movement of atrazine-^{14}C and diuron-^{14}C was observed.

Endothal-^{14} and -^{14}C labelled photosynthate translocated from exporting leaves of secondary plants into the young expanding leaves. Translocation between secondary plants on the same and opposite sides of the primary plant was also demonstrated.

A relatively limited symplastic translocation was obtained in E. canadensis following combined leaf and stem treatment with endothal-^{14}C and $Na^{14}CO_3$. Accumulation of radioactivity was evident in the apical leaves and buds of the treated and proximal branches.

DISCUSSION

Uptake Studies.

The internal concentrations of ^{14}C isotope obtained in both P. nodosus and E. canadensis were much higher than in the external (absorbing) solution. This indicates accumulation of endothal-^{14} against a concentration gradient. Accumulation was inhibited by approximately 95 percent in the presence of the metabolic inhibitors, 2,4-dinitrophenol, potassium cyanide and sodium azide, indicating that this was a metabolic energy-linked process. It was not established if endothal-^{14}C diffused out of the plant tissues on transfer to the unlabelled endothal solution. In some experiments a decrease in radioactivity was noted after the desorption period but this may have been due to loss of surface adsorbed endothal-^{14}C.

Quantitatively E. canadensis adsorbed less endothal-^{14}C than P. nodosus. The greater susceptibility of the latter species to endothal may be related to this differential uptake. However in some subsequent experiments accumulation of endothal-^{14}C was approximately the same in both species. The quantitative variation in uptake was probably due to variability of the tissues used in the separate experiments.

The loss of ^{14}C isotope from the experimental tissues is of interest in view of work reported previously (Blackman et al., 1959; Blackman 1961; Chlor, 1959). The loss of radioactivity from the more susceptible P. nodosus may have been due to phytotoxic effects of the endothal. Evidence of phytotoxicity to P. nodosus in field experiments by low concentrations (o.1 ppm) of endothal support this view. However loss of radioactivity from E. canadensis is difficult to comprehend on a basis of phytotoxicity alone as this plant is normally resistant to endothal concentrations greater than 5 ppm. It is conceivable that the sublethal dose of endothal affected membrane permeability or some physiological processes which could account for the observed effect. Furthermore, loss of herbicide may occur more rapidly from excised plant parts than from intact plants. This is an important factor in interpreting any possible practical significance of the above results.

$^{14}CO_2$ evolution subsequent to breakdown of the endothal-^{14}C molecule might also account for the loss of radioactivity noted. However, based on the patterns of herbicide uptake (Figs 1b and 1c), this suggests a greater rate of endothal-^{14}C metabolism in the susceptible P. nodosus, a phenomenon not indicated in endothal-^{14}C metabolism studies (Thomas, unpublished data).

Uptake and subsequent release of herbicides by aquatic plants is a possible factor of importance in determining herbicide residue in treated water. The present study showed an accumulation of herbicide within aquatic plants which was equivalent to 12 times the concentration in the external solution. Accumulation, followed by a subsequent release of the unmetabolised herbicide could be reflected in a disappearance and recurrence of the herbicide in treated water, especially where there is a dense aquatic vegetation. Disappearance and recurrence of diquat in reservoirs has been reported by Yeo (1967). In more detailed experiments, Davies (1968) showed that diquat when adsorbed onto E. canadensis plants was subsequently released into the water to become available to other plants. It is however probable that under field conditions released herbicides would be adsorbed quickly on soil or plant material and thus the process of release may be undetectable.

Translocation Studies.

The principal research findings on the movement of herbicides in terrestrial plants has been summarised by Crafts (1961a, 1961b). It is established that certain herbicides move in the symplast, others in the apoplast and a third category which can move in both the symplast and the apoplast. The gross radioautographs in the present study indicated that foliar applied herbicides (or their metabolites) and photosynthate moved in typical symplastic fashion from exporting leaves to meristematic tissues in both P. nodosus and E. canadensis. It is presumed that the movement of ^{14}C isotope occurred in phloem tissue which has been observed in P. nodosus (Thomas, unpublished data) and in Elodea densa (Currier and Shih, 1966).

Stem uptake and subsequent movement of herbicides may be of considerable importance in the control of emersed aquatic plants which have partly submersed stems. Phytotoxic concentrations of herbicide could accumulate in emersed leaves and stems of aquatic plants following entry through the emersed part of the stems and subsequent movement in the transpiration stream. The kill of Phragmites communis Trin. which is sometimes observed following application of diuron to lakes, canals etc. may be explained by this phenomenon, as root uptake of the herbicide may be relatively limited due to possible adsorption on soil and debris. The radioautographs in the present study indicated that stem uptake and subsequent acropetal translocation in the symplast is also a possible mode of herbicide distribution in the plant.

The lack of movement of atrazine-^{14}C and diuron-^{14}C following stem treatments indicates an absence of water movement between roots and shoot. However as pointed out by Thomas and Seaman (1968) it is possible that the technique of gross radioautography may not be sufficiently precise to detect movement of relatively small amounts of ^{14}C isotope from the roots into the shoot. Most experimental evidence (Thoday and Sykes, 1909; Reide, 1921; Thut, 1932) indicates that water movement from roots to shoot does occur in many submersed aquatic plants including Potamogeton spp. and Elodea spp. The present evidence nonetheless suggests that apoplastic movement of herbicides does not occur in P. nodosus plants which have no floating leaves. It is possible that movement of water and herbicides from the roots and P. nodosus would increase considerably after the development of floating leaves which possess stomata.

Translocation from the primary to secondary plants in P. nodosus continues for a considerable time after the development of photosynthesizing leaves on the secondary plants. Export from the primary to a secondary plant was observed when the secondary plant had 3 to 4 leaves, some of which were exporting photosynthate to other secondary plants. This indicates the existence of a simultaneous import and export of photosynthate in secondary plants. The movement of ^{14}C isotope between secondary plants situated on opposite sides of the primary plant is of considerable interest as this, together with the other observations cited above, suggests a complex system of translocation which is presently under further investigation.

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SOME STUDIES OF THE PERSISTENCE OF 2,4-D IN NATURAL SURFACE WATERS

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Summary The rate of inactivation of 2,4-D in different surface waters and in distilled water were compared. The results demonstrated that 2,4-D can persist in surface waters with little decrease in phytotoxic activity for periods of at least 9 weeks but under certain conditions inactivation takes place within one week. A lag-phase and subsequent accelerated inactivation was observed in Lambourne River water but not in a fresh sample taken at a later date from the same place. Rapid inactivation was induced in all waters, including distilled water, by the addition of a small quantity of soil which had been treated regularly for some years with MCPA.

INTRODUCTION

In 1966 it was reported (Robson 1966) that the inactivation of 2,4-D amine in water taken from a natural pond can follow a similar pattern to that demonstrated originally by Audus in soil (Audus 1949). This pattern comprised a lag-phase of a few days immediately after the introduction of the herbicide (0.5 ppm) during which phytotoxicity diminished slowly, followed by an increasingly rapid rate of inactivation. After a subsequent treatment of the same water with a concentration 10 times as great (5.0 ppm) there was no evidence of a lag-phase and the 2,4-D was inactivated within a week. Faust and Aly (1964) working in America were not able to demonstrate any appreciable breakdown of 2,4-D in water but they did observe a pattern of inactivation in bottom mud similar to that described by Audus.

Following this experience in 1966 a further series of experiments were carried out at the Weed Research Organization involving water from several sources, and the results are reported here.

METHOD

All the experiments were carried out in the laboratory and greenhouse and although the methods varied slightly in detail they were basically similar in each case. Water was collected from each source in large plastic containers which had been well cleaned with detergent and tap water and rinsed with distilled water. These bulk supplies were covered and stored at room temperature until needed. In early experiments 5 litres of water were used for each treatment but later this was reduced to 200-250 ml in 500 ml beakers. The containers were covered with finely perforated transparent plastic held in place by elastic bands to prevent evaporation and contamination by dust. No water was added during the course of the experiments. Samples were taken by means of pipettes, one of which was kept free of any herbicide and was used only for sampling the untreated controls.

The concentration of 2,4-D was determined either by a gas chromatographic method or by a sorghum root bioassay (Parker 1964).

Experiment 1.

Water was collected from two very different sources at the end of April. One batch was drawn from a highly fertile backwater to the River Thames at Wytham, Berkshire and at the time of the collection, it was supporting a well-developed community of emergent, floating and submerged macrophytes and a fauna of invertebrates and fish. The other was obtained from the upper reaches of a fast-flowing, clear, chalk stream, the River Lambourne, which has a gravel bottom and supports characteristic submerged macrophytes such as Ranunculus spp.

Large glazed earthenware jars were filled with a solution of detergent and left for 3 days. They were th n emptied and rinsed thoroughly with alcohol and distilled water. Five litres of distilled water and the water from Wytham and Lambourne river was placed in separate jars in a greenhouse with a minimum temperature of 10°C and treated with a commercial amine formulation of 2,4-D containing 31.9 a.e. w/v to give a concentration of 5.0 ppm 2,4-D a.e. Untreated controls were included. The pH readings of the two surface waters were Wytham 8.25 and Lambourne river 8.35 and the water temperature in all jars was 12°C.

At each sampling date 25 ml were taken after stirring each jar in the order - distilled water, Lambourne river, Wytham. The concentration of 2,4-D in each was determined by gas chromatography. Samples were taken on the day of treatment and subsequently at 4, 7, 9, 11, 14, 33, 44 and 51 days after treatment.

The results of this experiment are presented in Figure 1. To compare the concentrations at different sampling dates the difference between the concentration in the distilled water and that in the other waters has been expressed as a percentage of the 2,4-D concentration in the distilled water at each sampling date.

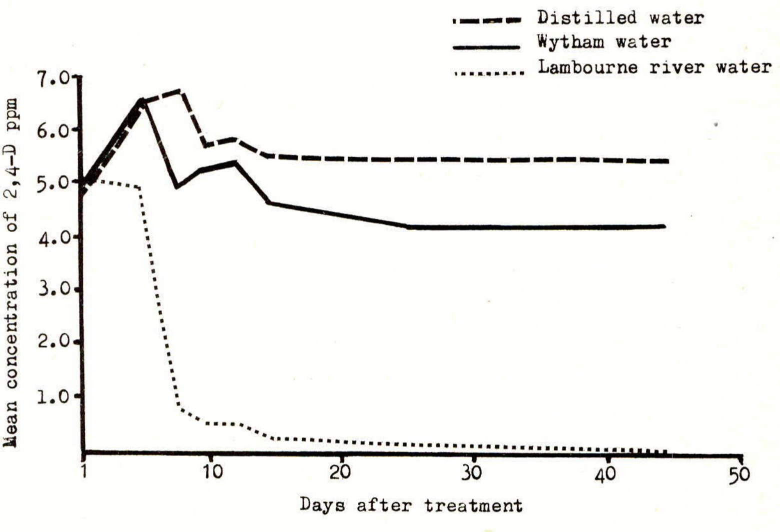

Figure 1: Experiment 1 - A comparison of the rate of inactivation of 2,4-D in Lambourne river, Wytham and distilled water.

In the water obtained from Wytham the inactivation of 2,4-D proceeded slowly until day 23 when it appeared to stop and about 75% of the herbicide persisted to day 51. In contrast breakdown of 2,4-D in the water from the Lambourne river was rapid and 90% had disappeared within 9 days. The rate of inactivation then seemed to drop and 2,4-D was still detected after 23 days, but it was no longer detectable by the 44th day after treatment.

Experiment 2.

In September fresh samples were taken from the same sites at Wytham and on the Lambourne river and the same treatments were applied but with two more added to investigate the rate of inactivation in water filtered through an asbestos pad in a Seitz microbiological filter. This treatment was an attempt to remove any micro-organisms that might cause breakdown of 2,4-D.

The experiment was again set up in the greenhouse with a minimum air temperature of 10°C. Immediately after treatment the first water samples were collected and the concentration of 2,4-D was determined by means of sorghum root bioassays. Subsequent samples were taken 7 and 15 days after treatment.

The results of this experiment are presented in Table 1. To compare the concentrations at different sampling dates the difference between the concentration in the distilled water and that in the other waters has been expressed as a percentage of the 2,4-D concentration in the distilled water at each sampling date.

Table 1.

Experiment 2 - Differences between the concentration of 2,4-D in the Wytham and Lambourne river water and in distilled water expressed as a percentage of the concentration of 2,4-D in distilled water

Number of days after treatment	1	7	15
Mean estimated concentration of 2,4-D in distilled water	6.1 ppm	7.95 ppm	6.1 ppm
Lambourne river water + 2,4-D			
unfiltered	+ 1.64%	- 5.24%	- 11.5%
filtered	0	- 5.9 %	- 11.5%
Wytham water + 2,4-D			
unfiltered	+ 4.9 %	+ 1.26%	- 8.2%
filtered	+ 4.9 %	- 6.3 %	- 11.5%
S.E.	11.5 %	6.3 %	5.7%

There was a gradual reduction in active 2,4-D as measured by bioassay in all of the treatments. When the deviation is expressed as a percentage of the concentration in distilled water it can be calculated that over 85% of the 2,4-D remained after 2 weeks in all the treatments. The rapid inactivation that took place in the Lambourne river water during the first week after treatment in Experiment 1 did not occur in either the filtered or unfiltered treatments.

Experiment 3.

The same 2,4-D treatments were compared using water collected from ponds on Port Meadow, Oxford which in earlier work had shown an ability to inactivate 2,4-D (Robson 1966).

The pondwater was collected in April, part of it was filtered through a microbiological filter and the experiment was set up in the same way as in Experiment 2 except that the initial concentration of 2,4-D was 1.0 ppm.

The concentrations of 2,4-D were again assessed by means of the sorghum root bioassay. Samples were taken 2, 7, 14 and 21 days after treatment. The results are given in Table 2 and show no reduction in 2,4-D concentration over the first three weeks. Fifty-six days after treatment a small quantity of soil obtained from a plot which had received MCPA regularly for a number of years in the experiment reported by Kirkland and Fryer (1966) and which was known to inactivate MCPA within 3 days, was added to one replicate of each of the treatments. Samples were taken eight days later and it was not possible to detect any active 2,4-D in any of the waters, whatever its original source, which had been treated with the soil (Table 2).

Table 2.

Experiment 3 - Concentration of 2,4-D in water (ppm)

No. of days after treatment	2	7	14	21	64
Pondwater + 1 ppm 2,4-D	0.97	0.87	0.91	0.90	0.89
Pondwater + 1 ppm 2,4-D with soil added on 56th day	0.93	0.90	0.88	0.92	0.00
Distilled water + 1 ppm 2,4-D	0.98	0.86	0.89	0.98	1.02
Distilled water + 1 ppm 2,4-D with soil added on 56th day	0.96	0.92	0.90	0.93	0.00
S.E.	0.035	0.04	0.035	0.045	0.07

A further experiment was carried out with water and soil from the same source. The soil was added 3 days after treatment and the initial concentration of 1.0 ppm 2,4-D was reduced to 0.08 ppm in the pond water and 0.06 ppm in distilled water within 4 days. The concentration in the pond and distilled water that did not receive the soil remained at 1.0 ppm and 1.15 ppm respectively.

DISCUSSION

This series of experiments has indicated that while 2,4-D can be inactivated rapidly in some surface waters it can also persist in an active form for long periods in others and also in the same waters at different times of the year. In the Wytham backwater which supports highly productive floral and faunal populations there was only a very slow degradation of 2,4-D in all samples tested, whereas in the less fertile water of the Lambourne river it rapidly disappeared in the first sample collected in May but not in that collected in September.

The reasons for these differences in rate of inactivation have not been established. However, the rapid de-toxification that followed the addition of the soil suggests that the factors responsible for the breakdown of MCPA in the soil are also capable of breaking down 2,4-D in water. The lag-phase and the subsequent rapid inactivation of 2,4-D reported in the previous work on the Port Meadow ponds (Robson 1966) and seen in the Lambourne river water in Experiment 1 of this series, is similar to that frequently found to occur in soils and thought to indicate a build-up in population of micro-organisms capable of decomposing 2,4-D (Audus 1960). This similarity suggests that the breakdown of 2,4-D in water may be caused by micro-biological activity and that the variations in rate of inactivation could be the result of the presence or absence of an active population of certain organisms. However, much more work is needed to clarify and explain these results and to study the mode of inactivation. It is only possible from the work so far completed to establish that the rate of 2,4-D inactivation in water varies and that there is no way at present of predicting how long the herbicide will remain in a phytotoxic form.

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THE EFFECT OF CONTACT AND SOIL-ACTING HERBICIDES ON THE YIELD OF PEAS IN NORTHERN IRELAND

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Summary Experiments are described in which both contact and soil-acting herbicides were applied to peas (var. Early Onward). Yields of marketable pods and of pods plus haulms showed that simazine, atrazine prometryne, lenacil, terbacil (5-chloro-3-t-butyl-6-methyluracil), linuron, propachlor, chlorbromuron, C 7019 (2-azido-4-isopropylamino-6-methylmercapto-S-triazine), UC 22463 (3,4-dichlorobenzyl-N-methyl carbamate) CP 50144 (2-chloro-2',6'-diethyl-N-(methoxy methyl) acetanilide), dinoseb amine, dinoseb acetate and dinoseb in oil can all be applied to this crop at appropriate doses without adverse effects. In some cases e.g. terbacil safety margins are small and in others weed control may be inadequate e.g. prometryne and dinoseb. The evidence suggests that simazine or atrazine at doses up to 1.0 lb/ac may be the most suitable herbicides for this crop under Loughgall conditions but a further examination of a number of soil-acting herbicides would appear to be desirable to confirm the most suitable treatment.

INTRODUCTION

In recent years substituted triazine herbicides have been used increasingly for weed control in peas and have tended to replace contact materials such as dinoseb amine. King (1966) and Cassidy (1966, 1967) have reported good results with prometryne applied as a pre-emergence treatment. Roberts and Wilson (1964) and Allott (1965), however, have produced evidence to indicate that prometryne may well provide the most satisfactory weed control when applied after weed emergence which in the case of peas would also mean after crop emergence. Due to the rapid weed growth that can follow the sowing of peas under Northern Ireland conditions and due to the fact that weather conditions can frequently prevent post-emergence treatments at the correct time the use of a pre-emergence application remained desirable at Loughgall. Experience with prometryne, however, suggested that this herbicide would not provide adequate results when applied as a pre-emergence treatment at doses up to 2.0 lb/ac. It was, therefore, decided to examine other soil-acting herbicides in this crop in an attempt to evaluate a more effective herbicide programme. In trials which were conducted annually for three years simazine was shown to be a promising pre-emergence herbicide in this crop. The results from these trials are reported in this paper.

METHOD AND MATERIALS

Experiments 1, 2 and 3 which were conducted in 1966, 1967 and 1968 respectively were designed to examine the effect of a range of herbicides on the yield of peas. The herbicides were applied as emulsifiable concentrates or as wettable powders, according to formulation, in the equivalent of 50 gals of water/ac, using a pressure retaining knapsack sprayer. Herbicide doses are presented in terms of lb/ac a.i.

Herbicides were applied as pre-emergence treatments with a few exceptions which are specified in the tables.

Treatments were arranged in randomised blocks with four replicates in experiment

1 and three in experiments 2 and 3. The weight of marketable pods and the total weight of pods and haulms were recorded.

Fertilizer treatment, pest and disease control followed normal practice.

The soil on the experimental sites had the following physical analyses:

	% Coarse sand	Fine sand	Silt	Clay	Loss on ignition
Experiment 1	17.8	36.0	11.1	27.2	10.6
Experiment 2	17.4	39.0	12.7	23.4	9.3
Experiment 3	29.9	41.2	8.8	11.3	6.2

RESULTS

Experiment 1

The mean yields of peas are presented in Table 1 from which it is evident that although the weights of both marketable pods and the total weights of pods and haulms show some variation, there are no significant treatment differences. On this evidence it would appear that both simazine and atrazine at doses up to 1.0 lb/ac can be used as pre-emergence treatments under Loughgall conditions. Weed records are not presented, but weed scores indicated that these treatments also provided the most satisfactory weed control. Where yields were apparently reduced lower yields coincided with increased weed competition.

Table 1

Mean yield of peas (var. Early Onward) following pre- or post-emergence herbicide treatments

	lb/ac	Mean wt. of pods + haulms lb/plot	Mean wt. of marketable pods lb/plot
1. No herbicide		8.84	4.56
2. Simazine	0.5	7.97	3.47
3. Simazine	1.0	11.75	5.69
4. Simazine	0.75	5.78	2.78
5. Propachlor	4.5	5.37	2.78
6. CP 50144	3.5	8.37	4.28
7. GS 14260*	1.0	12.75	7.34
8. Methoprotryne + simazine	1.0	8.81	4.47
9. Methoprotryne	1.0	10.50	5.37
10. Atrazine	1.0	7.56	3.25
11. Pentanochlor	4.0	6.81	3.15
12. Dinoseb amine	2.5	6.25	3.12
13. Dinoseb acetate	2.5	7.04	4.15
14. Dinoseb in oil	1.0	7.15	3.81
S.E. of a difference between two means		2.94	1.63
Variance within treatment means		N.S.	N.S.
Error d.f.	39		

*2 methylthio-4-ethylamino-6 tert. butylamino-S-triazine

Note: Treatments 4, 11, 12, 13 and 14 were applied post-emergence at the 2 - 3 node stage and when the weeds were at variable growth stages up to the 2 - 3 true leaf stage.

Experiment 2

The mean weights of marketable pods and of pods and haulms together are presented in Table 2, from which it is evident that differences in the mean weights of marketable pods are generally not significant. It is apparent that yield was depressed when no herbicide was applied. This was due to weed competition. There are also indications that lenacil at 2.0 lb/ac, GS 14260, methoprotryne and CP 50144 depressed yield slightly. These observations are supported by the weights of the haulms and pods together. It is noticeable that simazine, atrazine, prometryne and linuron at 1.0 lb/ac, chlorbromuron at 2.0 lb/ac and propachlor at 7.0 lb/ac had no adverse effects. Weed scores six weeks after the herbicide applications showed that simazine, atrazine and lenacil at 2.0 lb/ac gave the most efficient weed control. Simazine was slightly superior to the other herbicides.

The principal weeds on this site were:

Stellaria media chickweed, Senecio vulgaris groundsel, Poa annua annual meadow grass, Capsella bursa-pastoris shepherd's purse.

Experiment 3

The mean weights of marketable pods and of pods and haulms together are presented in Table 3 from which it is evident that yields were unaffected by the treatments. Weed scores, however, which were recorded five weeks after the treatment applications suggest that simazine, atrazine, lenacil and a combination of terbacil and linuron were the most effective herbicides in controlling the predominant weeds.

Table 2

Mean yield of peas (var. Early Onward) following pre-emergence herbicide treatments

Herbicide dose	lb/ac	Mean wt. of pods + haulms lb/plot	Mean wt. of marketable pods lb/plot
1. Unsprayed control		16.29	7.37
2. Simazine	1.0	33.53	14.37
3. Atrazine	1.0	30.04	12.54
4. Prometryne	1.0	29.16	12.91
5. Prometryne	2.0	23.57	10.12
6. Lenacil	1.0	25.28	11.29
7. Lenacil	2.0	21.49	8.62
8. Linuron	1.0	32.66	12.72
9. Chlorbromuron	2.0	34.20	13.49
10. Propachlor	7.0	33.45	14.87
11. GS 14260	1.0	22.49	9.79
12. Methoprotryne	1.0	15.20	6.42
13. CP 50144	2.0	21.95	8.83
S.E. of a difference between two means		5.74	2.80
Variance within treatment means		*	N.S.
Error d.f.	26		

Table 3

Mean yield of peas (var. Early Onward) and weed scores following pre-emergence herbicide treatments

Herbicide dose		lb/ac	Mean wt. of pods + haulms lb/plot	Mean wt. of marketable pods lb/plot	Mean weed scores
1.	Unsprayed control		71.52	28.92	4.33
2.	Simazine	1.0	66.20	28.17	1.00
3.	Atrazine	1.0	65.25	29.33	0.33
4.	Prometryne	1.5	68.10	30.28	2.66
5.	Prometryne	3.0	70.00	28.50	1.66
6.	Lenacil	1.0	74.07	30.58	1.00
7.	Terbacil	0.125	72.40	31.38	2.00
8.	Terbacil Linuron	0.125) 0.75)	71.60	30.00	1.00
9.	Linuron	1.0	72.92	28.75	1.66
10.	Propachlor	7.0	65.03	29.62	1.66
11.	Chlorbromuron	2.0	67.83	27.17	1.00
12.	GS 14260*	1.0	72.17	30.00	2.66
13.	Methoprotryne	0.5	64.17	24.08	4.00
14.	CP 50144	1.5	72.33	27.75	1.66
15.	C 7019	1.0	65.73	26.42	3.33
16.	C 7019	2.0	69.17	33.58	2.00
17.	UC 22463 (liquid)	3.0	64.23	21.89	3.33
18.	UC 22463 (granular)	3.0	62.17	22.83	2.33
S.E. of a difference between two means			5.54	3.18	-
Variance within treatment means			N.S.	N.S.	-
Error d.f.		34			

Note 1: The principal weeds on this site were:

Spergula arvensis spurrey, Poa annua annual meadow grass, Stellaria media chickweed, Polygonum persicaria redshank, Fumaria officinalis fumitory, and Galeopsis tetrahit hempnettle.

2. Weed scores 0 - 5 0 = No weeds 5 = Weeds dominant

3. Treatments 15 and 16 were applied as pre- and post-emergence treatments.

DISCUSSION

The relative selectivity of a number of contact and soil-acting herbicides is well illustrated by these trials. The results suggest that simazine and atrazine can both be used as pre-emergence herbicides in peas without crop damage under conditions of soil and climate at Loughgall. It is also evident that these herbicides can provide a better weed control than the other materials tested as shown by the weed scores in Table 3. Even at a dose of 3.0 lb/ac prometryne tended to be less effective as a herbicide, apart from which the cost of such an application would be uneconomic. These trials have also shown that other herbicides such as a mixture of terbacil and linuron, chlorbromuron, lenacil, CP 50144 and linuron can give good results in peas and merit further investigation.

Where soil-acting herbicides such as simazine are used in a short term crop such as peas the problem of the potential effect of soil residues on subsequent crops inevitably arises. It has been shown, however, that under Loughgall conditions the danger of a carry over residue from one year to the next is minimal (Allott 1968). At Loughgall it was shown to be possible to follow a simazine treated pea crop with overwintering transplanted broccoli without adverse effects even when a repeated application of the herbicide was applied to the broccoli after transplanting.

Whilst a number of soil-acting herbicides have given as good or better results in peas than prometryne further work is required with respect to crop tolerance and the soil-residue position, under as many and varied conditions of soil and climate as possible, before universal recommendations for their use can be made

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WEED CONTROL TRIALS IN PEAS; 1964 - 1968

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Summary Results are presented of trials carried out over the period 1964-67 in which pre-emergence application of prometryne and linuron was compared with the standard treatment dinoseb-amine, applied post-emergence. These results show that both herbicides have a high degree of crop selectivity and can give more effective weed control than dinoseb-amine.

Of a number of new herbicides examined in 1967, 1968, 2-azido-4-isopropylamino-6-methylthio-1, 3, 5-triazine (C 7019) was the most promising. Peas showed considerable tolerance to both pre- and post-emergence applications of this compound.

INTRODUCTION

The problem of obtaining successful weed control with dinoseb formulations, particularly in early sown pea crops has been described by King (1966).

In Ireland during April and early May, low temperatures and wet conditions often occur and in most years weed control with dinoseb applied during this period is generally unsatisfactory. For these reasons extensive investigations have been carried out since 1964 to find alternative, more effective and reliable herbicides for the pea crop. Prometryne and linuron were the main herbicides tested over this period and the results are summarised in this report.

METHOD AND MATERIALS

Two types of trials were conducted:-

(a) Replicated small plot trials of randomised block design. Plot size varied from 10-30 yd^2. All applications were made with an Oxford Precision Sprayer or a pressure retaining knapsack in a volume of 40 gal/ac.

(b) Large unreplicated plots (0.25 ac per treatment) in commercial crops. A tractor field sprayer or knapsack was used. Treatments were applied in a volume of 40-50 gal/ac.

Time of application of pre-emergence treatments varied from immediately after drilling to 3-4 days before crop emergence but was generally 10-14 days after sowing in early crops and 4-7 days in late crops (Mid.April - Mid. May). Dinoseb-amine was applied usually at the 3-6 leaf stage when seedlings were still small.

In all trials at least two visual assessments of treatment effect on crop and weeds were made. Replicated trials were harvested by hand and a small plot viner was used to obtain yield data. Some difficulty was experienced in obtaining satisfactory yield figures from the large unreplicated plots. These were harvested and vined as for the commercial crop. All doses are given as lb/ac a.i.

RESULTS

1964

Prometryne at doses of 1.0 and 2.0 lb and linuron at 0.5 and 1.0 lb were examined in 4 replicated trials at different sites.

No crop damage occurred with the lower doses of these herbicides at any site. Slight temporary growth check and marginal scorching of the basal leaves was evident where the higher rates were used, particularly on a gravelly fine sandy loam at site D (clay 7.9%). At the latter site this effect persisted and yields were reduced compared to plots treated at the lower doses (Table 1). Weed populations were low at sites B, C and D and although pre-emergence treatments gave more effective weed control than dinoseb there were no marked differences in yield between plots. At site A, prometryne treated plots considerably outyielded those sprayed with linuron. This was due to a very heavy infestation of *Fumaria officinalis* which linuron failed to control. Linuron, however, was more effective against Veronica spp. and Lamium purpureum at this site.

Table 1
Effect of treatments on crop and weeds at 4 sites - 1964

Treatment	Dose (lb/ac)	Site A Medium loam clay 25.6%		Site B Coarse sandy loam clay 16%		Site C Coarse sandy loam clay 15.2%		Site D Gravelly fine sandy loam clay 7.9%	
		Yield (cwt/ac)	Weed rating	Yield (cwt/ac)	Weed rating	Yield (cwt/ac)	Weed rating	Yield (cwt/ac)	Weed rating
Prometryne	1.0	34	7.3	28	7.9	21	8.5	23	9.3
"	2.0	37	9.0	28	9.0	20	9.3	17	9.9
Linuron	0.5	21	5.2	27	7.9	22	8.4	19	8.8
"	1.0	27	6.0	33	9.0	23	8.1	15	9.8
Dinoseb-amine	1.85	28	6.5	29	3.5	21	7.0	20	8.9
S.E.(df=51)		3.4		2.0		1.3		1.7	

Rating scale : Weeds; 0(dense cover of weeds) - 10(no weeds).

1965

Work on weed control in peas was considerably expanded in 1965. Four replicated and 35 large plot observation trials were carried out. The latter trials were conducted on many different soil types in the main pea growing areas using prometryne 1.0 and 1.5 lb and linuron 0.75 lb. Soils varied from coarse sandy loams to medium loams with organic matter ranging from 2.9 - 8.5% and clay from 8-25%. Assessments made during the growing season indicated that these treatments were highly selective. On the lighter soils, slight chlorosis and yellowing was apparent in the early stages of growth, particularly in plots treated with prometryne 1.5 lb. At one site on a light stony soil (clay 10%, coarse sand+gravel 44.2%) and where the seed was sown less than 1 in. deep, severe chlorosis and approximately 10% reduction in plant stand occurred with this treatment.

Effective weed control was maintained throughout the growing season where prometryne 1.5 lb and linuron 0.75 lb were applied. With prometryne 1.0 lb, weeds tended to become established before harvesting, particularly on the medium-heavy soils. Control of Sinapis arvensis and Polygonum persicaria was generally better with linuron than prometryne.

Although it was only possible to obtain yields from a small percentage of these trials, it was evident at all sites that crops treated with prometryne or linuron had greater yield potential than those sprayed with dinoseb-amine by growers in the areas adjoining the trials. This was due to the more effective weed control given by the pre-emergence treatments and also to the lack of tractor wheel damage. Results obtained are given in Table 2.

In the replicated trials prometryne at doses of 1.0, 1.5 and 2.0 lb and linuron at 0.5, 0.75 and 1 lb were tested and compared with post-emergence application of dinoseb-amine 1.85 lb. On the lighter soil types (coarse sandy loam) at sites F, G, H, slight marginal chlorosis and check to growth was evident with the higher doses of prometryne and linuron and yields were generally not as high as with the lower doses (Table 3). Although no visible crop injury effects were noted at site E on the heavier soil type there was also a tendency for yields to be reduced at the higher doses. There was no marked difference in weed control between treatments at any site. Even the lower doses used gave satisfactory control of Stellaria media, Chenopodium album, Polygonum persicaria and Spergula arvensis which were the main species occurring at sites F, G and H. Fumaria officinalis was one of the principal weeds at site E and as a result weed control was more satisfactory with prometryne. Dinoseb-amine also gave good weed control except at site H where weeds were advanced in growth when this treatment was applied.

Table 2

Yield and assessments of crop vigour and weed control - 1965

Treatment	Dose (lb/ac)	Mean yield (cwt/ac)	No. of sites	Assessments at 2-4 leaf stage (mean of 16 sites) Crop	Weed	Assessments prior to harvesting[1] (mean of 16 sites) Crop	Weed
Prometryne	1.0	39	9	9.6	8.5	9.9	7.1
"	1.5	32	10	9.0	9.0	9.7	8.8
Linuron	0.75	40	10	9.1	9.2	9.7	8.5

[1] Rating scale : Crop; 0(complete kill)-10(no damage). Weeds; 0(dense cover of weeds)-10(no weeds)

Table 3

Effect of treatments on yield and weeds at 4 sites-1965

Treatment	Dose (lb/ac)	Site E Yield (cwt/ac)	Site E Weed rating	Site F Yield (cwt/ac)	Site F Weed rating	Site G Yield (cwt/ac)	Site G Weed rating	Site H Yield (cwt/ac)	Site H Weed rating
Prometryne	1.0	34	8.1	54	7.4	32	9.9	28	8.8
"	1.5	31	7.9	52	8.5	22	10.0	24	8.6
"	2.0	28	9.0	49	8.5	26	10.0	26	9.1
Linuron	0.5	27	6.6	48	9.0	26	10.0	29	8.6
"	0.75	29	7.4	59	9.4	24	10.0	23	9.1
"	1.0	24	7.3	50	9.5	29	9.9	24	9.3
Dinoseb-amine	1.85	29	9.4	54	8.0	26	-	26	4.5
S.E.(df=57)		4.3		3.7		4.0		2.3	

[1] Weed rating : 0 (dense cover of weeds) - 10(no weeds).
Ratings taken prior to harvesting at sites E, F and H and at 3-4 leaf stage prior to application of dinoseb at site G).

1966

Prometryne and linuron were again tested at doses of 1.0, 1.5 lb and 0.75 lb respectively in 14 large unreplicated plot trials in 1966. These were sited principally in County Carlow on the lightest soils available in the area. Soils were of the coarse sandy loam type having a clay content ranging from 8-14%, silt (0.002-0.2 mm) 21-27%, and coarse sand (0.06-2.0mm) 22-37%. Organic matter content varied from 2.9 - 8.4%. Excellent crop selectivity was shown by the treatments at all sites and yield data obtained from 6 trials indicated no differences. Prometryne 1.0 lb did not completely control *Polygonum persicaria*, *Sinapis arvensis* or *Polygonum aviculare* at some sites. However, weed control at harvesting was commercially acceptable and was superior to that obtained with dinoseb-amine applied post-emergence by growers in the adjacent commercial areas. At the higher dose of 1.5 lb all annual weeds which occurred in these trials, with the exception of Euphorbia helioscopia were effectively controlled. *Brassica rapa* ssp. *campestris* which was prevalent at one site showed partial resistance to linuron. However, taking all sites into consideration, linuron 0.75 lb was equally as effective as prometryne 1.5 lb.

1967

Prometryne and linuron at normal and twice normal doses were included in two replicated trials on coarse sandy loam soils in the Carlow area in 1967. The main purpose was to compare them with two new herbicides, 3,4-dichlorobenzyl-N-methyl carbamate (UC 22463) and a mixture containing ametryne 25% + trietazine 16.6% (EPS 269/1) - which has shown promise in logarithmic screening trials the previous year. Results are given in Table 4.

Table 4

Yield of vined peas (cwt/ac) - 1967

Herbicide	Prometryne		Linuron		UC 22463		EPS 269/1		Dinoseb-amine	Control	S.E.
Dose (lb/ac)	1.25	2.5	0.75	1.5	3.0	6.0	0.83	1.66	1.85		
Site I	59	54	59	50	57	55	n.u.	n.u.	52	56	2.52 (df= 21)
Site K	28	18	20	2	44	5	43	38	31	24	7.3 (df= 27)

n.u. = not used

Slight reduction in crop vigour was evident in plots treated with the higher doses of all herbicides at site I, but yields were not significantly reduced compared to plots sprayed with dinoseb-amine post-emergence. When pre-emergence treatments were applied at site K approximately 80% of the crop had emerged and very severe scorch and plant kill resulted, particularly with linuron 1.5 lb and UC 22463 6.0 lb. Damage was less severe with prometryne. Although the crop received a severe check from UC 22463 3.0 lb, it recovered well and yields were higher than those obtained with dinoseb-amine applied at the 6 leaf stage. EPS 269/1 showed good selectivity even at the higher dose of 1.66 lb.

All treatments gave good weed control at site I where the main weeds were Stellaria media, Polygonum persicaria and Sinapis arvensis. Polygonum spp and Poa annua were the prevalent species at site K. Prometryne and EPS 269/1 gave slightly better control of Polygonum aviculare and P. convolvulus than UC 22463 or linuron.

1968

Following the results obtained in 1967, UC 22463 and EPS 269/1 were again examined for pre-emergence application in two replicated trials on light coarse sandy loam soils in the Carlow area, (sites N,O). Also included were terbacil and 2-azido-4-isopropylamino-6-methylthio-1,3,5-triazine (C7019). In two other trials N-(4-bromo-3-chlorophenyl)-N-methoxy-N'-methylurea (C6313) was also tested at 1.5 and 3.0 lb/ac (sites L,M). Prometryne 1.25 lb and linuron 0.75 lb which were included in all trials as standard treatments showed excellent crop selectivity except at site M (Table 5) where on a very free draining light soil, crop check occurred following heavy rain after application. Although prometryne caused less damage than linuron, yields were significantly reduced as compared with untreated control plots. The crop in this trial was sown late and was harvested at an immature stage. It is possible that if the peas had been allowed to reach proper maturity differences in yield would not have been so marked.

At this site, C 6313 1.5 lb caused more severe damage than linuron, and at 3.0 lb, stand was reduced and yield was significantly lower than in other treated and untreated plots (Table 5). At both sites weed populations were low. The most prevalent species were Spergula arvensis, Matricaria matricarioides and Polygonum persicaria at site L and Sinapis arvensis at site M. All treatments gave complete control of these species.

In the other two trials C 7019 was the most promising of the newer herbicides tested. No crop damage was evident where this herbicide was applied at a dose of 4.0 lb. Weed control, however, at the lower dose of 2.0 lb was not as effective as with prometryne 1.25 lb or linuron 0.75 lb (Table 6). Spergula arvensis, Polygonum persicaria and Sinapis arvensis which were the prevalent weeds at these sites were not completely controlled with this treatment.

Severe crop check was evident in plots treated with UC22463 and EPS 269/1 following emergence and at site O where the clay and organic matter content were low, yields were reduced with the higher doses of these treatments. Both herbicides gave good weed control.

Table 5

Yield of vined peas, plant and weed counts - 1968

Herbicide	Dose (lb/ac)	L (O.M.= 3.6% Clay = 17.2%) Yield (cwt/ac)	Peas per 10 ft^2	M (O.M. = 4.3% Clay = 8.9%) Yield (cwt/ac)	Peas per 10 ft^2
Prometryne	1.25	59.3	86	12.0	55
Linuron	0.75	56.0	92	8.2	50
[1]C 6313	1.5	52.5	90	5.7	45
"	3.0	33.9	69	0.9	24
Control		53.8	82	17.5	49
S.E.(df=12)		2.04	6.0	1.75	4.1

Table 6

Yield of vined peas, plant and weed counts-1968

Herbicide	Dose (lb/ac)	N (O.M.=5% Clay=10.6%) Yield (cwt/ac)	Peas per 10 ft^2	O (O.M.=3.5% Clay = 9.0%) Yield (cwt/ac)	Peas per 10 ft^2	Weeds/10 ft^2 *Spergula arvensis*	*Sinapis arvensis*	*Polygonum persicaria*
Prometryne	1.25	61.0	64	59.9	67	1	0	0
Linuron	0.75	64.2	66	52.3	81	0	0	0
UC22463	4.0	56.3	63	59.5	81	5	0	3
"	8.0	51.0	74	46.6	61	0	0	0
EPS269/1	0.83	58.2	66	66.6	73	0	0	0
"	1.66	56.7	65	44.9	66	0	0	0
[1]C 7019	2.0	65.2	69	54.2	79	28	5	12
"	4.0	56.6	61	60.6	75	3	1	2
Terbacil	0.125	69.4	70	53.4	68	30	0	0
"	0.25	65.3	71	52.3	66	18	0	0
Control		54.9	61	54.4	67	184	45	49
S.E.(df=33)		4.69		3.99				

Terbacil 0.25 lb severely checked the crop at site O, but only slight vigour reduction in the early growth stages was observed at a dose of 0.125 lb. Although yield was slightly lower than untreated control plots at this site this treatment gave the highest yield at site N. *Spergula arvensis* was the only species not completely controlled with terbacil even at 0.25 lb.

Two further trials were carried out in 1968 to examine C7019, phenmedipham and 3,5-dibromo-4-hydroxy-benzaldoxime-0-(2,4-dinitrophenyl)-ether(C9122) for post-emergence application in peas. Treatments were applied at the 3-leaf stage when the weeds were in the cotyledon-2 rough leaf stage. C7019 at 2.0, 4.0 lb was very selective and the only damage observed was very slight scorch of the leaf margins for a few weeks after application. C9122 at 1.5 and 3.0 lb caused severe crop kill at both doses. Phenmedipham at 1.0 and 2.0 lb severely scorched the crop and vigour was significantly reduced. *Capsella bursa pastoris* and *Polygonum aviculare* were resistant to C7019 while phenmedipham gave poor control of *Poa annua* and *Polygonum aviculare*.

DISCUSSION

The results of the many trials carried out with prometryne and linuron from 1964-1968 indicate that both herbicides have a high degree of crop selectivity and can give effective season long weed control in peas. Compared with post-emergence application of dinoseb-amine weed control was, in most trials, much superior.

These trials were conducted mainly on light sandy loams in the principal pea growing areas. Although these soils were light in texture they had a relatively high organic matter content ranging from 3 to 8%.

This factor has undoubtedly contributed to the high crop tolerance obtained in these trials with prometryne and linuron at doses up to 2.5 and 2.5 lb/ac respectively.

Although little differences were observed or recorded in selectivity between prometryne 1.5 lb and linuron 0.75 lb in the majority of these trials the results at site M would suggest that prometryne is the safer treatment. At this site on a light soil linuron 0.75 lb caused appreciably more injury than prometryne 1.25 lb when heavy rain followed application. This is also supported by the greater damage which occurred with linuron at site K where peas were emerging at time of application. King (1964) has also reported greater selectivity with prometryne than linuron on light soils.

Both herbicides controlled a wide range of annual weeds but there were differences in the susceptibility of some species. Linuron generally gave better control of Sinapis arvensis, Veronica spp. and Polygonum persicaria whereas prometryne was more effective against Fumaria officinalis and Brassica rapa ssp. campestris.

Following the good results obtained in these trials, prometryne was recommended for commercial use in Ireland in 1967. Approximately 2,000 acres were treated with this herbicide in 1968. Weed control has been entirely satisfactory and no crop damage was reported. Linuron was also used on a limited commercial scale in 1968 with good results.

C7019 was the most promising of the newer herbicides tested. This material was very selective pre-emergence and no damage was caused at a dose of 4.0 lb/ac. At 2.0 lb weed control was not as effective as with prometryne 1.25 lb or linuron 0.75 lb. This herbicide merits further investigation, particularly on very light soils low in organic matter where greater crop tolerance might be expected than with prometryne or linuron. However, the excellent post-emergence selectivity shown by C7019 suggests that it may have greater potential as an early post-emergence treatment where its combined contact and residual properties can be utilised more fully.

Terbacil at 0.125, UC22463 at 4.0 and EPS269/1 at 0.83 lb showed useful selectivity, but further investigation is required on a wider range of soil types to determine the efficiency of these treatments compared with prometryne or linuron. The results obtained in two trials with C6313 indicate that this herbicide has not sufficient selectivity at doses necessary for effective weed control on light soils.

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Proc. 9th British Weed Control Conf. 1968

EXPERIMENTS WITH HERBICIDES IN PEAS AND FRENCH BEANS - A PROGRESS REPORT

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Summary Four experiments are reported in which a number of newer herbicides were compared with dinoseb amine and prometryne on peas and French beans. In peas, prometryne and dinoseb amine gave excellent results in both seasons, and C7019 showed promise both as a pre and post-emergence treatment. C6313 gave a high level of weed control in both years, but in 1968, after heavy rain, checked crop growth. However, none of the herbicide treatments significantly reduced crop yields in comparison with untreated controls in 1967 or 1968. In French beans, dinoseb amine applied pre-emergence gave the best weed control, followed closely by dinoseb acetate plus monolinuron. Lenacil, propachlor, trifluralin and prometryne did not control weeds effectively for the duration of the crop. Lenacil checked the crop slightly in 1967, but there were no significant differences in yield between herbicide treatments and untreated controls in either year.

INTRODUCTION

Experiments were commenced in 1967 to evaluate some newer residual herbicides for use in peas and French beans under Scottish conditions. French beans are not grown to any extent in Scotland, but the imminent release from S.H.R.I. of a new variety bred for northern conditions made it desirable to study the performance of available herbicides on this variety.

METHODS AND MATERIALS

All four experiments were carried out on a medium sandy clay loam soil. Treatments were replicated at least four times in randomised block layouts. The herbicides evaluated and the dosage rates applied in lb a.i./ ac. are shown in the appropriate tables. Herbicides were applied in 40-80 gal. water/ac with an Oxford Precision Sprayer or a Mistifier Knapsack Sprayer. Peas were drilled in rows 4 in. apart in beds 5 ft wide and 16 ft long. The eventual population in 1967 averaged 8-10/ft ^{2} (variety Kelvedon Wonder) and in 1968 (variety Dark Skinned Perfection) 11-12/ft^2. Pea germination counts were made on 2 or 3 x 1 yd^2 plot. Beans (variety Glamis) were drilled in $1\frac{1}{2}$ ft rows each 18 ft long in 3-row plots with a shared discard row between plots. Germination counts were made on 2 or 3 rows/plot. Weed counts were made on 2 x 1 yd^2/plot. Assessments of percentage weed control (100 = no weeds, 70 = minimum acceptable level of weed control) were made at regular intervals.

RESULTS

Peas 1967 Treatments are shown in Table 1. The crop was drilled on 2nd May, and the pre-emergence herbicides were applied on 8th May. When the dinoseb amine treatment was applied and the control plots were handweeded on 12th June, weeds on the untreated plots averaged 30% ground cover and the peas were 4-6 in. high. Table 1 shows total weeds present at this stage. All treatments gave excellent control although N-(4-bromo-3-chlorophenyl)-N'-methoxy-N'methyl urea (C6313) did not completely control Fumaria officinalis and 2-azido-4-isopropylamino-6-methylthio-s triazine (C7019) allowed a few plants of Poa annua to emerge. The crop developed rapidly thereafter and remained very clean until harvested on 15th August. No treatment had any visible adverse effect on the crop and differences between treatments in germination counts and weight of peas vined were not statistically significant (Table 1). Nor were total weight of plants harvested, average vine length and weight of peas/20 pods.

Table 1

Peas 1967. Weed and Crop records.

Treatment	Dosage rate lb/ac	Total Weeds /2yd^2 12/6/68	Germination /2yd^2 12/6/68	Wt peas vined lb/plot
Control	-	451	158.5	7.67
Dinoseb amine	2.00	450*	183.8	7.72
Prometryne	1.25	8	193.3	7.87
C6313	2.00	13	159.8	6.90
C7019	2.00	27	191.8	8.70
S.E. Mean			± 20.2	± 0.63
Coeff of variation %			23.4	16.2

*Not yet treated

Peas 1968 The crop was drilled on 16th April and the pre-emergence herbicides were applied on 23rd April. One set of control plots was kept weed-free and the other left untreated.

Table 2 shows the total weeds on 3rd June immediately before the post-emergence herbicides were applied, the crop being 4-6 in. high at this time. All pre-emergence herbicides gave excellent control. The least effective was the 2lb/ac rate of C7019 and the most effective was the 3lb/ac rate of C6313. Fumaria officinalis again proved rather resistant to C6313, and to the lower rate of C7019. The latter treatment also failed to eliminate Poa annua, Lamium amplexicaule and Veronica spp. The level of overall weed control in the experiment was so high, however, that detailed comparisons are not justified. C7019 at both rates and dinoseb amine at the slightly lower rate used in 1968 were highly effective as post-emergence treatments, most weeds being burned off within a few days. Even on the totally unweeded plots, the crop completely smothered the weeds by late June and virtually none were present on any plot at harvest (15th August).

No signs of damage attributable to herbicides were visible up to 2nd May when the crop was ½-1 in. high. Later, after heavy rain, chlorosis which led to some plant loss, was caused by the 3lb/ac rate of C6313 and to a lesser extent by the 1.5 lb/ac rate. There were no visible effects on the crop of post-emergence treatment with dinoseb amine or with C7019 at the 2lb/ac rate, but the 4lb/ac rate caused the crop to turn a lighter shade of green for a few days.

There were no significant differences between treatments in germination counts taken on 16th May, weight of peas vined or tenderometer reading at harvest (Table 2). Nor were there significant differences in weight and number of plants harvested or average plant weight.

Table 2

Peas 1968. Weed and Crop records.

Treatment	Dosage rate lb/ac	Total weeds /2yd^2 3/6/68	Germination count/3yd^2 16/5/68	Wt peas vined oz/plot	Tenderometer reading at harvest
Weedfree	-	-	314.3	238.8	135.8
Unweeded	-	522	314.5	248.3	135.7
C6313 Pre-emergence	1.50	17	307.3	214.3	130.4
C6313 Pre-emergence	3.00	7	297.8	204.3	120.3
C7019 Pre-emergence	2.00	118	328.8	246.5	147.2
C7019 Pre-emergence	4.00	13	305.0	237.3	161.3
Prometryne Pre-emergence	1.25	14	329.8	233.3	133.8
C7019 Post-emergence	2.00	418*	318.8	219.5	143.4
C7019 Post-emergence	4.00	472*	331.5	265.5	136.9
Dinoseb amine Post-emergence	1.85	605*	335.5	279.0	131.8
S. E. Mean			± 12.4	± 24.6	± 18.1
Coeff of variation %			7.8	20.6	26.3

*Not yet treated

There was a tendency for plots treated with C6313, particularly at the higher dosage rate, to have lower values for number of plants harvested, yield of peas, and tenderometer reading. Plants on these plots were also slightly heavier, suggesting that some compensation may possibly have taken place for those plants killed earlier.

French beans 1967 The crop was drilled into a stale seedbed on 26th May and the residual herbicides applied on 30th May after the application of paraquat/diquat to burn off seedling weeds. No adverse effects of herbicide treatment were noted at this time but a few days later, chlorosis was noted on plots treated with lenacil and a small number of plants died. This coincided with a period of heavy rain.

Table 3 gives the percentage weed control on 6th July. Plots treated with lenacil were hoed the next day; those treated with prometryne and propachlor were not hoed until they had fallen below 70% weed control two weeks later. The dinoseb amine treatment did not require hoeing before harvest but a few of the larger weeds were hand-pulled on 7th August. The main resistant weeds on all herbicide plots were *Fumaria officinalis*, *Stellaria media*, and *Polygonum convolvulus* and the date of hoeing was largely determined by the size and number of these species. At harvest (August 23rd) the lenacil treatment produced the lowest weight of plants (less pods) and weight of marketable pods/plot but neither these nor any individual plant weight or pod measurements showed significant difference between herbicide treatments and the untreated control. Germination counts and yield of marketable pods are given in Table 3.

Table 3

French beans 1967. Weed and crop records.

Treatment	Dosage rate lb/ac	% weed control 6/7/67	Germination count/3 crop rows 15/6/67	Wt Marketable pods cwt/ac
Control	-	-	268	85.4
Dinoseb amine	3.7	96	270	87.7
Prometryne	1.0	85	274	88.2
Propachlor	3.9	86	289	88.4
Lenacil	1.6	70	271	81.9
S.E. Mean			± 9	±3.0
Coeff of variation %			8.0	8.5

French beans 1968 The crop was drilled on 28th May. There was no opportunity to use the stale seedbed technique due to unfavourable soil conditions. Trifluralin was incorporated to 2 in. depth by rotovator just prior to drilling and the other herbicide treatments were applied just after the first weeds had emerged. No adverse effect of any herbicide treatment was noted at any time. The hoeing of the control plots was delayed by bad weather and weeds were level with the crop before they could be removed. As a result, growth on the control plots was retarded for some time afterwards. Top dressing the experiment with nitrogen assisted recovery on these plots but by harvest time (23rd August) the check was still visible. Hoeing was a little delayed on plots treated with trifluralin and prometryne and weed competition may have slightly checked the crop here also. Table 4 shows the percentage weed control on these plots the day before they were hoed. Chenopodium album, Matricaria spp. and Capsella bursa-pastoris were the main weed species resistant to trifluralin, while Fumaria officinalis and Stellaria media were only partially controlled by prometryne. Plots treated with dinoseb amine and dinoseb-acetate plus monolinuron did not become sufficiently weedy to require hoeing or hand-weeding. At harvest, dinoseb amine maintained a slightly higher percentage weed control than dinoseb acetate plus monolinuron. There were no significant differences between treatments in germination counts, weight of plants or marketable pods harvested, pod size or percentage unmarketable pods, although plant weights were slightly lower on plots treated with trifluralin and on control plots. Germination counts and yield of marketable pods are shown in Table 4.

Table 4

French beans 1968. Weed and crop records.

Treatment	Dosage rate lb/ac	% weed control 24/7/68	Germination count/2 crop rows 28/6/68	Wt Marketable pods cwt/ac
Control	-	-	197	60.3
Dinoseb amine	3.7	83	196	55.6
Prometryne	1.25	66	193	56.8
Dinoseb acetate plus monolinuron	2.5	76	202	56.5
Trifluralin	1.0	63	204	57.1
S.E. Mean			± 5	± 2.4
Coeff of variation %			4.7	8.4

DISCUSSION

Peas King (1966a) reported favourably on the effectiveness and crop safety of prometryne for weed control in peas. Results in these two trials and in general application over pea cultural and varietal trials at S.H.R.I. in 1967 and 1968 confirm the excellent performance of this herbicide. Neither of the newer materials applied pre-emergence at the lower dosage rate tested showed any worthwhile advantage over prometryne on the weed spectrum present, and there is some doubt as to whether they would have been able to give adequate control of Fumaria officinalis without the aid of a vigorous crop. The wide range of other species not completely controlled by the pre-emergence application of C7019 at 2lb/ac in these trials suggests that investigations of its performance at slightly higher dosage rates may be desirable. The level of weed control with the same dosage rate applied post-emergence was very promising. The adverse effect produced by C6313 on the crop in 1968 is similar to that found by King (1968) after excessive rainfall early in the season. In his experiments, however, a much larger percentage of the crop was killed at both dosage rates. The lack of crop injury by prometryne or C7019 at S.H.R.I. under these conditions is reassuring.

French beans The standard dinoseb amine treatment, although reported by other workers to be unsatisfactory in many seasons (Cassidy, 1966, King 1966b) gave the best weed control in both these experiments. None of the other herbicides, despite help from a stale seedbed treatment with paraquat/diquat in 1967, was able to keep the crop as free from weeds and, with the exception of dinoseb amine plus monolinuron, they all required supplementary hoeing. Lenacil and propachlor failed to keep *Fumaria officinalis* under control in 1967 and it was the size and density of this weed that was the main factor determining the need for hoeing. Prometryne was slightly more effective. Lenacil, as well as giving the shortest duration of acceptable weed control, also caused slight damage to the crop after heavy rain. Propachlor and prometryne in these trials did not cause damage of the type reported by King (1966) or Cassidy (1966). However, since any risk of check to growth is undesirable in an area marginal for the growth of this crop, none of these three herbicides can at present be recommended to growers in the East of Scotland. Trifluralin did not check the crop but was relatively ineffective in this experiment due to the presence of a high population of *Matricaria spp*. Dinoseb acetate plus monolinuron was the most successful of the alternatives to dinoseb amine and merits further investigation. The new variety Glamis did not show any susceptibility to either dinoseb amine or to dinoseb acetate plus monolinuron at the dosage rates used in these experiments.

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