Click here for previous

CLIMATIC AND SOIL EFFECTS

Experiments in controlled environment rooms at WRO have demonstrated that the climatic conditions under which wild-oat plants are grown can have dramatic effects on the dormancy of their seed. Plants grown at high temperatures, particularly if simultaneously subjected to moisture stress, give rise to seed of low dormancy. In one experiment, seed matured at 20°C under soil moisture stress gave 78% emergence during the first autumn after shedding, as compared with only 10% when the seed was matured at 15°C without soil moisture stress (Peters, 1978).

It would be expected therefore, that field-grown plants subjected to high temperatures and moisture stress during the later stages of growth would shed seed of low dormancy. Even where no environmental stress occurs some non-dormant seeds will be produced, and in practice these will become particularly significant if they establish in winter cereals sown in late September or October. Work at WRO has already shown that seedlings emerging with early sown winter crops are those most likely to over-winter and subsequently produce more seeds (Holroyd 1972).

Wilson & Cussans (1975) at WRO observed that the numbers of wild-oat seedlings emerging in the autumn are considerably reduced when seed shedding during the previous summer is prevented. It was concluded from their experiment, that autumn seedlings were mainly derived from newly shed seed.

Although the main period of emergence of wild-oats is in the spring, while that of winter wild-oat is in the autumn, each of the species can produce some seedlings in both autumn and spring. The regularity of this emergence pattern suggests that there are basic environmental and/or genetical factors regulating it. So far, the only factor investigated in any detail is soil temperature. Dormancy in wild-oat seeds can be broken if they are stored either in cold soil (5°C) or in warm soil (25°C), the effectiveness of temperature in reducing dormancy depending on wild-oat strain. However, in warm soil the seed does not then germinate because the high temperature enforces another type of dormancy*. This probably explains the lack of wild-oat emergence in the field during the summer months (Peters 1978). Subsequently, when the seed has experienced a change in the soil temperature during the autumn and winter, this secondary dormancy is lost. The chilling soil temperatures of winter will, in themselves, also break dormancy but there is some evidence from work at WRO that, before

* This can be demonstrated by removing the seed stored in soil at 25°C and placing it on moist filter paper in petri dishes kept at 15°C, when germination will occur.

dormancy of the seed is reduced to any great extent, the seed must experience fairly long periods of both cool and warm soil conditions. This may explain why the greatest emergence of wild-oat seedlings occurs in the second spring after seed shedding. This was evident both in pots buried in the soil (Peters 1978), and in a long-term field experiment. In the latter, thirteen times as many seedlings emerged in the second spring as compared with the first, even though the viable seed reserves had fallen by a half in the first year (Wilson, pers. comm.).

The effect of soil temperature on the breakdown of dormancy in winter wild-oat is less well known, although there is evidence that the seed has a slightly lower optimum germination temperature, (10°C) compared with that of wild-oat (15°C). (Quail & Carter 1968). Winter wild-oat is also known to be induced into secondary dormancy at high temperatures as described above for wild-oat (Thurston 1960). Seedling growth below 8°C is very slow in both species so that emergence as a result of dormancy loss in winter may take a long time.

EFFECT OF BURNING

Burning can have considerable effects on seed survival and dormancy. A proportion of the seeds are directly destroyed by burning, and the dormancy of the remainder is reduced. In one field experiment at WRO, 68% of the seeds were destroyed on the burnt areas. The burn was incomplete and seeds between the straw swathes reduced the overall loss to 32%. Of the seeds surviving in the burnt areas just under half were non-dormant. More seedlings emerged on the burnt area as a result of this loss of dormancy. Where no burning took place 11% of seed germinated and 89% remained dormant. (Wilson & Cussans 1975).

EFFECT OF CULTIVATION

Cultivation has been shown to influence wild-oat populations in two ways. Firstly the timing of cultivation of the stubble after seeds have shed affects the entry and survival of viable seeds in the soil. Delayed cultivation allows considerable natural mortality of seeds on the surface which would otherwise survive and remain dormant when buried with early autumn cultivations (Wilson & Cussans 1972, 1975; Wilson, 1972). Secondly, the number of seedlings emerging can be influenced by the type of cultivation. More seedlings emerged in the first year after seeding following tine cultivation than after ploughing (Wilson & Cussans 1975). It was suggested that if new seeding was prevented, annual tine cultivation would deplete the seed reserves more rapidly than annual ploughing. In later work at WRO (Wilson 1978) seed reserves declined rapidly (over 80%/year) and reached low levels after 3 years of both tine cultivation and ploughing.

The availability of moisture appears to be another important factor governing autumn germination. In the wet autumn of 1979 ten times as many seedlings emerged from similar numbers of seeds broadcast and tine cultivated into the soil compared with those that emerged in the drier autumns of 1977 and 1978. Dry autumns in a long-term barley experiment (Whybrew 1964) also gave rise to lower than expected emergences of wild-oats.

The effect of cultivation has always been related to field populations of seed containing a natural mixture of the larger lower and smaller upper seeds of spikelets. The individual effect of cultivation on the upper and lower seeds in the spikelets was therefore unknown and investigated at WRO. Lower and upper seeds of wild-oat were collected in late summer of 1975 and planted separately in pots of soil. The pots were immersed to their rims in soil out of doors. The seed was covered with a 2.5 cm layer of soil and the soil surface in some of the pots was cultivated monthly. By the following spring 52% of the lower seeds had emerged in the cultivated pots as compared with only 39% in the uncultivated ones. The corresponding figures for the smaller upper seeds were 31% and 12% respectively. The figures for the lower seed in the second spring were 89% in cultivated and 81% in non-cultivated pots and for the upper seed 89% in cultivated and 60% in non-cultivated pots. Thus, the effect of cultivation was to stimulate the very dormant upper seed into germination and hence speed up the reduction of the number of seeds in the soil (Peters 1978).

CONCLUSION AND AGRICULTURAL SIGNIFICANCE

Climatic factors are of considerable importance to the emergence pattern of wild-oats. In particular, soil temperature has to be sufficiently high to allow growth, and plays a vital role in the breakdown of dormancy. High temperatures and soil water stress during seed maturation reduce seed dormancy. Plants which survive late application of herbicides like benzoylprop-ethyl or flamprop-isopropyl, will produce viable seeds of reduced dormancy. The numbers of seedlings which emerge can be influenced by straw burning and by cultivations. With both these practices a farmer can augment the natural seed mortality and so reduce the rate of population increase, but alone they cannot reduce a severe infestation in a short time. This can only be achieved by using herbicides effectively to restrict the entry of new seeds into the soil. The long term decline of a population will be hastened if the use of herbicides is integrated with cultural measures which encourage mortality of seeds produced by the survivors. This systematic approach to control will be necessary for three or four years to allow for the loss of dormancy and depletion of the reserve of old seeds in the soil.

REFERENCES

AAMISEPP, A. (1959). The effect of phenoxyacetic acids on the vegetative development, seed formation and germination biology of wild oats. *Vaxtodling*, **10,** 58–67.

ANDREWS, C. J. & SIMPSON, G. M. (1969). Dormancy studies in seed of *Avena fatua. 6. Germinability of the immature caryopsis. Canadian Journal of Botany*, **47,** 1841–1849.

CHEN, S. S. C. & CHANG, J. L. L. (1972). Does gibberellic acid stimulate seed germination via amylase synthesis. *Plant Physiology*, **49,** 441–442.

CHEN, S. S. C. & PARK, WON-MOK. (1973). Early actions of gibberellic acid on the embryo and on the endosperm of *Avena fatua* seeds. *Plant Physiology*, **52,** 174–176.

HOLROYD, J. (1972). Wild oats. *Report Agricultural Research Council Weed Research Organization*, (4), 1969–71, 50–7.

NAYLOR, J. M. (1966). Dormancy studies in seed of *Avena fatua*. 5. On the response of aleurone cells to gibberellic acid. *Canadian Journal of Botany*, **44,** 19–22.

NAYLOR, J. M. (1969). Regulation of enzyme synthesis in aleurone tissue of *Avena* species. *Canadian Journal of Botany*, **47,** 2069–72.

PETERS, N. C. B. (1978). *Factors influencing the emergence and competition of* Avena fatua L. *with spring barley*. Ph.D. Thesis, University of Reading.

QUAIL, P. H. & CARTER, O. G. (1968). Survival and seasonal germination of seeds of *Avena fatua* and *A. ludoviciana. Australian Journal of Agricultural Research*, **19,** 721–729.

THURSTON, J. M. (1957). Morphological and physiological variation in wild-oats (*Avena fatua* L. and *Avena ludoviciana* Dur.) and in hybrids between wild and cultivated oats. *Journal of Agricultural Science, Cambridge*, **49,** 259–274.

THURSTON, J. M. (1960). Dormancy in weed seeds. In: *The Biology of Weeds*. (Ed. J. L. Harper), pp. 69–82. Blackwell, Oxford.

WHYBREW, J. E. (1964). The survival of wild-oats (*Avena fatua*) under continuous spring barley growing. *Proceedings 7th British Weed Control Conference*, 614–620.

WILSON, B. J. (1972). Studies of the fate of *Avena fatua* seeds on cereal stubble, as influenced by autumn treatment. *Proceedings 11th British Weed Control Conference*, 242–247.

WILSON, B. J. (1978). The long term decline of a population of *Avena fatua* L. with different cultivations associated with spring barley cropping. *Weed Research*, **18,** 25–31.

WILSON, B. J. & CUSSANS, G. W. (1972). The effect of autumn cultivations on the emergence of *Avena fatua* seedlings. *Proceedings 11th British Weed Control Conference*, 234–241.

WILSON, B. J. & CUSSANS, G. W. (1975). A study of the population dynamics of *Avena fatua* L. as influenced by straw burning, seed shedding and cultivations. *Weed Research*, **15,** 249–258.

The role of crop tolerance tests in the development of strawberry herbicides

D. V. CLAY

Weed problems are generally worse in strawberries than other fruit crops because of the greater susceptibility of the crop to herbicides. Not only are the plants smaller with a shallower root system but it is difficult to avoid the foliage when spraying herbicides. In addition, evaluation of the safety of soil-acting herbicides in strawberries, as with other crops, is greatly affected by the weather, especially rainfall. In certain conditions herbicides such as simazine which are normally toxic to young strawberries are safe (Fig. 1). Soil properties also have a big influence on herbicide availability and movement so that field evaluation has to continue for a number of years on a range of soil types to be certain of crop safety.

In order to short-cut this expensive process methods of testing the herbicide tolerance of pot-grown plants have been developed at the Weed

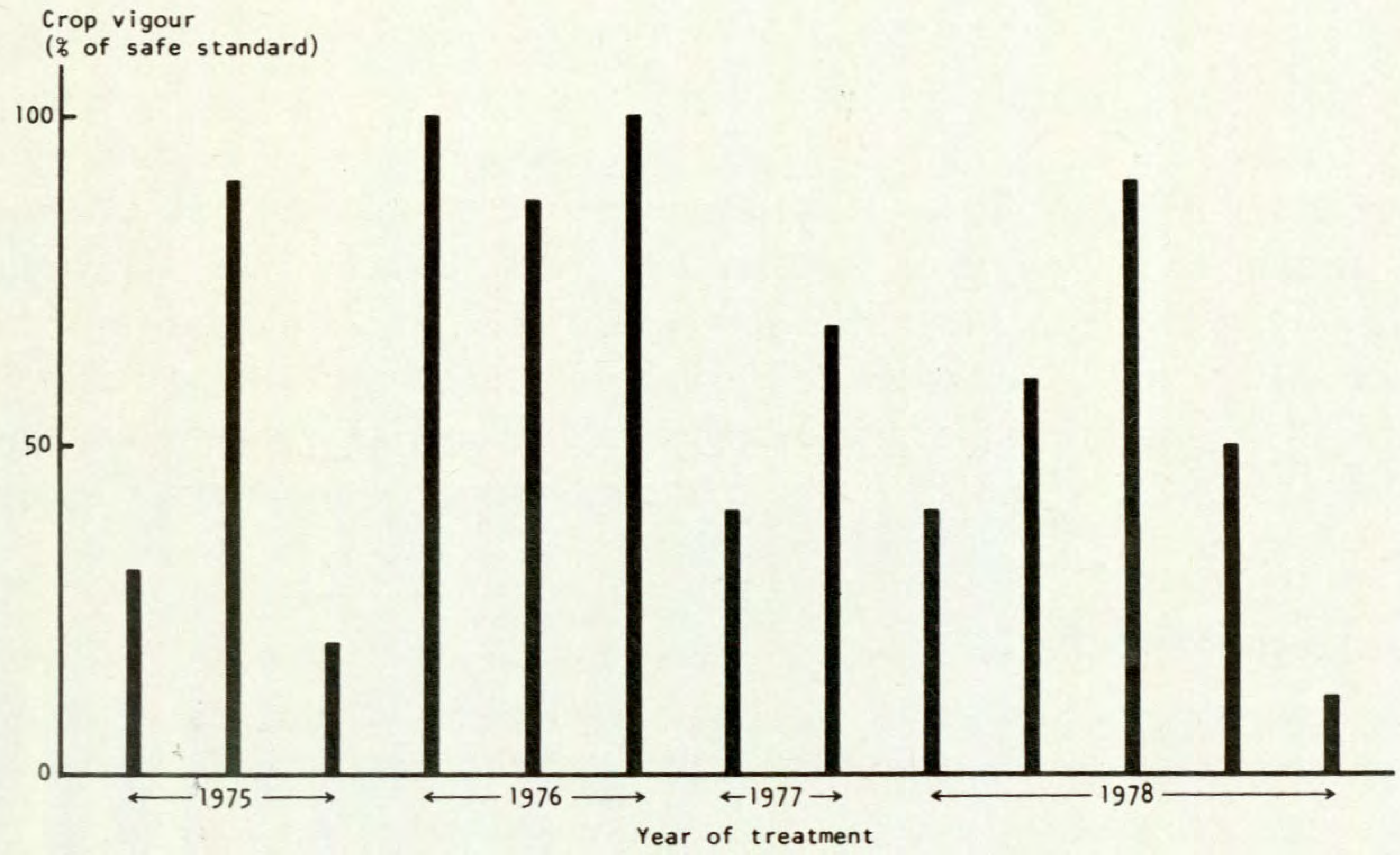


Fig. 1. The variable effect of simazine applied to young strawberries in successive field experiments at WRO. Crop vigour recorded 1–2 months after treatment.

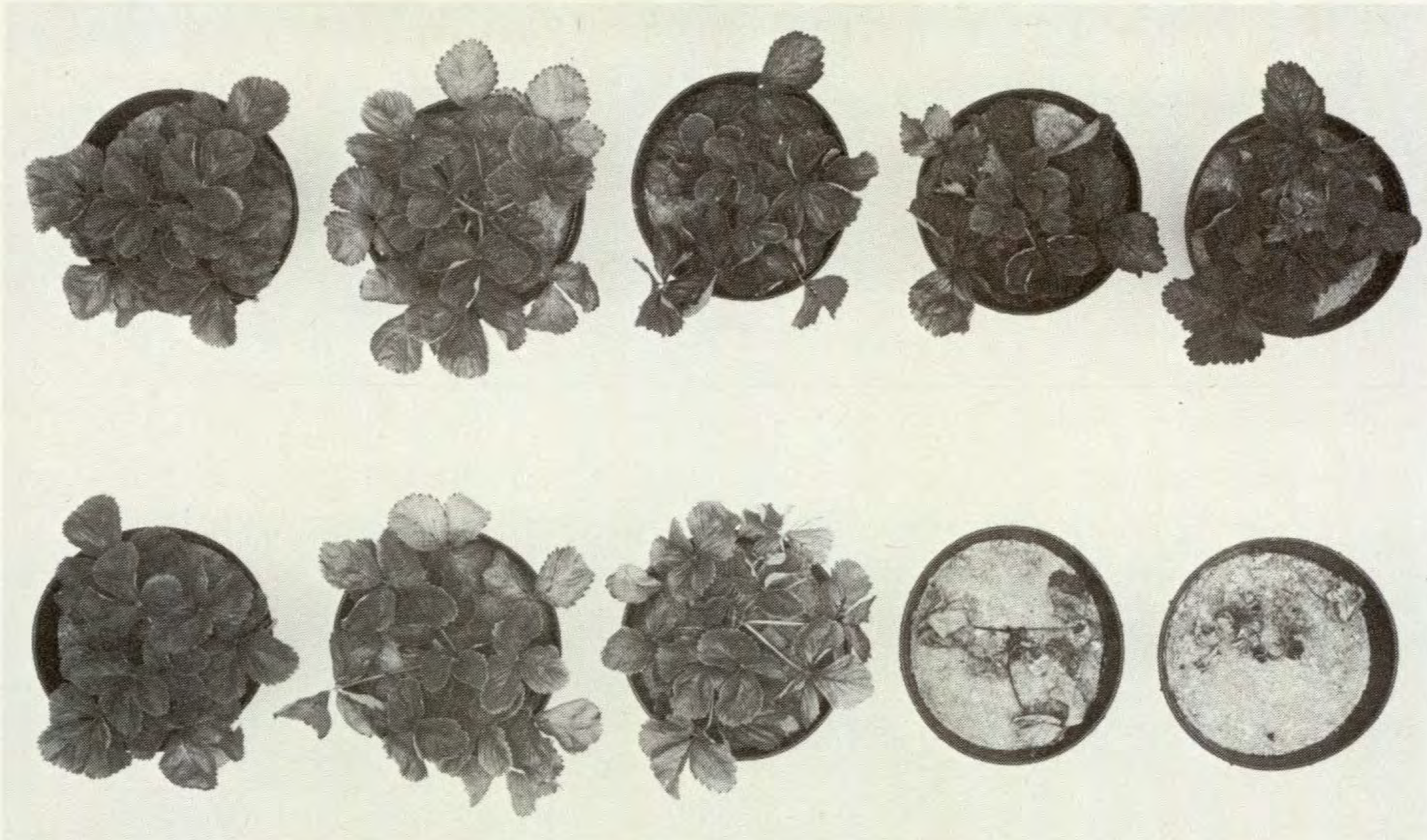


Fig. 2. The effect of trifluralin (above) and simazine (below) applied to the roots of plants grown in sand. Doses (mg/pot) from left – trifluralin 0, 1.6, 4.8, 14, 43; simazine 0, 0.16, 0.43, 1.4, 4.3.

Research Organization. The tests have been used not only for screening new herbicides for selective use in the crop, but also for assessing the tolerance of standard herbicides by new crop cultivars and for elucidating the principles governing crop response (Clay & Davison, 1978). The tests on pot-grown plants have been followed by field trials to confirm their reliability. The herbicides tested were all either commercially available in the U.K. or at a late stage of development for other crops. As a result of this work a number of new herbicide treatments have been found for use in strawberries.

ROOT AND SHOOT TESTS

The screening of herbicides on strawberries at WRO involves separate applications to the roots and the foliage in order to assess the relative importance of root and shoot entry in causing damage. In the root activity tests, plants are grown in pots of silica sand and watered with dilute nutrient solution. Four or five doses of each herbicide are applied to obtain a full range of response (Fig. 2).

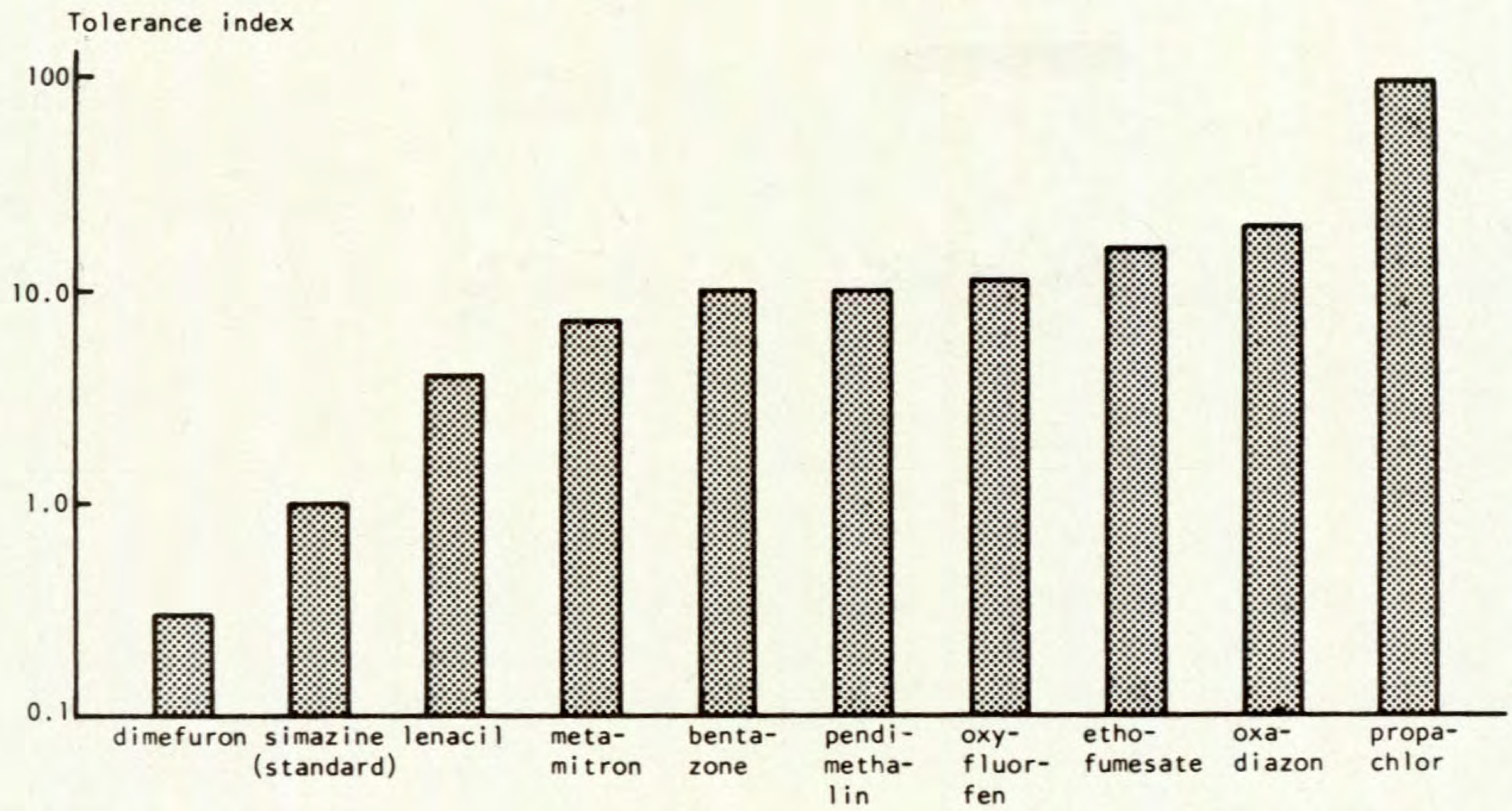


Fig. 3. The response of strawberries in sand culture to applications of herbicides to the roots. Tolerance index = ED_{20} test herbicide/ED_{20} simazine standard, derived from mean of values for vigour scores and fresh wt 2 months after treatment. With the exception of dimefuron all the herbicides tested are safer than simazine.

This test enables the symptoms caused by each herbicide to be recorded, as well as its speed of action, tolerance level and the degree of response to increases in dose. Results are expressed as the dose of each herbicide causing and equivalent level of effect (ED value) to that of a standard herbicide of known field performance such as simazine or lenacil. The tolerance levels of a number of herbicides from a series of experiments can be conveniently compared by calculating a tolerance index for each herbicide (tolerance index = ED_{20} test herbicide divided by ED_{20} standard herbicide where ED_{20} = the dose reducing growth by 20%); a number of these are shown in Figure 3 (Clay, 1980a).

The effect of doses above the ED_{20} value is also important in predicting the likely effects of overdosing in field use; this is shown by the slope of the dosage-response lines (Fig. 4). These can be conveniently compared by calculating a dose-response index for each herbicide (dose-response index = ED_{50} test herbicide divided by ED_{20} test herbicide); the nearer this index is to 1 the bigger the effect of dose increases (Clay, 1980a).

For the foliar activity test plants are grown in soil-based compost and the herbicide spray kept off the compost surface (Clay, 1980b). The range of

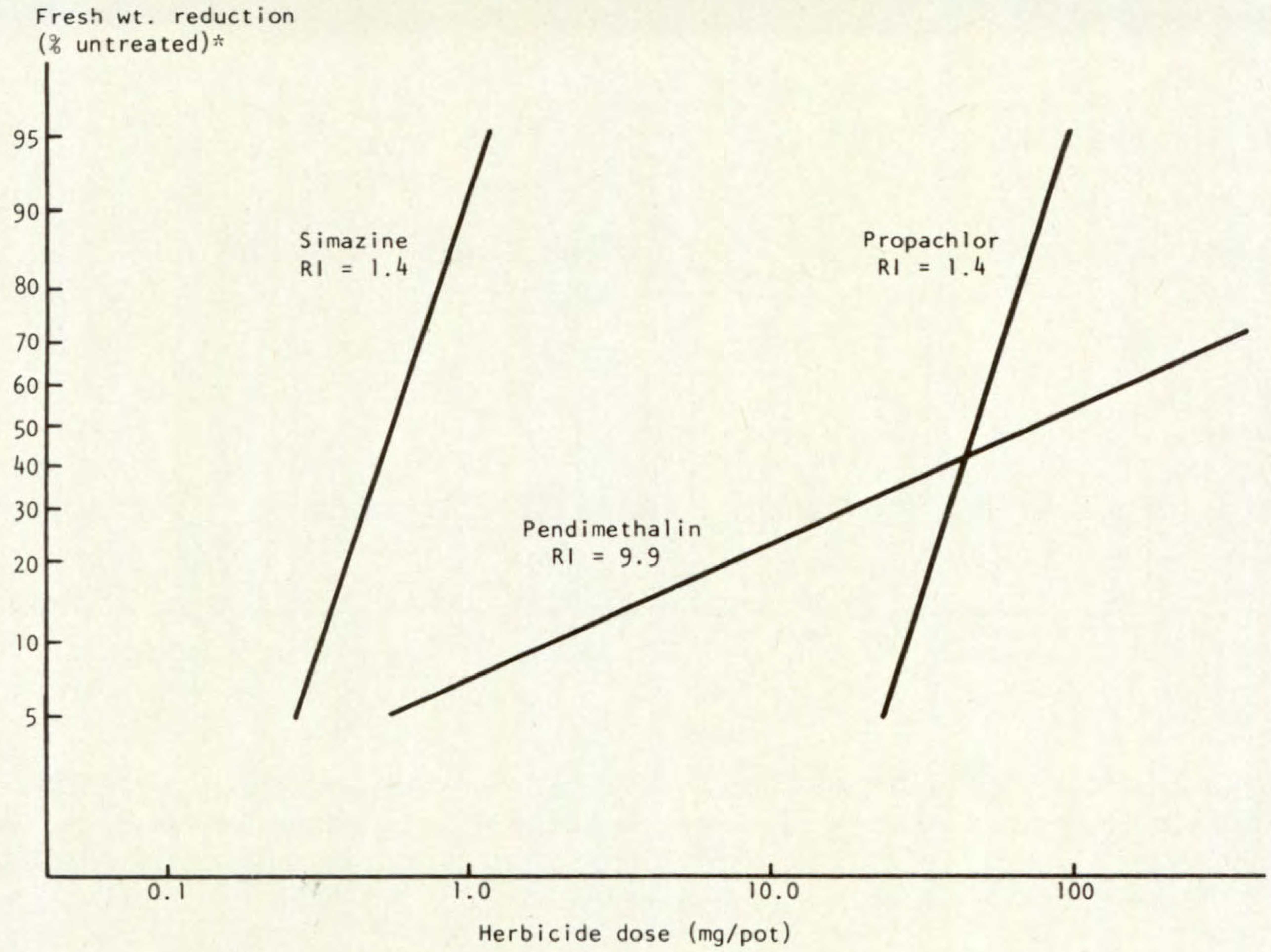


Fig. 4. Dosage-response lines for three herbicides applied to the roots of strawberries grown in sand. Dose response index (RI) = ED_{50}/ED_{20} test herbicides based on leaf fresh wt 9 months after treatment. *Logistic scale.

doses tested enables the type of symptoms, the margin of tolerance and the persistence of any effects on growth and development to be studied. The response of strawberries to foliar applications of a number of the herbicides also tested for root activity in sand culture is shown in Figure 5.

The tolerance of over 60 herbicides by strawberries has been evaluated in this way. Selected herbicides have also been tested in a series of eight field experiments at WRO from 1975–8 to assess the reliability of the pot tests for indicating relative tolerance and as the next stage in developing new herbicide uses in the crop.

FIELD TESTING

In the field tests on young crops lenacil, a recommended treatment, was included as a standard for assessing the tolerance of the new herbicides; simazine, a treatment that would normally be toxic, was also included to

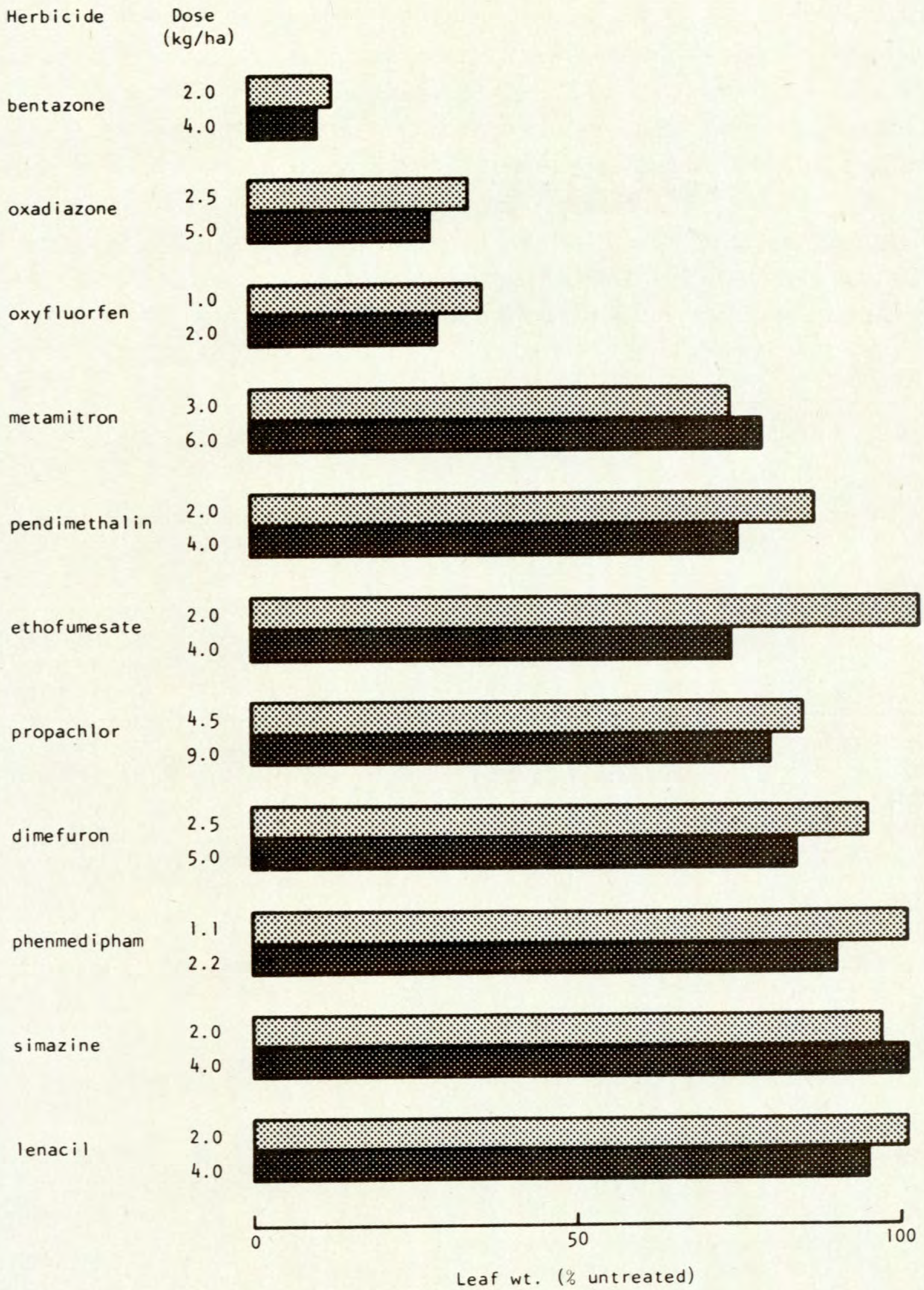


Fig. 5. The response of strawberries to normal and twice normal doses of herbicides applied in summer to the foliage. Leaf fresh wt recorded 2 months after spraying.

show whether the conditions of each experiment were conducive to damage from soil-acting herbicides. There was a good correlation between results of pot and field tests (summarised in Table 1); herbicides such as ethofumesate, pendimethalin and propachlor that were relatively safe when applied to roots and foliage in pot tests were also safe in the field (Clay, 1980b). Dimefuron was very toxic in sand culture and in the field. Metamitron was similar in toxicity to lenacil in pot tests (Fig. 3, 5) but more damaging in the field probably because of the higher doses needed for weed control and greater mobility in the soil.

Table 1 Grouping of herbicides according to response to root and foliar applications in pot experiments and overall applications in the field

Herbicide	Standard field dose (kg/ha)	Pot experiments		Field experiments
		Root activity (sand)*	Foliar activity‡	Root + foliage‡
dimefuron	2.0	●●●	o	●●●●
simazine	1.5	●●	o	●●●
lenacil	2.0	●	o	o
metamitron	4.5	●	●	●●
propachlor	4.5	o	●	o
pendimethalin	1.5	o	●	●
ethofumesate	1.0	o	●	●
bentazone	2.0	o	●●●	●●●
oxadiazon	2.0	o	●●●	●●●
oxyfluorfen	2.0	o	●●●	●●●

* Key to root activity

o ED_{20}/standard field dose twice that of lenacil or greater

● ED_{20}/ ,, ,, ,, approx equal that of lenacil

●● ED_{20}/ ,, ,, ,, approx one quarter that of lenacil

●●● ED_{20}/ ,, ,, ,, approx one tenth that of lenacil

‡ Key to foliar activity and field response

o No damage at double dose at any time

● Some damage (ca 20% inhibition) at double dose

●● Severe damage (>50%) at double dose or slight damage at standard field dose

●●● Severe damage (>50%) at standard dose, some recovery

●●●● Severe damage at standard dose, no recovery

Where a herbicide was tested in several experiments the assessment given above is based on the result where damage was severest

Oxadiazon was not toxic at any dose when applied to the roots but plants were severely checked by a foliar spray; in the field there was severe leaf scorch and yield reduction from spring treatment but the plants completely recovered from this. Similarly oxyfluorfen and bentazone, which were severely damaging as foliar sprays also caused severe damage in the field but the crop largely recovered by the end of the year. Such herbicides would only be considered for use in the crop if there was no alternative means of containing or eradicating patches of perennial weed.

Additional information on the safety of some of these herbicides has been obtained from experiments at other centres organized through the ARC Fruit Weed Control Group. Trials at both the Scottish Horticultural Research Institute at Dundee and at the Loughgall Horticultural Centre, N. Ireland have confirmed the safety of ethofumesate, pendimethalin and propachlor on young crops (Clay, Rutherford & Wiseman, 1974; UK, Loughgall Horticultural Centre, 1976; Lawson & Wiseman, 1978; UK, Department of Agriculture for Northern Ireland, 1978).

NEW RECOMMENDATIONS

As a result of this work two of the herbicides, ethofumesate and propachlor, are now recommended by the manufacturers for use in strawberries. Ethofumesate is recommended for use in autumn on established crops for the post-emergence control of clover (*Trifolium repens*), cleavers (*Galium aparine*), chickweed (*Stellaria media*) and some annual grass weeds. Clover has been a severe problem in some strawberry crops in Kent for many years and now occurs frequently on pick-your-own enterprises where strawberries are grown on former pasture land. Ethofumesate is the first herbicide to give selective control (Clay, 1979). At present the recommendation covers only the main variety Cambridge Favourite; WRO trials have shown that some varieties can be damaged by ethofumesate at the dose needed to control clover. In the future ethofumesate may find a major use in mixture with other herbicides, as occurs in sugar beet. Preliminary results at WRO suggest that the mixture of ethofumesate and phenmedipham, which gives broad spectrum post-emergence annual weed control, may be safe on young strawberry crops. Work is also in progress elsewhere to establish the tolerance by newly-planted crops of mixtures of lenacil and ethofumesate—a treatment that gives control of important lenacil-resistant weeds and is somewhat more effective than lenacil alone in dry conditions.

Propachlor has been extensively used in vegetable crops for many years usually following pre-planting trifluralin treatment or in a mixture with other herbicides such as chlorthal dimethyl. It is a cheaper treatment than lenacil but does not give such persistent weed control and is therefore unlikely to replace it for widespread use in spring or on newly planted crops. However, it has proved very safe on strawberries (Clay, 1978) and should prove useful on light soils, where lenacil is not recommended, and in mixture with chlorthal dimethyl where lenacil-resistant weeds such as cleavers, field pansy (*Viola arvensis*) and speedwells (*Veronica* spp.) have become a problem.

Pendimethalin has proved superior to existing treatments in strawberries in dry soil conditions and could replace lenacil for spring use on newly-planted and established crops (Clay, Rutherford & Wiseman, 1974). Alternatively application in winter, following autumn-applied simazine, could remove the need for a residual herbicide treatment in spring. Pendimethalin however, has checked leaf growth when applied to established crops in early spring but this check was outgrown, crops appeared normal at harvest and there was no reduction in yield. In fact in one trial yield was 20% higher than with lenacil and in another the pendimethalin treatment increased the amount of fruit at the first two picks (Clay, 1978). Further work is in progress at sites throughout the country to check on the tolerance on newly-planted and established crops.

Other herbicides that are promising for strawberries are alloxydim-sodium for the control of common couch (*Agropyron repens*) and 3,6-dichloropicolinic acid for the control of creeping thistle (*Cirsium arvense*). Pot screening and preliminary field trials by WRO provided evidence of the tolerance of these herbicides by strawberries (Clay, 1980c); further field trials by official bodies and the manufacturers are in progress to confirm tolerance and determine doses and timing appropriate to this crop.

COLLABORATION

The progress that has been made in finding new herbicides for strawberries and obtaining commercial recommendations for some of the serious weed problems in strawberries has been possible only by collaborative effort. Herbicide manufacturers are understandably reluctant to carry out much of the work necessary to establish crop tolerance and conditions of use for their products in minor acreage but high value crops. But they have been prepared to obtain PSPS clearance and make label recommendations when they are satisfied about the safety of the treatment. This information has been obtained through collaborative experiments by members of the ARC Fruit Weed Control Group, including ADAS staff, and has also involved the supply of treated fruit to the manufacturers who then obtain the requisite herbicide residue information. Thus, as a result of the basic work on crop tolerance at WRO, subsequent collaborative experiments with other research groups and the co-operation of manufacturers, strawberry growers should soon have a number of new herbicide treatments to deal with some of their most pressing weed problems.

REFERENCES

CLAY, D. V. (1978). The response of strawberries to propachlor, pendimethalin and trifluralin used alone, in mixture or sequentially. *Proceedings British Crop Protection Conference—Weeds,* 175–182.

CLAY, D. V. (1979). Knocking clover over. *The Grower,* **92,** (24), 30.

CLAY, D. V. (1980a). Indices and criteria for comparing the tolerance of herbicides to strawberries in dose-response experiments. *Weed Research,* **20,** 91–96.

CLAY, D. V. (1980b). The use of separate root and shoot tests in the screening of herbicides for strawberries. *Weed Research,* **20,** 97–102.

CLAY, D. V. (1980c). New herbicides for strawberries. *Technical Leaflet ARC Weed Research Organization,* **16.**

CLAY, D. V. & DAVISON, J. G. (1978). An evaluation of sand-culture techniques for studying the tolerance of fruit crops to soil-acting herbicides. *Weed Research,* **18,** 139–147.

CLAY, D. V., RUTHERFORD, S. J. & WISEMAN, J. S. (1974). New herbicides for strawberries: crop tolerance and weed control performance. *Proceedings 12th British Weed Control Conference,* 699–706.

LAWSON, H. M. & WISEMAN, J. S. (1978). New herbicides for spring-planted strawberries. *Proceedings British Crop Protection Conference—Weeds,* 167–174.

UK, DEPARTMENT OF AGRICULTURE FOR NORTHERN IRELAND (1978). The control of weeds in soft fruit by herbicides. *Annual Report Research and Technical Work at the Department of Agriculture Northern Ireland, 1976,* 220–221.

UK, LOUGHGALL HORTICULTURAL CENTRE (1976). Strawberries: weed control. *Annual Report Loughgall Horticultural Centre, 1975,* 35–36.

Investigating the effects of weather on foliage-applied herbicides

J. C. CASELEY

It is widely recognised, both from practical usage and research, that aerial and soil environmental factors are a major cause of inconsistencies in the performance of herbicides, resulting in either inadequate control of weeds or crop damage. Most recommendations for herbicide use are based primarily on field experimentation where weed control and crop damage are observed, but only limited weather records are taken from the nearest—but often quite distant—meteorological site.

While this may provide an overall view of performance under contrasting soil and weather conditions, usually it does not establish the role of individual environmental factors since these are constantly changing and the influence of one cannot readily be distinguished from that of another. For example, as weather conditions change from sunny to cloudy, first light intensity falls, then temperature drops and in turn other factors such as humidity and air movement are affected.

In order to reach a more precise understanding of the relationship between weather and herbicide performance, the Weed Research Organization has developed a facility where one weather factor can be varied while the others are held constant. Cabinets and rooms in which light, temperature and humidity are controlled are used in conjunction with more specialised purpose-built equipment including a controlled environment sprayer (Fig. 1) and a rain simulator.

Research in the laboratory is complemented by experimentation in the glass-house and pot-standing area where the microclimate is closely monitored. Data from the institute meteorological site are integrated hourly and processed by computer, facilitating correlation of results of experiments undertaken in the controlled environment laboratory, glasshouse, pot-standing area and the field.

The aims of the WRO work are achieved in two stages. In the first, the role of individual environmental factors in influencing the overall response of a plant to the herbicide is investigated. This information is used as an aid to the interpretation of results from experiments from different sites and seasons, and enables the precision of field recommendations to be

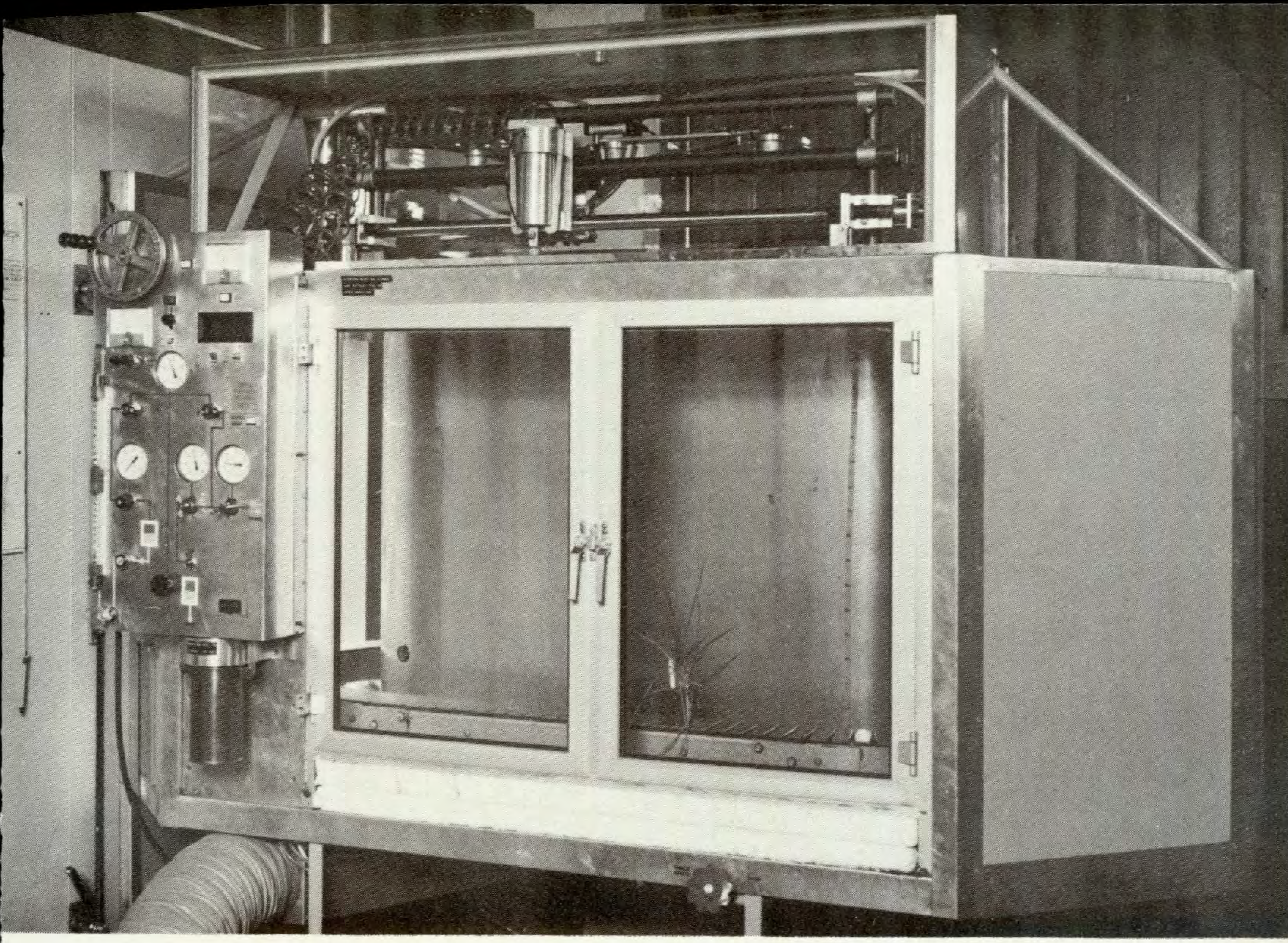
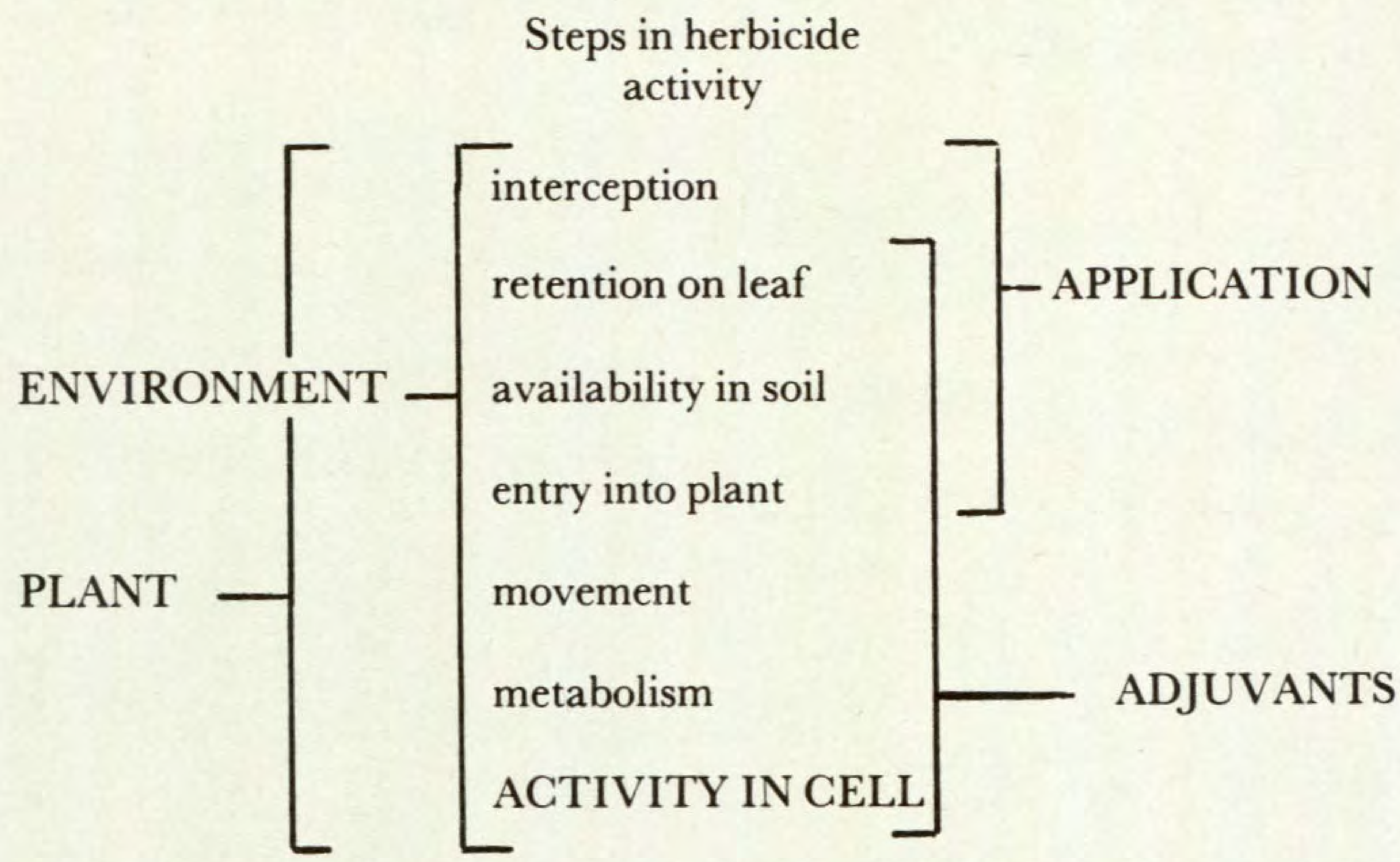


Fig. 1. Growth room with controlled environment pot sprayer attached to the entrance. This enables potted plants to be sprayed with herbicide in the same environment as obtains in the growth room.

increased. In the second stage of the work, physiological and biochemical techniques are used to identify the effect of single environmental factors on the individual steps involved in herbicide performance. These studies pinpoint the causes of loss of activity in weeds and increased phytotoxicity to crops, and provide a logical basis for improvements in application and formulation (Table 1).

The importance of this type of research is being recognised increasingly by the farming community and industry. The latter have incorporated WRO findings in their labels and one company now grant-aids work on crop tolerance. The requirement for more research in this area is reflected in the large number of questions regarding environmental factors which are raised at the British Crop Protection Council's *Annual Review of Herbicide*

Table 1 Factors that affect the steps involved in herbicide activity



Usage. The need for improved liaison between researchers from industry, government and universities has recently led to the formation by the European Weed Research Society of a working party on this topic.

HOW AND WHEN DOES WEATHER AFFECT HERBICIDE PERFORMANCE?

It is generally accepted that certain weather criteria must be met for successful application results. It is less widely appreciated that environmental factors before and after application exert a major influence on herbicide performance, interacting with the steps involved in herbicide activity (Table 1).

The pre-spraying environment

During this period the weather affects the size, form, habit and cuticular characteristics of shoots, all factors of particular importance in relation to the efficacy of post-emergence herbicides. In recent studies at WRO, the susceptibility of common couch (*Agropyron repens*) to glyphosate increased as the pre-spraying day/night temperature was raised from cool (10/6°C) to warm (16/10°C) to hot (26/16°C), and the penetration and translocation of ^{14}C glyphosate followed the same trend. Investigations on the underlying reasons for such differences include collaborative plant surface studies with

Long Ashton Research Station. The pre-spraying environment will also influence the development of storage and regenerative organs in perennials to which herbicide must be transported for effective control. Common couch grown at $50W/m^2$, a low light regime found, for example, within a cereal canopy during the summer, had less than half the weight of rhizome of plants grown at $200W/m^2$. Furthermore, the shade-grown plants had a higher ratio of shoots to nodes which is conducive to control by foliage-applied herbicides (Caseley 1974).

These examples illustrate that the pre-application environment may have a major influence on the target plant with concomitant effects on the performance of foliage-applied herbicides.

Environment at the time of application

Weather conditions are a key consideration in deciding time of application. Tottman and Phillipson (1974) found that wind and rain prevented application on 37 out of 61 days when spring cereals were at the correct growth stage. Once application is in progress, wind and rain have a direct influence on the amount of active ingredient deposited on the target.

The post-application environment

The hours immediately following application are of paramount importance to post-emergence treatments. Herbicide deposits on the surface of the plant are vulnerable to removal by, for example, heavy rain, and the success of a treatment is not assured until a lethal quantity has penetrated the cuticle. In a recent experiment at WRO the activity of 1 kg/ha of difenzoquat against wild oats was halved when 2.0mm of rain was applied immediately after the herbicide treatment. Lesser amounts of rain, up to 0.5mm immediately after spraying, had no adverse effects on difenzoquat activity although almost one third of the herbicide was removed from the wild oat foliage. Most of this loss occurred from the leaf blade and some herbicide deposit was redistributed to the ligule and inner surface of the leaf sheath—areas known to be more responsive to herbicide treatment (Caseley & Coupland 1980, Coupland, Taylor & Caseley 1978) (Fig. 2).

One way to minimise the risk of loss of foliage-applied herbicides is to apply them under humid warm conditions which are conducive to rapid penetration of a wide range of compounds and formulations. Control of common couch with glyphosate, when the herbicide was washed off two hours after application, was three times as effective at a relative humidity (RH) of 90% as it was at 45% RH. Re-wetting the foliage without causing

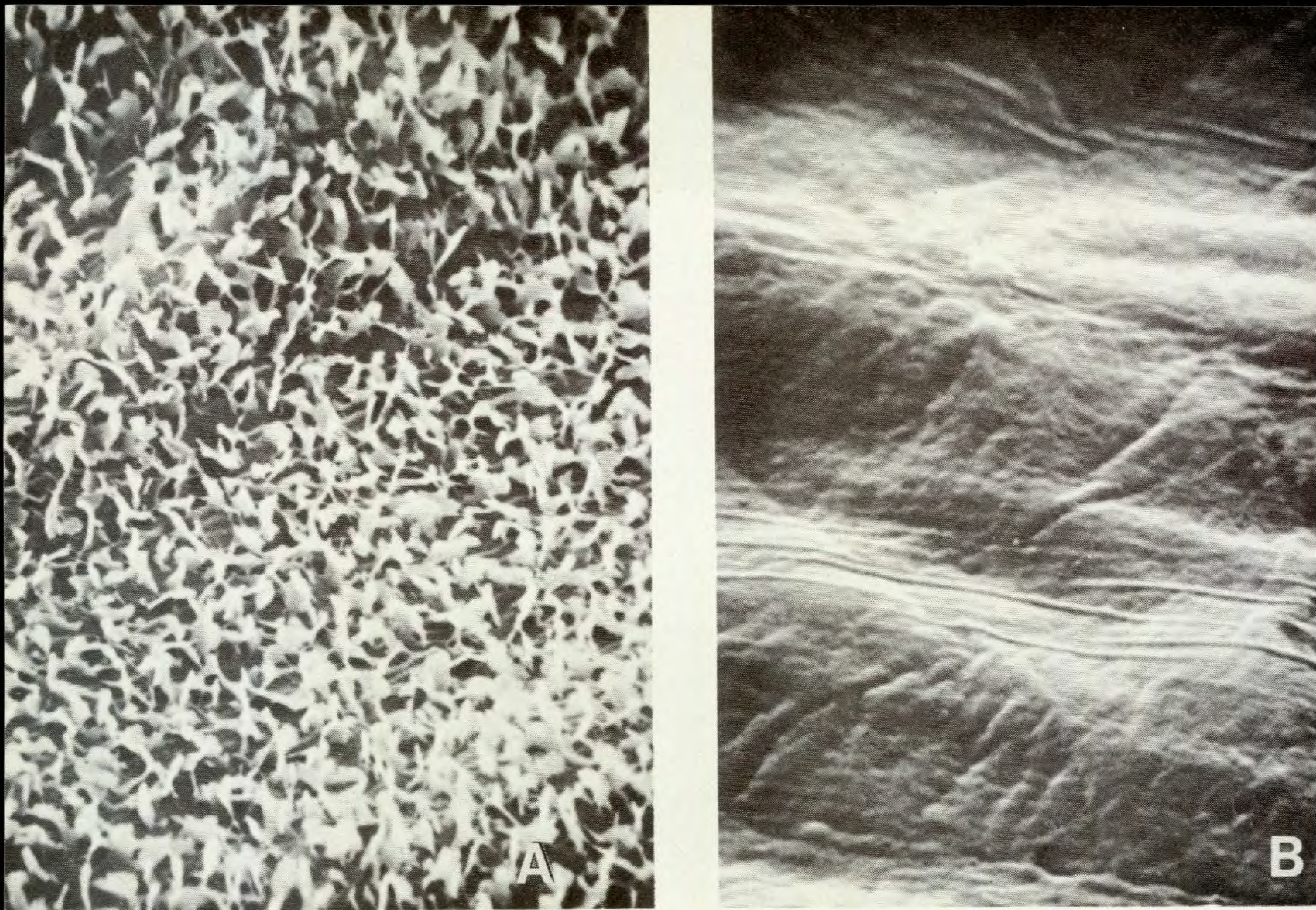


Fig. 2. Scanning electron micrograph of surface of wild-oat leaf in (a) mid-lamina region with abundant wax platelets and (b) inner leaf sheath without wax platelets. The latter surface has been shown to be more responsive than the former to herbicide treatment. (Microphotographs by courtesy of Long Ashton Research Station).

runoff, as might occur during dew deposition, doubled the effectiveness of glyphosate against common couch in a low humidity regime, but had little effect at 90% RH (Caseley, Coupland & Simmons 1975).

During the hours immediately following application of a foliage-applied herbicide, retention and penetration are of key importance. Conditions that are optimal for these steps in herbicide activity may not be the same as those required for the concurrent and subsequent processes of movement and activity. Thus, entry and movement of glyphosate are favoured by humid warm conditions but, after the herbicide has reached the meristematic tissue of the nodes, a cool environment results in maximum activity (Caseley 1972). In contrast, the most rapid action of difenzoquat is favoured by high temperatures throughout the post-application period

(Coupland, Caseley & Simmons 1976) whereas barban is more effective when the temperature is low at this time (Anon, 1978). Although the penetration of most foliage-applied herbicides is enhanced by humid conditions, the optimum environment for the other steps involved in herbicide action appears to depend on individual herbicide/species combinations.

THE ENVIRONMENT/HERBICIDE PERFORMANCE PROFILE

Information collected in controlled environment experiments as described above may be considered together with results from outside experiments and synthesised into a herbicide/environment profile. Data from WRO work relating to glyphosate are illustrated in Table 2.

Table 2 Individual environmental factors leading to maximum control of common couch with glyphosate

Period and duration of occurence of factor	Pre-application period Long	Pre-application period Short	Time of application	Post-application period Short	Post-application period Long
light	low**	low*	—	high**	—
temperature	low	high**	—	high**	low**
humidity	—	high*	—	high***	—
rain	—	0–0.5*	0–0.5***	0–0.5***	—
wind	—	—	≤8 mph***	—	—

Relative importance of factor: *(least)–***(most)

Low light and temperature for a lengthy pre-application period results in plants with little rhizome and high ratio of foliage to nodes. High temperature in the week immediately before application favours the development of leaves which are readily wettable and easily penetrated. High humidity, dew or slight rain immediately before application ensures that the cuticle is fully hydrated thus aiding penetration. The occurence of these conditions after application keeps the herbicide in solution thus facilitating penetration, while warmth and high light during this period favour phloem transport. Finally, low temperature for a lengthy period after application improves herbicide activity in buds on the rhizomes.

PHYSIOLOGICAL AND BIOCHEMICAL STUDIES

Studies on the effect of individual environmental factors on the component steps involved in herbicide activity can identify where and at what stage loss or accumulation of the active ingredient occurs, resulting in some of the effects reported earlier. Recent WRO studies on common couch using radio-active labelled ^{14}C glyphosate show that penetration of this compound is slow, especially under adverse conditions such as a cold pre-application environment or a low humidity regime immediately after application. In order to improve the rainfastness and overall performance of glyphosate, attention was focussed on increasing uptake. The addition of Agral surfactant to the recommended dose of glyphosate, formulated as Roundup, significantly increased penetration of the mid-lamina region at one, three and six days after application. Application of ^{14}C glyphosate to the inner sheath of the leaf led, when compared with the lamina, to much more rapid penetration and translocation of the herbicide. It also minimised the reduction in uptake brought about by low humidity in the post-spraying period. Positioning the herbicide in the ligule/inner leaf sheath area rather than the lamina also greatly increased the activity of benzoylprop-ethyl, diclofop-methyl and difenzoquat against wild oats, and isoproturon and chlortoluron against blackgrass and wild oats. The formulation and application of herbicides for grass weed control in a way that will result in deposition in this highly sensitive area is a topic worthy of further research.

Wheat cultivars such as Sicco, with a low tolerance of difenzoquat, suffer more damage under high than under low temperature regimes. Studies with ^{14}C labelled difenzoquat show that this is due to greater penetration and movement at the higher temperature. Under the same environmental conditions mobility is the same in both susceptible and tolerant spring wheats, but DNA synthesis, a vital process involved in cell division in the meristem, is several times as sensitive in susceptible cultivars as in tolerant ones. As a result of this work a test is being developed so that plant breeders can rapidly determine the difenzoquat tolerance of new cultivars.

THE FUTURE

Recent progress in the development of controlled drop application and low ground pressure spraying vehicles has necessitated a re-appraisal of what constitutes acceptable weather for herbicide application in winter cereals. Our future work will define more closely the limits of these criteria and when they occur. For example, since the existing criteria are met more often at night than in daylight hours, the consequences of application in the dark, as already practised in the United States, on uptake, movement and activity will be investigated. This illustrates how our physiological and chemical research, aimed at understanding the underlying scientific principles, takes practical problems as its starting point. Thus the WRO research programme on the influence of the environment on herbicide performance will continue, in liaison with manufacturers, to be a synthesis of controlled environment studies and closely monitored outside experimentation, while the analysis of meteorological data will facilitate the extrapolation of controlled environment information to the improvement of field performance of selected herbicides.

REFERENCES

ANON (1978). *Report Weed Research Organization 1976–77*, p. 22.

CASELEY, J. C. (1972). The effect of environmental factors on the performance of glyphosate against *Agropyron repens*. *Proceedings 11th British Weed Control Conference*, **2,** 641–647.

CASELEY, J. C. (1974). Possible approaches to the enhancement of herbicide efficiency. *Proceedings 12th British Weed Control Conference*, **3,** 977–985.

CASELEY, J. C, COUPLAND, D. & SIMMONS, R. C. (1975). The effect of precipitation on the control of *Agropyron repens* with glyphosate. *Proceedings EWRS Symposium Status, Biology and Control of Grassweeds in Europe*, **1,** 124–130.

CASELEY, J. C. & COUPLAND, D. (1980). Effect of simulated rain on retention, distribution, uptake, movement and activity of difenzoquat applied to *Avena fatua*. *Annals of Applied Biology* (in press).

COUPLAND, D., CASELEY, J. C., & SIMMONS, R. C. (1976). The effect of light, temperature and humidity on the control of *Avena fatua* with difenzoquat. *Proceedings British Crop Protection Conference—Weeds*, **1,** 47–55.

COUPLAND, D., TAYLOR, W. A., & CASELEY, J. C. (1978). The effect of site of application on the performance of glyphosate on *Agropyron repens* and barban, benzoylprop-ethyl and difenzoquat on *Avena fatua*. *Weed Research*, **18,** 123–128.

TOTTMAN, D. R. & PHILLIPSON, A. (1974). Weather limitations on cereal spraying in the spring. *Proceedings 12th British Weed Control Conference*, **1,** 171–176.

Testing sorghum and other crops for resistance to witchweed

C. PARKER and D. C. REID

THE PROBLEM

Witchweeds (*Striga* species) are hemi-parasitic weeds causing serious losses of tropical cereal crops and cowpeas in Asia and Africa.

The damage caused by the witchweeds has long been recognised and classical studies in Sudan, India and South Africa between 1925 and 1955 provided basic information on their biology, and indicated ways in which they could be at least partially controlled by rotation, catch cropping, irrigation, improved soil fertility and hand pulling. Unfortunately most of these practices are impracticable for a majority of the small farmers on infertile soils, in semi-arid areas, where the problem is most severe. The alternative approach, that of producing some relatively resistant varieties has, in the past, only been exploited for local use; the strains selected and bred were rarely used over any wide area and were often of poor yield or quality. Nevertheless, it is now felt that this latter approach is by far the most promising.

ORIGINS OF THE INVOLVEMENT OF THE ARC WEED RESEARCH ORGANIZATION

The biology and control of witchweed was a subject of research by the ARC Unit of Experimental Agronomy from the mid 1950s and, since 1970, it has been further studied by the Tropical Weeds Group of WRO. In the course of this work simple techniques were developed for determining the ability of sorghum varieties to stimulate germination of witchweed seed, an essential step in the process of a witchweed attack on sorghum. The seeds of this parasite will not normally germinate unless stimulated to do so by exudates from the host roots and the simplest way in which a sorghum variety can be resistant is by *not* producing the necessary stimulant.

In 1972 the International Crops Research Institute for the Semi Arid Tropics (ICRISAT) was established at Hyderabad in India as one of the family of international agricultural research institutes, under the Consultative Group for International Agricultural Research (CGIAR). The crops for which ICRISAT is particularly responsible include sorghum and millet, the two tropical cereals most severely affected by witchweed species, and from the outset one of the plant breeding objectives for sorghum was witchweed or *Striga* resistance. An ICRISAT plant breeder, Dr K V Ramaiah, has been responsible for this work, based first at Hyderabad and, since early 1979, in Upper Volta, West Africa.

In 1975 Dr Ramaiah came to WRO for several weeks to learn techniques and then proceeded to set up a laboratory at ICRISAT for the systematic screening of the world sorghum collection, testing the ability of each variety to stimulate germination of the local *Striga asiatica*.

Preliminary studies at WRO (Parker *et al*, 1977) had shown a correlation between the response to sorghum root exudates of the Indian *S. asiatica* and that of the more serious African weed, *S. hermonthica*. This suggested that varieties selected for their low stimulation of *S. asiatica* would also have little stimulatory effect upon the seed of *S. hermonthica* and thus be relatively resistant to this species. This characteristic is termed 'low stimulant' resistance. It was felt important, however, that this should be checked more systematically with a wide range of samples of *S. hermonthica* from different parts of Africa.

To import *Striga* seeds from Africa to India would have been dangerous and thus the WRO *Striga* project was initiated at ICRISAT's request in October 1977 and now forms part of the work of the Tropical Weeds Group at WRO, financed under the UK overseas aid programme by the Overseas Development Administration of the Foreign and Commonwealth Office. As *Striga* requires temperatures of at least 30°C for development, it poses no significant threat to UK crops. An extensive visit was made to six West African countries in late 1977 to collect *Striga* seeds and intensive laboratory and glasshouse work began in the summer of 1978.

STUDIES ON THE RESISTANCE OF SORGHUM

To date, three major pot experiments have been conducted in the WRO glasshouses to test the resistance of a selected range of sorghum varieties to a range of *Striga* species and strains.

In the first two experiments it was confirmed that those sorghum varieties which had been selected by sorghum breeders in Northern Nigeria for their 'low-stimulant' resistance to *S. hermonthica* (SRN 4841, Framida, IS 7091, IS 2643, IS 7471 and line 187) all showed good broad-spectrum resistance to a wide range of strains of both *S. asiatica* and *S. hermonthica* (Table 1).

Other varieties in those two experiments had also been selected, either in Africa or India, for their field resistance to *Striga* but were known to

Table 1 Partial results of three pot experiments indicating total emergence of *Striga* per three replicate pots (Expt. 1) or four replicate pots (Expts. 2, 3)

Crop variety	Resistance type	*Striga* strain: *Striga asiatica* India		Africa		*Striga hermonthica* West Africa				Sudan/Ethiopia		
Expt. 1		A	B	C	D	E	F	G	H	J	K	
Framida	low	1	0	5	2	0	0	0	0	4	0	
SRN 4841	low	0	0	3	1	0	0	0	0	5	5	
IS 7091	low	0	0	0	0	0	0	0	0	11	8	
IS 2643	low	1	0	9	1	1	1	4	0	1	7	
148	pos	6	8	9	9	2	10	4	15	19	13	
N13	pos	2	1	30	5	0	37	19	1	35	30	
Swarna	susc	59	14	45	14	0	38	26	45	37	45	
YE 90L	susc	41	18	62	24	2	52	57	11	51	58	
Expt. 2		A	B	C		E	F	G	H	L	K	M
SRN 4841	low	0	0	0		0	0	0	0	3	0	0
IS 7471	low	1	3	1		0	1	1	1	14	6	0
187	low	0	0	0		0	1	10	6	6	4	2
N13	pos	1	3	1		0	11	6	7	56	14	8
IS 9985	pos	0	35	6		0	1	12	21	84	17	3
Swarna	susc	9	35	17		0	14	22	24	84	22	10
Expt. 3		A	B	C	N	E	F	G	H	L	K	M
23/15	?	0	0	4	0	0	1	2	5	12	31	5
IS 3924	low	0	0	0	0	1	13	7	18	24	13	19
IS 4415	low	0	0	3	1	0	0	8	5	4	17	8
IS 3923	low	0	13	9	0	0	2	10	14	13	28	31
8/55	pos	3	13	5	1	0	0	10	25	21	38	9
E35-1	pos	2	22	42	8	1	10	27	6	61	51	32
Swarna	susc	10	56	102	13	1	18	34	28	57	37	26
Millet (ex Bornu)		5	30	11	7	108	16	7	28	1	2	0

NOTES:– All *Striga* strains were from sorghum hosts except D (from maize) and E (from millet)

Resistance type – 'low' = low stimulant
'pos' = stimulant positive
'susc' = susceptible standards

stimulate germination of either or both main *Striga* species. These are referred to as 'stimulant-positive' and their resistance is presumed to be due to some mechanical or physiological mechanism which results in failure of *Striga* to attach and develop normally. These varieties performed less consistently in these pot experiments, showing apparent resistance to some *Striga* strains but not to others. Varieties N13 and IS 9985, which had been among the best in field trials in Africa as well as India, failed in the pot experiment when exposed to *Striga* even when, in some instances, the *Striga* had come from the same field sites where the varieties had proved promising (Table 1).

The third pot experiment included a number of varieties selected by ICRISAT on the basis of low stimulation of the Indian *S. asiatica*. Their resistance to two Indian and one African strain of *S. asiatica* (Fig. 1) was in general confirmed but they proved relatively susceptible to several strains of *S. hermonthica*, especially those from the Sudan and Ethiopia. Again, the 'stimulant-positive' lines were generally disappointing, including variety E 35-1 which had been one of the best in field experiments (Table 1).

In addition to these pot experiments there has been a large volume of laboratory germination studies to try and confirm the extent to which the 'low-stimulant' character is likely to be reliable over all strains of *S. asiatica* and *S. hermonthica*. Earlier work (Parker *et al*, 1977) had suggested that varieties 'low-stimulant' for *S. hermonthica* were also 'low-stimulant' for *S. asiatica*. High pressure liquid chromatography had also indicated that a similar complex of stimulant substances affected both species. It was on this assumption of the related behaviour of the two species, that ICRISAT embarked on the systematic screening of the world sorghum collection, using only the local Indian *S. asiatica* as the test organism.

Out of some 14,000 varieties tested, several hundred were selected as causing less than 10% of the germination caused by a susceptible standard variety Swarna. One hundred of these selections were passed to WRO and their stimulant activity was tested on four samples of *Striga* seed (two from each of two main species). Results of these and later tests with a smaller number of sorghum varieties and a larger range of *Striga* strains have not given as simple a picture as had been hoped. There is a broad tendency for the varieties causing least germination of *S. asiatica* also to cause lower germination of *S. hermonthica*, but whereas the activity of the exudate from a 'low-stimulant' variety can be one hundred times less than that of a susceptible variety when tested on Indian *S. asiatica*, the difference may only be about five times less when the same exudates are tested on *S. hermonthica*.

Fig. 1. *Striga asiatica* growing on root of sorghum in Botswana.

Hence the absolute level of resistance to *S. hermonthica* is liable to be lower, so explaining the relatively poor results in the third pot experiment. These differences suggest that there are components of the stimulant exudates which trigger germination of *S. hermonthica* but not *S. asiatica*. This can only be fully confirmed by more detailed chromatographic separation of the stimulant exudates. Meanwhile, some inconsistencies in experimental results are further suggesting that the ratios of different active substances in the root exudate may vary from one experiment to another, perhaps due to the activity of rhizosphere organisms. Further work is in progress to clarify this. Meanwhile more of the ICRISAT 'low-stimulant' sorghum selections will be studied to determine which ones are likely to be most resistant when exposed to *S. hermonthica*.

The failure of the 'stimulant-positive' varieties in pot experiments has suggested that environmental conditions may be important in the manifestation of these alternative forms of resistance. The most likely factor to be involved is soil moisture and work is in progress to determine if moisture stress is an essential pre-requisite to mechanical or other resistance. Better understanding of these alternative mechanisms is badly needed so that suitable screening procedures can be devised.

STRIGA AND BULLRUSH MILLET

A striking feature of the pot experiments has been the almost perfect specificity of certain strains of *S. hermonthica* to bullrush millet (*Pennisetum americanum*). Wilson Jones (1955) suggested that there were distinct strains of *Striga* in the Sudan but it had not previously been confirmed in West Africa. Field observations had, however, suggested the existence of millet-specific strains in Mali, Upper Volta and Niger and WRO experiments have now not only confirmed their existence but shown that the specificity is due to quite different germination requirements. Root exudate tests have shown that, in general, strains of *S. hermonthica* associated with sorghum fail to germinate in response to millet and, conversely, the strains associated with millet fail to germinate in response to sorghum (Fig. 2).

Although millet often escapes *Striga* attack in predominantly sorghum-growing areas there has so far been little success in finding varieties of millet that are resistant in the areas affected by the millet strains of *S. hermonthica*. Root exudate tests at WRO have so far shown relatively small differences in stimulant production in the random selection of millet varieties tested. Meanwhile, the realisation that the millet strains of *Striga* respond to different stimulant substances has made it necessary to re-consider what

Fig. 2. Host specificity in strains of *Striga hermonthica.*
Left to right
Millet without *Striga*
Millett with *Striga hermonthica* from sorghum
Millet with *Striga* from millet
Sorghum with *Striga* from sorghum
Sorghum with *Striga* from millet
Sorghum without *Striga.*

crops may be suitable as rotational 'trap crops', i.e., crops stimulating germination but not being parasitised, so helping to reduce the population of seed in the soil. For strains of *Striga* attacking sorghum or maize, cotton is known to be an effective trap crop but WRO work has shown that cotton fails to stimulate germination of the millet strains of *S. hermonthica*. Cowpea (*Vigna unguiculata*) and pigeon pea (*Cajanus cajan*) however, are potential trap crops (Parker & Reid, 1979).

Further work is in progress with millets, particularly exploring the possibility of resistance in semi-wild 'sebra' types.

STRIGA AND COWPEAS

While the host specificity of different strains of *S. hermonthica* has been shown to be based on germination factors, different results have been obtained from comparable studies on *S. gesnerioides*, the species mainly important as a parasite on cowpeas. It is common in the drier parts of West Africa but it also attacks tobacco in Southern Africa and a range of other wild hosts in the Leguminosae, Convolvulaceae and Euphorbiaceae. The four strains studied so far have been associated with cowpea, tobacco, *Tephrosia pedicellata* and *Jacquemontia tamnifolia* hosts. Each was found to be quite specific to its original hosts, but exudate tests have shown that this specificity is not due to simple differences in germination requirement. Further work is now in progress to determine what mechanism is involved and so to suggest ways in which cowpea varieties might be systematically screened for resistance, without the need for large field experiments.

THE FUTURE

The WRO project on witchweed, which is supported by HM Overseas Development Administration under Research Scheme R 3327, has been extended to at least 1981, in order to help clarify the various problems that have arisen. Meanwhile ICRISAT's own programme continues with collaboration in many parts of Africa and India. These combined efforts seem likely to yield valuable results within the next few years.

REFERENCES

PARKER, C., HITCHCOCK, A. M. & RAMAIAH, K. V. (1977). The germination of *Striga* species by crop root exudates: techniques for selecting resistant cultivars. *Proceedings 6th Asian Pacific Weed Science Society Conference, Jakarta,* 67–74.

PARKER, C. & REID, D. C. (1979). Host specificity in *Striga* species—some preliminary observations. *Second Symposium on Parasitic Weeds,* 79–90.

WILSON JONES, K. (1955). Further experiments on witchweed control. II. The existence of physiological strains of *Striga hermonthica*. *Empire Journal of Experimental Agriculture,* **23,** 206–213.

LIST OF RESEARCH AND RELATED SERVICE PROJECTS 1978/79

WEED CONTROL DEPARTMENT

Head of Department: J. G. Elliott

ANNUAL CROPS GROUP (*Leader:* G. W. Cussans)

1. Herbicide treatments for the control of wild-oat and blackgrass in cereals: Dr P J Lutman, M E Thornton
2. Study of the weed problems of minimum tillage especially the grasses *Alopecurus myosuroides, Bromus sterilis:* F Pollard, S R Moss
3. Long term economic weed control in cereals including rationalisation of herbicide use and agroecology of weeds: B J Wilson, P Ayres
4. Growth of cereals in reduced tillage systems: J G Elliott, F Pollard
5. Control of perennial grass weeds in cereal cropping systems: G W Cussans, P Ayres
6. Effect of high organic matter soils on use of herbicides: Dr P J Lutman, M J May
7. Control of potato groundkeepers: Dr P J Lutman, G W Cussans
8. Cereal tolerance of herbicides: D R Tottman, G W Cussans
9. Factors affecting the success of weed beet in agricultural land: G W Cussans, C J Bastian
10. Studies of the effects of herbicides and weed competition on the establishment and growth of oilseed rape: Dr P J Lutman, M E Thornton

GRASS AND FODDER CROPS GROUP (*Leader:* Dr R J Haggar)

1. The agro-ecology and control of important broad leaved weeds including bracken in grass/legume swards: A K Oswald
2. The role of herbicides in manipulating sward composition with particular reference to clover encouragement: Dr R J Haggar, F W Kirkham
3. Minimum cultivation/herbicide systems for establishing grasses, legumes and fodder crops in existing swards: N R W Squires, Dr R J Haggar
4. The agro-ecology and control of important grass weeds in leys and seed crops: A K Oswald, F W Kirkham

PERENNIAL CROPS GROUP (*Leader:* Dr J G Davison)

1. Fruit crop tolerance of soil-and foliage-applied herbicides: D V Clay, Dr J G Davison
2. Effect of important weeds on fruit production: Dr J G Davison, J A Bailey
3. Response of newly planted fruit crops and nursery stock to weed competition and herbicides: Dr J G Davison, J A Bailey
4. Evaluation of new herbicides for the control of annual and perennial weeds in strawberries: D V Clay, Dr J G Davison

SPECIAL SERVICES

1. Survey and analysis of information about weeds and weed control in agriculture: J G Elliott
2. Supervision, development and maintenance of application equipment for experimental use: M E Thornton
3. Field chemical laboratory: J A Slater
4. Management of Begbroke Hill Farm: J G Elliott, R Dale

WEED SCIENCE DEPARTMENT

Head of Department: Dr K Holly

HERBICIDE PERFORMANCE GROUP (*Leader:* J Holroyd)

1. Evaluation of new herbicides and investigation of specific short term problems: W G Richardson, J Holroyd
2. Influence of formulation factors on the activity of herbicides: Dr D J Turner
3. Improvement of methods for the application of herbicides: W A Taylor, J Holroyd
4. Basic studies of the interaction of herbicides with one another: Dr H F Taylor, M P C Loader
5. Evaluation of herbicides for forestry: Dr D J Turner, W G Richardson

ENVIRONMENTAL STUDIES GROUP (*Leader:* Dr J C Caseley)

1. Effect of environmental factors on the activity of herbicides and growth regulators: Dr J C Caseley, A M Blair, Dr D Coupland, C R Merrit, R C Simmons
2. Development of experimental techniques and equipment for monitoring the environment; establishment of controlled environment systems: R C Simmons, Dr J Caseley

CHEMISTRY GROUP (*Leader:* Dr R J Hance)

1. Analysis of herbicides in soil, water and plant material; T H Byast, E G Cotterill
2. Development of analytical methods for herbicides and their decomposition products: T H Byast, E G Cotterill
3. Soil factors affecting the performance of soil-applied herbicides: Dr R J Hance
4. Influence of repeated applications of MCPA, tri-allate, simazine and linuron on fertility of soil: P D Smith
5. Persistence in soil of paraquat applied repeatedly to plant cover or soil: P D Smith
6. Effects of repeated applications of glyphosate on fertility of soils and growth of cereals at Begbroke Hill: P D Smith

MICROBIOLOGY GROUP (*Leader:* M P Greaves)

1. Effects of herbicides and their metabolites on natural microbial populations and their activities in the soil: J A Marsh, H A Davies
2. The effects of herbicides and breakdown products on the microflora of the root region of plants: M P Greaves, G I Wingfield
3. Interactions between herbicides and the physiology and population dynamics of model microbial ecosystems: G I Wingfield, M P Greaves

WEED BIOLOGY GROUP (*Leader:* R J Chancellor)

1. Periodicity of germination of weed seeds. Chemicals for breaking seed dormancy: R J Chancellor, Dr N C B Peters
2. Vegetative regeneration of weeds: R J Chancellor
3. Grassland weed ecology: E D Williams, R J Chancellor
4. Inter-action of factors affecting competition between crops and weeds: Dr N C B Peters
5. Arable weed ecology: R J Chancellor, R J Froud-Williams
6. Influence of light on seed germination and vegetative regeneration of weeds: R J Chancellor, J Hilton

SPECIAL SERVICES

1. Plant raising facilities for pot experiments: R H Webster

EXTRA-DEPARTMENTAL RESEARCH GROUPS

DEVELOPMENTAL BOTANY GROUP (*Leader:* Dr D J Osborne)

1. Dormancy and viability of weed seeds: Dr J Osborne, Dr J A Sargent, Dr R Hooley
2. Importance of stress conditions in seed germination and seedling establishment: Dr D J Osborne, Dr J A Sargent, Dr M Wright
3. Factors regulating perennation and regeneration of plant parts: Dr D J Osborne, Dr J A Sargent, Dr M Wright
4. Control of seed shedding in weed species: Dr D J Osborne, Dr J A Sargent, Dr R Hooley

AQUATIC WEED AND UNCROPPPED LAND GROUP (*Leader:* T O Robson)

1. Development of chemical methods of controlling aquatic vascular plants and algae: T O Robson, P R F Barrett
2. Assessment of potential of grass carp for the control of aquatic weeds: M C Fowler, T O Robson (Joint project with MAFF Freshwater Fisheries Laboratory)
3. The role of herbicides and growth regulators in the management of vegetation on uncropped land: E J P Marshall, T O Robson
4. Advisory service on aquatic weed control: T O Robson, P R F Barrett

ODA TROPICAL WEEDS GROUP (*Leader:* C Parker)

1. New herbicide treatments for use in tropical crops against annual and established perennial weeds: C Parker
2. Study of the resistance of sorghum and millet varieties to a range of *Striga* species and strains: C Parker
3. Liaison and advisory work on weed control in developing countries: C Parker, A K Wilson

INFORMATION DEPARTMENT

Head of Department: J E Y Hardcastle

1. Library, information, editorial and public relations services: J E Y Hardcastle, B R Burton, H R Broad, N Kiley
2. Production of *Weed Abstracts:* W L Millen, J L Mayall, P J Kemp, H R Broad, M Turton

ADMINISTRATION DEPARTMENT

Head of Department: B A Wright

1. Photographic services: R N Harvey, S G Bebb
2. Workshop/maintenance services to experimenters: R Kibble-White, R W Foddy, J A Drinkwater, C J Stent

LIST OF PUBLICATIONS 1978–79

787* AYRES, P. The influence of application method on the control of wild oats (*Avena fatua* L. and *Avena ludoviciana* Dur.) in winter wheat by difenzoquat applied at a range of growth stages. *Monograph British Crop Protection Council*, 1978, **22,** 163–170.

847 AYRES, P. The influence of application method on the control of blackgrass (*Alopecurus myosuroides* Huds). in winter cereals by post-emergence applications of a range of herbicides. *Proceedings British Crop Protection Conference—Weeds*, 1978, 687–694.

817 AYRES, P and MERRITT, C R. Field experiments with controlled drop applications of herbicides for the control of dicotyledonous weeds. *Weed Research*, 1978, **18,** (4), 209–214.

837 BAILEY, J A. The tolerance of strawberry to 2,4-D, MCPA, mecoprop and dichlorprop applied in the year of planting, *Proceedings British Crop Protection Conference—Weeds*, 1978, 183–190.

836 BAILEY, J A. The control of *Convulvulus arvensis* with cultivations and/or glyphosate and MCPA. *Proceedings British Crop Protection Conference—Weeds*, 1978, 231–235.

BAILEY, J A. SARD treatments. *Grower*, 1978, **90,** (7), 323.

BARLOW, P W and SARGENT, J A. The ultrastructure of the regenerating root cap of *Zea mays* L. *Annals of Botany*, 1978, **42,** 791–799.

BARRETT, P R F. Localised control of water weeds. *Technical Leaflet ARC Weed Research Organization,* 1978, **4,** pp 2.

813 BARRETT, P R F. Aquatic weed control: necessity and method. *Fisheries Management,* 1978, **9,** (3), 93–101.

852 BARRETT, P R F. Some studies on the use of alginates for the placement and controlled release of diquat on submerged aquatic plants. *Pesticide Science*, 1978, **9,** (5), 425–433.

805 BLAIR, A M. Interactions between barban and protectants on maize, oats and barley. *Weed Research*, 1978, **18,** (3), 77–81.

864 BLAIR, A M. Some studies on the sites of uptake of chlortoluron, isoproturon and metoxuron by wheat, *Avena fatua* and *Alopecurus myosuroides. Weed Research*, 1978, **18,** (6), 381–387.

881 BLAIR, A M. The interaction of protectants with EPTC on field bean and tri-allate on wheat. *Annals of Applied Biology*, 1979, **92,** (1), 105–111.

BLAIR, A M. Antidotes for the protection of field bean (*Vicia faba* L.) from damage by EPTC and other herbicides. *Technical Report ARC Weed Research Organization*, 1979, **52,** pp. 24. Price – £1.35.

BLAIR, A M. Antidotes for the protection of wheat from damage by tri-allate. *Technical Report ARC Weed Research Organization*, 1979, **53,** pp. 36. Price – £2.00.

900 CASELEY, J C. Techniques for investigating effects of weather on herbicide performance. *Proceedings EWRS Symposium—The influence of different factors on the development and control of weeds*, 1979, 105–113.

* The numbers appearing on the left hand side of this list are the WRO serial numbers for the items. Reprints and Technical Leaflets are available free from the Librarian, ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford, OX5 1PF; please quote number(s) required and enclose postage at the rate of 60p *per order*. Technical Reports and Annotated Bibliographies can be ordered (cash with order) at prices quoted.

CHANCELLOR, R J. Facts about perennial garden weeds. *Technical Leaflet ARC Weed Research Organization*, 1978, **6**, pp. 2.
863 CHANCELLOR, R J. The long-term effects of herbicides on weed populations. *Annals of Applied Biology*, 1979, **91**, (1), 141–144.
893 CHANCELLOR, R J. Grass seeds beneath pastures. *Proceedings British Grassland Society Occasional Symposium*, 1979, **10**, 147–150.
902 CHANCELLOR, R J. The seasonal emergence of dicotyledonous weed seedlings with changing temperature. *Proceedings EWRS Symposium—The influence of different factors on the development and control of weeds*, 1979, 65–72.
CHEAH, K S E and OSBORNE, D J. The integrity of DNA in loss of viability of embryos of ageing rye seeds. *Nature*, 1978, **272**, 593–599.
922 CLAY, D V. The consequences of repeated applications of chlorthiamid and dichlobenil in blackcurrants. *Report ARC Weed Research Organization 1976–1977*, 1978, **7**, 70–76.
CLAY, D V. A sand culture technique for testing herbicides in perennial crops. *Technical Leaflet ARC Weed Research Organization*, 1978, **10**, pp. 2.
802 CLAY, D V. Simazine mix—better annual weed control in strawberries. *Grower*, 1978 (June 8), 1275–1276, 1279.
CLAY, D V. Simazine rates on young apple trees. *Grower*, 1978, **90**, (17), 827.
799 CLAY, D V. Residues of simazine in soil following repeated applications to fruit, ornamental and forestry crops. *Experimental Horticulture*, 1978, **30**, 46–55.
840 CLAY, D V. The tolerance of young strawberry crops to a trietazine/simazine mixture. *Proceedings British Crop Protection Conference—Weeds*, 1978, 151–158.
841 CLAY, D V. The response of strawberries to propachlor, pendimethalin and trifluralin used alone, in mixtures or sequentially. *Proceedings British Crop Protection Conference—Weeds*, 1978, 175–182.
CLAY, D V. Knocking clover over. *Grower*, 1979, **92**, (24), 30.
809 CLAY, D V and DAVISON, J G. An evaluation of sand-culture techniques for studying the tolerance of fruit crops to soil-acting herbicides. *Weed Research*, 1978, **18**, (3), 139–147.
905 CLAY, D V and McKONE, C E. Effects of repeated applications of high rates of chlorthiamid and dichlobenil to blackcurrants. *Pesticide Science*, 1979, **10**, (5), 429–437.
COOKSON, C and OSBORNE, D J. The stimulation of cell extension by ethylene and auxin in aquatic plants. *Planta*, 1978, **144**, 39–47.
913 COOKSON, C and OSBORNE, D J. The effect of ethylene and auxin on cell wall extensibility of the semi-aquatic fern, *Regnellidium diphyllum*. *Planta*, 1979, **146**, 303–307.
806 COOPER, S L, WINGFIELD, G I, LAWLEY, R and GREAVES, M P. Miniaturized methods for testing the toxicity of pesticides to microorganisms. *Weed Research*, 1978, **13**, (3), 105–107.
804 COTTERILL, E G. Determination of 3,6-dichloropicolinic acid residues in soil by gas chromatography of the 1-butyl ester. *Bulletin of Environmental Contamination & Toxicology*, 1978, **19**, (4), 471–474.
869 COTTERILL, E G. Rapid simultaneous determination of residues of MCPA, mecoprop and MCPB in soil by gas chromatography of the pentafluorobenzyl ester. *Journal of Chromatography*, 1979, **171**, 478–481.
898 COTTERILL, E G. Effects of ammonium nitrate on the gas-chromatographic determination of some pesticide residues in soils. *Analyst*, 1979, **104**, 878–880.

895 COUPLAND, D and CASELEY, J C. Presence of 14^C activity in root exudates and guttation fluid from *Agropyron repens* treated with ^{14}C-labelled glyphosate. *New Phytologist*, 1979, **83**, (1), 17–22.
810 COUPLAND, D, TAYLOR, W A and CASELEY, J C. The effect of site of application on the performance of glyphosate on *Agropyron repens* and barban, benzoylprop-ethyl and difenzoquat on *Avena fatua*. *Weed Research*, 1978, **18**, (3), 123–128.
CRAKER, L E, COOKSON, C and OSBORNE, D J. Control of proton extrusion and cell elongation by ethylene and auxin in the water-plant *Ranunculus sceleratus*. *Plant Science Letters*, 1978, **12**, 379–385.
CUMING, A C and OSBORNE, D J. Membrane turnover in imbibed dormant embryos of the wild oat (*Avena fatua* L.) I. Protein turnover and membrane replacement. *Planta*, 1978, **139**, 209–217.
CUMING, A C and OSBORNE, D J. Membrane turnover in imbibed dormant embryos of the wild oat (*Avena fatua* L.) II. Phospholipid turnover and membrane replacement. *Planta*, 1978, **139**, 219–226.
CUMING, A C and OSBORNE, D J. Membrane protein and phospholipid turnover in imbibed dormant embryos of wild oats. *Proceedings of the International Symposium on Recent Advances in the Biochemistry of Cereals, Bangor, 1978.* 1979, Chapter 5, 105–118.
CUSSANS, G W. Weeds and weed control in relation to yield. *Journal of the Science of Food and Agriculture*, 1978, **29**, (7), 651–652.
859 CUSSANS, G W. The problem of volunteer crops and some possible means of their control. *Proceedings British Crop Protection Conference—Weeds*, 1978, 915–921.
848 CUSSANS, G W and AYRES, P. A feasibility study on a low ground pressure spraying vehicle. *Proceedings British Crop Protection Conference—Weeds*, 1978, 633–640.
CUSSANS, G W. Notes on the control of some individual weeds. In: *Weed Control Handbook*, Vol. 2, 8th ed. (Ed. J D Fryer and R J Makepeace), Oxford, Blackwell, 1978, 354–393.
899 CUSSANS, G W and DALE, R J. Arable silage as an arable breakcrop. *Big Farm Management*, 1979 (October), 51, 53.
903 CUSSANS, G W, MOSS, S R, POLLARD, F and WILSON, B J. Studies of the effects of tillage on annual weed populations. *Proceedings EWRS Symposium—The Influence of different factors on the development and control of weeds*, 1979, 115–122.
773 CUSSANS, G W and TAYLOR, W A. Controlled drop application—what does it all mean? *Arable Farming*, 1978 (January), 45–47.
882 CUSSANS, G W and TAYLOR, W A. Progress in the development of controlled drop application of herbicides. *ARC Research Review*, 1978, **4**, (3), 84–86.
924 CUSSANS, G W and TAYLOR, W A. Progress in the development of controlled drop application of herbicides. *Report ARC Weed Research Organization 1976–1977*, 1978, 49–54.
846 DAVISON, J G. The influence of dose and incorporation on the activity and persistence of metham-sodium. *Proceedings British Crop Protection Conference—Weeds*, 1978, 459–466.
851 DAVISON, J G. Pre-planting action—key to strawberry weed control. *Grower*, 1978, (July 23), 177–179.
DAVISON, J G. Recommendations for the use of herbicides in perennial vegetable crops, fruit, flowers, nursery stock and glasshouse crops In: *Weed*

Control Handbook, Vol. 2, 8th ed. (Ed. J D Fryer and R J Makepeace), Oxford, Blackwell 1978, 131–195.
860 DAVISON, J G. Weed control in fruit crops—what's needed. *Proceedings British Crop Protection Conference—Weeds*, 1978, (3), 897–904.
DAVISON, J G. Suggestions for the control of giant hogweed (*Heracleum mantegazzianum*). *Technical Leaflet ARC Weed Research Organization*, 1978, **9**, pp. 3.
DAVISON, J G. Developments in fruit weed control. *Technical Leaflet ARC Weed Research Organization*, 1979, **14**, pp. 3.
912 DAVISON, J G. Polythene mulching for fruit crops 1 & 2. *Kent Focus*, 1979, **9**, (9), 9; **9**, (10), 9.
776 DAVISON, J G and BAILEY, J A. The use of 2, 4-D amine for perennial weed control on strawberries. *ARC Research Review*, 1978, **4**, (1), 13–16.
880 DAVISON, J G and BAILEY, J A. Black polythene for weed control in young fruit and other perennial crops. *ARC Research Review*, 1979, (BGLA Issue), 11–14.
763 DAVISON, J G and CLAY, D V. Some aspects of weed control in strawberries. *Proceedings—Conference, Strawberries for Processing, Wisbech (ADAS/Wisbech Fruit Growers Association, Merchants and Manufacturers)*, 1978, 1–11.
769 DAVISON, J G and CLAY, D V. Controlling weeds with care. *Grower*, 1978 (January 12), 11–12.
915 DIBB, C and HAGGAR, R J. Evidence of effect of sward changes on yield. *Proceedings British Grassland Society Occasional Symposium*, 1978, **10**, 11–20.
878 DIBB, C and HAGGAR, R J. Evidence of effect of sward changes on yield. *ADAS Quarterly Review*, 1979, **32**, 1–14.
DUDDRIDGE, J A and SARGENT, J A. A cytochemical study of lipolytic activity in *Bremia lactucae* Regel. during germination of the conidium and penetration of the host. *Physiological Plant Pathology*, 1978, **12**, 289–296.
858 ELLIOTT, J G. The economic objectives of weed control in cereals. *Proceedings British Crop Protection Conference—Weeds*, 1978, 829–839.
928 ELLIOTT, J G. Are tractors limiting the expansion of direct drilling? *Report ARC Weed Research Organization 1976–1977*, 1978, 57–63.
812 ELLIOTT, J G. The implications of direct-drilling for vegetable production. *Acta Horticulturae*, 1978, **72**, 93–100.
774 ELLIOTT, J G. Wet autumn creates new field of spray research. *Shropshire Farmer*, 1978, (January).
781 ELLIOTT, J G. Large area of low infestation is the problem. *Arable Farming*, 1978, (March), 13–14, 16.
800 ELLIOTT, J G. Fast low pressure ground sprayers. *Big Farm Management*, 1978, (June), 16, 21, 23.
856 ELLIOTT, J G. Roguing needs mechanising. *Arable Farming*, 1978, (February), 84–85.
ELIOTT, J G. Grassland—renovate or reseed? *Technical Leaflet ARC Weed Research Organization*, 1979, **13**, pp. 2.
883 ELLIOTT, J G. Are tractors limiting the expansion of direct drilling? *ARC Research Review*, 1978, **4**, (3), 76–78.
888 ELLIOTT, J G. Strategy for cereal weed. *Big Farm Management*, 1979, (August), 13–14.
ELLIOTT, J G. Cereal weeds. *Farmers Weekly Extra Arable*, 1979, (Feb. 2) 9–11.
ELLIOTT, J G. Work at the Weed Research Organization. *Agrospray*, 1979, (2), 11–12.

ELLIOTT, J G. In defence of droplet control. *Farmers Weekly*, 1979, **90**, (7), 58–59.

ELLIOTT, J G. Control systems for weeds, pests and diseases. *Proceedings NAC Conference Progress with Reduced Cultivations*, 1979.

879 ELLIOTT, J G, CHURCH, B M, HARVEY, J J *et al.* Survey of the presence and methods of control of wild oat, black grass and couch grass in cereal crops in the United Kingdom during 1977. *Journal of Agricultural Science*, 1979, **92**, (3), 617–634.

796 ELLIOTT, J G, DALE, R J and BARNES, F. The performance of beef animals on a permanent pasture. *Journal of the British Grassland Society*, 1978, **33**, (1), 41–48.

930 ELLIOTT, J G and POLLARD, F. (in collaboration with R Q Cannell, F B Ellis, B T Barnes and K R Howes). The WRO/Letcombe Joint Tillage Project in its closing stages. *Report ARC Weed Research Organization 1976–77*, 1978, **7**, 55–56.

ELLIOTT, J G and POLLARD, F. (in collaboration with R Q Cannell, F B Ellis, B T Barnes and K R Howes). Effect of reduced cultivations on soil conditions and root development of cereals: joint project with ARC Weed Research Organization. *Annual Report ARC Letcombe Laboratory 1977*, 1978, 46.

ELLIS, F B, CANNELL, R Q, GRAHAM, J P, HENDERSON, F K G, ELLIOTT, J G, and POLLARD, F. Long term effects of simplified cultivation. *Annual Report ARC Letcombe Laboratory 1978*, 1979, 12–13.

911 ELLIS, F B, ELLIOTT, J G, POLLARD, F, CANNELL, R Q and BARNES, B T. Comparison of direct drilling, reduced cultivation and ploughing on the growth of cereals. Part 3. Winter wheat and spring barley on a calcareous clay. *Journal of Agricultural Science*, 1979, **93**, 391–401.

931 FOWLER, M C. The biological control of water weeds. *Report ARC Weed Research Organization 1976–1977*, 1978, **7**, 85–89.

849 FOWLER, M C and ROBSON, T O. The effects of the food preference and stocking rates of grass carp (*Ctenopharyngodon idella* Val.) on mixed plant communities. *Aquatic Botany*, 1978, **5**, 261–276.

857 FRYER, J D. Status of weed science—a world's perspective. *Weed Science*, 1978, **26**, (6), 560–566.

867 FRYER, J D. Introduction to weed problems. *EPPO Bulletin*, 1979, **9**, (1), 73–81.

901 FRYER, J D. Key factors affecting important weed problems and their control. *Proceedings EWRS Symposium—The influence of different factors on the development and control of weeds*, 1979, 13–23.

FRYER, J D and MAKEPEACE, R J (Eds). *Weed Control Handbook*, Volume 2 Recommendations. 8th ed., Oxford, etc. Blackwell Scientific Publications, 1978, pp. 532.

872 FRYER, J D, SMITH, P D and LUDWIG, J W. Long-term persistence of picloram in a sandy loam soil. *Journal of Environmental Quality*, 1979, **8**, (1), 83–86.

FRYER, J D, SMITH, P D and LUDWIG, J W. Field experiments to investigate long-term effects of repeated applications of MCPA, tri-allate, simazine and linuron—effects on the quality of barley, wheat, maize and carrots. *Technical Report ARC Weed Research Organization*, 1978, **47**, pp. 19. Price – £1.20.

926 GREAVES, M P. Problems and progress in the evaluation of herbicide safety to the soil microflora. *Report ARC Weed Research Organization 1976–1977*, 1978, **7**, 95–103.

861 GREAVES, M P. Long term effects of herbicides on soil micro-organisms. *Annals of Applied Biology*, 1979, **91**, (1), 129–132.

908 GREAVES, M P. Measurement and interpretation of side-effects of pesticides on microbial processes. *Proceedings British Crop Protection Conference—Pests and Diseases*, 1979, 469–475.

GREAVES, M P, COOPER, S L, DAVIES, H A, MARSH, J A P and WINGFIELD, G I. Methods of analysis for determining the effects of herbicides on soil micro-organisms and their activities. *Technical Report ARC Weed Research Organization*, 1978, **45**, pp. 55. Price – £4.00.

839 GREAVES, M P, LOCKHART, L A and RICHARDSON, W G. Measurement of herbicide effect on nitrogen fixation by legumes. *Proceedings British Crop Protection Conference—Weeds*, 1978, 581–586.

865 GROSSBARD, E and WINGFIELD, G I. Effects of paraquat, aminotriazole and glyphosate on cellulose decomposition. *Weed Research*, 1978, **18**, (6), 347–353.

HAGGAR, R J. Recommendations for weed control in grassland and herbage legumes. In: *Weed Control Handbook*, Vol. 2, 8th ed. (Ed. by J D Fryer and R J Makepeace), Oxford, Blackwell, 1978, 216–249.

873 HAGGAR, R J. Competition between *Lolium perenne* and *Poa trivialis* during establishment. *Grass and Forage Science*, 1979, **34**, (1), 27–36.

906 HAGGAR, R J. The influence of herbicides, nitrogen fertilizer, seed rate and method of sowing, on the establishment and long-term composition of a perennial ryegrass ley. *Weed Research*, 1979, **19**, (1), 231–239.

HAGGAR, R J. Grass reseeding survey 1977–78. *Hurley British Grassland Society*, 1979, pp. 13.

795 HAGGAR, R J and ELLIOTT, J G. The effects of dalapon and stocking rate on the species composition and animal productivity of a sown sward. *Journal of the British Grassland Society*, 1978, **33**, (1), 23–33.

HAGGAR, R J and KIRKHAM, F W. Establishing ryegrass leys free of seedling grasses. *Technical Leaflet ARC Weed Research Organization*, 1978, **8**, pp. 2.

HAGGAR, R J and OSWALD, R K. Improving ryegrass swards by a low dose of dalapon. *Technical Leaflet ARC Weed Research Organization*, 1979, **1**, pp. 2.

825 HAGGAR, R J and PASSMAN, A. Some consequences of controlling *Poa annua* in newly sown ryegrass leys. *Proceedings British Crop Protection Conference—Weeds*, 1978, 301–308.

894 HAGGAR, R J and SQUIRES, N R W. The scientific manipulation of sward constituents in grassland by herbicides and one-pass seeding. *Proceedings British Grassland Society Occasional Symposium*, 1979, **10**, 223–234.

890 HAGGAR, R J, SQUIRES, N R W and ELLIOTT, J G and OSWALD, A K. Improving sward composition by selective herbicides and one-pass seeding. *ARC Research Review*, 1978, **4**, (2), 46–50.

917 HANCE, R J. Ecological aspects in the long term use of pesticides. *Proceedings S E Asian Workshop on Pesticide Management Bankok, 1977 Biotrop Special Publication*, 1978, **7**, 184–187.

871 HANCE, R J. Effects of pH on the degradation of atrazine, dichlorprop, linuron and propyzamide in soil. *Pesticide Science*, 1979, **10**, (20), 83–86.

862 HANCE, R J. Herbicide persistence and breakdown in soil in the long-term. *Annals of Applied Biology*, 1979, **91**, 137–141.

887 HANCE, R J and EMBLING, S J. Effect of soil water content at the time of application on herbicide content in soil solution extracted in a pressure membrane apparatus. *Weed Research*, 1979, **19**, (3), 201–205.

927 HANCE, R J, FRYER, J D and SMITH, P D. Herbicides and crop quality. *Report ARC Weed Research Organization 1976–1977*, 1978, **7**, 90–94.

838 HANCE, R J, SMITH, P D, BYAST, T H and COTTERILL, E G. Effects of cultivations on the persistence and phytotoxicity of atrazine and propyzamide. *Proceedings British Crop Protection Conference—Weeds*, 1978, 541–548.

778 HANCE, R J, SMITH, P D and COTTERILL, E G. The effect of age on the availability of linuron and simazine residues in soil. *Weed Research*, 1977, **17**, (6), 429–431.

853 HANCE, R J, SMITH, P D, COTTERILL, E G and REID, D C. Herbicide persistence: effects of plant cover, previous history of the soil and cultivation. *Mededelingen Faculteit Landbouwwetenschappen Rijksuniv. Gent*, 1978, **43**, (2), 1127–1133.

HARDCASTLE, J E Y (illustrated by H R BROAD). *Chemical Weed Control in your Garden.* Oxford, ARC Weed Research Organization, 3rd ed. 1978, pp. 22.

HARDCASTLE, J E Y (Ed.) *Report ARC Weed Research Organization 1976–1977*, 1978, **7**.

HARDCASTLE, J E Y (Ed.) *Booklet Weed Research Organization*, 4th ed, 1978.

884 HOLLY, K and TURNER, D J. Some effects of formulation on the biological activity of herbicides applied to foliage. *Proceedings 4th International Congress of Pesticide Science*, 1979, (3), 726–733.

HOLROYD, J. The principles of weed control in winter cereals. *Technical Leaflet ARC Weed Research Organization*, 1978, **5**, pp. 4.

HOLROYD, J and MAKEPEACE, R J. Weed control. In: *The Potato Crop* (Ed. P M Harris), London, Chapman and Hall, 1978, 376–405.

811 HOLROYD, J and STRICKLAND, A G. Roguing wild oats. *Weed Research*, 1978, **18**, (3), 175–180.

831 HOLROYD, J and THORNTON, M E. Mixtures of difenzoquat and dichlorprop for the control of *Avena fatua* and broad-leaved weeds in spring barley. *Proceedings British Crop Protection Conference—Weeds*, 1978, 9–14.

818 HOLROYD, J and THORNTON, M E. Factors influencing the control of bracken (*Pteridium aquilinum* (L.) Kuhn) with asulam. *Weed Research*, 1978, **18**, (4), 181–186.

IRVINE, R F and OSBORNE, D J. The effect of ethylene on the synthesis of the endoplasmic reticulum in etiolated pea stems. *Plant Science Letters*, 1978, **12**, 233–240.

KEMP, P J. PANS plant growth regulator index. *PANS*, 1979, **25**, (2), 211–218.

918 KEMPSON-JONES, G F and HANCE, R J, Kinetics of linuron and metribuzin degradation in soil. *Pesticide Science*, 1979, **10**, (6), 449–454.

766 LEAKEY, R R B, CHANCELLOR, R J and VINCE-PRUE, D. Regeneration from rhizome fragments of *Agropyron repens* (L.) Beauv. III Effects of nitrogen and temperature on the development of dominance amongst shoots on multi-node fragments. *Annals of Botany*, 1978, **42**, (177), 197–204.

767 LEAKEY, R R B, CHANCELLOR, R J and VINCE-PRUE, D. Regeneration from rhizome fragments of *Agropyron repens* (L.) Beauv. IV Effects of light on bud dormancy and development of dominance amongst shoots on multi-node fragments. *Annals of Botany*, 1978, **42**, (177), 205–212.

929 LUTMAN, P J W. The control of groundkeeper potatoes. *Report ARC Weed Research Organization 1976–1977*, 1978, **7**, 64–69.

LUTMAN, P J W. The control of groundkeeper potatoes. *Technical Leaflet ARC Weed Research Organization*, 1978, **7**, pp. 2.

904 LUTMAN, P J W. The selective application of glyphosate to volunteer potatoes in sugar-beet. *Proceedings EWRS Symposium—The influence of different factors on the development and control of weeds*, 1979, 375–382.

896 LUTMAN, P J W. The control of volunteer potatoes in the autumn in cereal stubbles. I. Factors affecting potato regrowth. *Annals of Applied Biology*, 1979, **93**, (I), 41–47.

897 LUTMAN, P J W. The control of volunteer potatoes in the autumn in cereal stubbles. II. The performance of glyphosate and aminotriazole. *Annals of Applied Biology*, 1979, **93**, (1), 49–54.

807 LUTMAN, P J W and RICHARDSON, W G. The activity of glyphosate and aminotriazole against volunteer potato plants and their daughter tubers. *Weed Research*, 1978, **18**, (2), 65–70.

843 LUTMAN, P J W and RICHARDSON, W G. Investigations into the control of potatoes with several post-emergence herbicides. *Proceedings British Crop Protection Conference—Weeds*, 1978, 393–400.

842 LUTMAN, P J W and THORNTON, M E. The control of *Avena fatua* and broad-leaved weeds in spring barley with herbicide mixtures containing diclofop methyl and its economic significance. *Proceedings British Crop Protection Conference—Weeds*, 1978, 15–22.

826 MARSH, J A P, Natural variation in some soil nutrients as a means of assessing the importance of herbicide effects on microbial activity. *Proceedings British Crop Protection Conference—Weeds*, 1978, 617–623.

798 MARSH, J A P and DAVIES, H A. The effect of herbicides on respiration and transformation of nitrogen in two soils. III Lenacil, terbacil, chlorthiamid and 2,4,5-T, *Weed Research*, 1978, **18**, (1), 57–62.

877 MARSH, J A P and GREAVES, M P. The influence of temperature and moisture on the effects of the herbicide dalapon on nitrogen transformations in soil. *Soil Biology and Biochemistry*, 1979, **11**, 279–285.

866 MARSH, J A P, KIBBLE-WHITE, R and STENT, C J. Apparatus for the automatic preparation of soil extracts for mineral-nitrogen determination. *Analyst*, 1979, **104**, 136–142.

820 MARSH, J A P, WINGFIELD, G I, DAVIES, H A and GROSSBARD, E. Simultaneous assessment of various responses of the soil microflora to bentazone. *Weed Research*, 1978, **18**, (5), 293–300.

824 MAY, M J. The work of the WRO fenland team. *Annual Review Arthur Rickwood Experimental Husbandry Farm*, 1978, 55–57.

829 MAY, M J. Glasshouse investigations with newer soil-applied herbicides for weed control on organic soils. *Proceedings British Crop Protection Conference—Weeds*, 1978, 777–784.

830 MAY, M J. Preliminary glasshouse experiments with various herbicides for swedes, cabbage and chicory in an organic soil. *Proceedings British Crop Protection Conference—Weeds*, 1978, 75–81.

MAY, M J. The work of the WRO Fenland Unit. *Annual Review Arthur Rickwood Experimental Husbandry Farm*, 1979, 69–72.

783 MAY, M J and AYRES, P A. A comparison of controlled drop and conventional application of three soil-applied herbicides to an organic soil. *Monograph British Crop Protection Council*, 1978, **22**, 157–161.

MERCER, E R and HILL, D in association with MAY, M J. Behaviour of herbicides in soil and their uptake by plants. *Annual Report ARC Letcombe Laboratory, 1978*, 1979, 62.

784 MERRITT, C R and TAYLOR, W A. Effects of volume rate and drop size on the retention of an aqueous solution by *Avena fatua* L. *Monograph British Crop Protection Council*, 1978, **22**, 59–66.

844 MOSS, S R. The effect of aminotriazole, glyphosate and paraquat applied to *Alopercurus myosuroides* seeds. *Proceedings British Crop Protection Conference—Weeds*, 1978, 483–490.

845 MOSS, S R. The effect of straw disposal method and cultivation on *Alopecurus myosuroides* populations and on the performance of chlortoluron. *Proceedings British Crop Protection Conference—Weeds*, 1978, 107–112.

854 MOSS, S R. The influence of tillage and method of straw disposal on the survival and growth of black-grass, *Alopecurus myosuroides*, and its control by chlortoluron and isoproturon. *Annals of Applied Biology*, 1979, **91**, 91–100.

MOSS, S R. Black-grass—a threat to winter cereals. *Technical Leaflet ARC Weed Research Organisation,* 1979, **15**, pp. 3.

827 NYFFELER, A and BLAIR, A M. The influence of burnt straw residues or soil compaction on chlortoluron and isoproturon activity. *Proceedings British Crop Protection Conference—Weeds, 1978*, 113–119.

916 OSBORNE, D J and CUMMING, A C. Membrane protein and phospholipid turnover in imbibed dormant embryos of wild oats. In: LAIDMAN, D L and WYN JONES, R G. *Recent advances in the biochemistry of cereals.* London, etc. Academic Press, 1979, 105–118.

695 OSBORNE, D J and WRIGHT, M. Gravity induced cell elongation In: *Gravity and Biological Systems. Proceedings of the Royal Society, London B.*, 1978, **199**, 551–564.

832 OSWALD, A K. The control of *Rumex obtusifolius* in grassland by selective application of herbicides. *Proceedings British Crop Protection Conference—Weeds*, 1978, 475–478.

833 OSWALD, A K. The use of TCA to control volunteer barley in rye-grass crops grown for seed. *Proceedings British Crop Protection Conference—Weeds*, 1978, 409–413.

OSWALD, A K. Factors affecting the toxicity of paraquat and dalapon to grass swards. *Technical Report ARC Weed Research Organization*, 1978, **48**, pp. 22. Price – £2.90.

875 OSWALD, A K. Weed control in herbage seed crops. *WHD Seeds Bulletin*, 1979, **18**, 6–8.

PALLETT, K E. Studies into the mode of action of some photosynthetic inhibitor herbicides. *Ph.D. Thesis, University of Bath*, 1978.

PALLETT, K E and DODGE, A D. The role of light and oxygen in the action of the photosynthetic inhibitor herbicide, monuron. *Zeitschrift fur Naturforsch*, 1979, **34c**, 1058–1061.

PALLETT, K and DODGE, A D. Sites of action of photosynthetic inhibitor herbicides: experiments with trypsinated chloroplasts. *Pesticide* Science, 1979, **10**, 216–220.

PALLETT, K E, DODGE, A D and ARMSTON, A. The role of excited singlet oxygen in the action of photosynthetic inhibitor herbicides. *Abstracts Photosynthesis Symposium, Society for Experimental Biology, University of York*, April, 1979.

874 PARKER, C. Pot experiments with some new herbicides on tropical perennial weeds. *COLUMA Troisieme Symposium sur le Desherbage des Cultures Tropicales*, 1978, 288–296.

934 PARKER, C. Integrated control of weeds in sorghum. *FAO Plant Production and Protection Paper*, 1979, **19**, 110–119.

891 PARKER, C and REID, D C. Host specificity in *Striga* species—some preliminary observations. *Proceedings Second International Symposium on Parasitic Weeds*, 1979, 79–80.

PETERS, N C B. Factors affecting wild oat and viability and survival. *Panicle*, 1978, **3**, (6), 3.

PETERS, N C B. Factors influencing the emergence and competition of *Avena fatua* L. with spring barley. *Ph.D. Thesis, University of Reading*, 1978.

909 POLLARD, F. The decay of straw on the surface of undisturbed soil in the field and the effect of herbicide. In: GROSSBARD, E (Ed) *Straw decay and its effect on disposal and utilization.* Chichester, etc. John Wiley, 1979, 177–184.

822 POLLARD, F and ELLIOTT, J G. The effect of soil compaction and method of fertilizer placement on the growth of barley using concrete track techniques. *Journal of Agricultural Engineering Research*, 1978, **23**, (2), 203–216.

821 POLLARD, F and WEBSTER, R. The persistence of the effects of simulated tractor wheeling on sandy loam subsoil. *Journal of Agricultural Engineering Research*, 1978, **23**, (2), 217–220.

889 QUILT, P. GROSSBARD, E and WRIGHT, S J L. Effects of the herbicide barban and its commercial formulation Carbyne on soil micro-organisms. *Journal of Applied Bacteriology*, 1979, **46**, 431–444.

892 REID, D C and PARKER, C. Germination requirements of *Striga* species. *Proceedings Second International Symposium on Parasitic Weeds*, 1979, 202–210.

RICHARDSON, W G. The tolerance of fenugreek (*Trigonella foenumgraecum* L.) to various herbicides. *Technical Report ARC Weed Research Organization* 1979, **58**, pp. 31. Price – £1.55.

RICHARDSON, W G and PARKER, C. The activity and post-emergence selectivity of some recently developed herbicides: NP 48, RH 5205 and pyridate. *Technical Report ARC Weed Research Organization*, 1978, **49**, pp. 38. Price – £2.50.

RICHARDSON, W G and PARKER, C. The activity and selectivity of herbicides methabenzthiazuron, metoxuron, chlortoluron, cyanazine. *Technical Report ARC Weed Research Organization*, 1978, **51**, pp. 40. Price – £2.20.

RICHARDSON, W G and PARKER, C. The activity and pre-emergence selectivity of some recently developed herbicides: alachlor, metolachlor, dimethachlor, alloxydim-sodium and fluridone. *Technical Report ARC Weed Research Organization*, 1979, **54**, pp. 60. Price – £3.00.

RICHARDSON, W G and PARKER, C. The activity and selectivity of the herbicides carbetamide, methazole, R 11913 and OCS 21693. *Technical Report ARC Weed Research Organization*, 1979, **55**, pp. 36. Price – £1.80.

RICHARDSON, W G, WEST, T M and PARKER, C. The activity and pre-emergence selectivity of some recently developed herbicides: R 40244, AC 206784, pendimethalin, butralin, acifluorfen and FMC 39821. *Technical Report ARC Weed Research Organization*, 1979, **57**, pp. 71. Price – £3.55.

910 ROBERTS, H A and CHANCELLOR, R J. Periodicity of seedling emergence and achene survival in some species of *Carduus, Cirsium* and *Onopordum. Journal of Applied Ecology*, 1979, **16**, 641–647.

823 ROBSON, T O. The present status of chemical aquatic weed control. *Proceedings EWRS 5th Symposium on Aquatic Weeds*, 1978, 17–26.

828 ROBSON, T O, FOWLER, M C and HANLEY, S. Observations on a lake treated with terbutryne in three alternate years. *Proceedings 5th Symposium on Aquatic Weeds*, 1978, 303–313.

SIMMONS, R C. Simple multiple thermistor thermometer unit for use with data loggers. *Laboratory Practice*, 1978, **27**, (1), 29.

SQUIRES, N R W and HAGGAR, R J. A guide to slot-seeding: the one-pass technique for establishing new grasses, legumes and forage crops in old swards. *Technical Leaflet ARC Weed Research Organization*, 1979, **12**, pp. 3.

SQUIRES, N R W, HAGGAR, R J and ELLIOTT, J G. A one-pass technique for establishing grass and legumes in existing swards. *Technical Leaflet ARC Weed Research Organization*, 1978, **2**, pp. 4.

885 SQUIRES, N R W, HAGGAR, R J and ELLIOTT, J G. A one pass seeder for introducing grasses, legumes and fodder crops into swards. *Journal of Agricultural Engineering Research*, 1979, **24**, (2), 199–208.

TAYLOR, H F and WAIN, R L. Studies on plant growth-regulating substances. LII. Growth retardation by 3,5-dichlorophenoxyethylamine and 3,5-dichlorophenoxybutyric acid through their conversion to 3,5-dichlorophenoxyacetic acid in tomato plants. *Annals of Applied Biology*, 1978, **89**, 271–275.

TAYLOR, W A. Controlled drop application (CDA). *Technical Leaflet ARC Weed Research Organization*, 1978, **3**, pp. 2.

876 TERRY, P J. Sedge weeds of East Africa. I. Identification. *East African Agricultural and Forestry Journal*, 1976, Publ. 1978, **42**, (2), 231–249.

TERRY, P J. Sedge weeds of East Africa. II. Distribution. *Technical Report ARC Weed Research Organization*, 1978, **50**, pp. 26. Price – £1.50.

868 TOTTMAN, D R. The effects of a dicamba herbicide mixture on the grain yield components of winter wheat. *Weed Research*, 1978, **18**, (6), 335–339.

925 TOTTMAN, D R. Cereal growth stages and their relevance to the safe use of herbicides in winter wheat. *Report ARC Weed Research Organization 1976–1977*, 1978, **7**, 44–48.

850 TOTTMAN, D R. Timing and herbicide selection for broad-leaved weed control. *NAC Conference Crop Protection for Cereals*, 1978, pp. 5.

815 TOTTMAN, D R and DAVIES, E Ll P. The effects of herbicides on the root system of wheat plants. *Annals of Applied Biology*, 1978, **90**, (1), 93–99.

834 TOTTMAN, D R and DUVAL, A. Leaf sheath length as a guide to apical development and spray timing in winter wheat. *Proceedings British Crop Protection Conference—Weeds*, 1978, 143–150.

907 TOTTMAN, D R and MAKEPEACE, R J (Drawings by H Broad). An explanation of the decimal code for the growth stages of cereals with illustrations. *Annals of Applied Biology*, 1979, **93**, 221–234.

835 TOTTMAN, D R and THOMPSON, W. The influence of herbicides on the incidence of take-all disease (*Gaeumannomyces graminis*) on the roots of winter wheat. *Proceedings British Crop Protection Conference—Weeds*, 1978, 609–616.

816 TURNER, D J and LOADER, M P C. Complexing agents as herbicide additives. *Weed Research*, 1978, **18**, (4), 199–207.

785 TURNER, D J and LOADER, M P C. Controlled drop application of glyphosate, difenzoquat and dichlorprop. *Monograph British Crop Protection Council*, 1978, **22**, 179–184.

771 TURNER, D J and RICHARDSON, W G. Research on uses of herbicides in forestry. *Report on Forest Research 1977*, 1978, 56–57.

923 TURNER, D J and RICHARDSON, W G. Herbicides for use in forestry. *Report ARC Weed Research Organization 1976–1977*, 1978, 77–84.

855 TURNER, D J and RICHARDSON, W G. Weed control: WRO's screening project. *Forestry and British Timber*, 1979 (February), 30–32.

TURNER, D J and RICHARDSON, W G. Pot experiments at the Weed Research Organization with forest crop and weed species. *Technical Report ARC Weed Research Organization*, 1978, **46**, pp. 13. Price – £2.70.

914 WALTERS, J and OSBORNE, D J. Ethylene and auxin-induced cell growth in relation to auxin transport and metabolism and ethylene production in the semi-aquatic plant, *Regnellidium diphyllum*. *Planta*, 1979, **146**, 309–317.

WARD, T M, TURNER, E M and OSBORNE, D J. Evidence that ethylene is produced by the mycelium of *Agaricus bisporus*: the relationship with sporocarp development. *Journal of General Microbiology*, 1978, **104**, 23–30.

WARD, T M, WRIGHT, M, ROBERTS, J A, SELF, R and OSBORNE, D J. Analytical procedures for the assay and identification of ethylene. In: *Isolation of Plant Growth Substances.* (Ed. Hillman, J R), Cambridge, University Press, 1978, 135–151.

801 WATT, T A. The biology of *Holcus lanatus* L. (Yorkshire fog) and its significance in grassland. *Herbage Abstracts*, 1978, **48**, (6), 195–204.

WATT, T A. Yorkshire fog (*Holcus lanatus* L.)—a review and some recent research. *Journal of the Sports Turf Research Institute*, 1978, **54**, 15–22.

WEBSTER, R H. Growing weeds from seeds and other propagules for experimental purposes. *Technical Report ARC Weed Research Organization* 1979, **56**, pp. 21. Price – £1.10.

WILLIAMS, E D. Germination and longevity of seeds of *Agropyron repens* L. Beauv. and *Agrostis gigantea* Roth. in soil in relation to different cultivation regimes. *Weed Research*, 1978, **18**, (3), 129–138.

WILLIAMS, E D. Botanical composition of the Park Grass plots. *Report Rothamsted Experimental Station, 1977, Part 2*, 1978, 31–36.

WILLIAMS, E D. Botanical composition of the Park Grass plots at Rothamsted 1856–1976. Harpenden. *Rothamsted Experimental Station*, 1978, pp. 61.

WILLIAMS, E D. Studies on the depth distribution and on the germination and growth of *Equisetum arvense* L. (field horsetail) from tubers. *Weed Research*, 1979, **19**, (1), 25–32.

797 WILSON, B J. The long term decline of a population of *Avena fatua* L. with different cultivations associated with spring barley cropping. *Weed Research*, 1978, **18**, (1), 25–31.

886 WILSON, B J. The effect of controlling *Alopecurus myosuroides* Huds. and *Avena fatua* L. individually and together, in mixed infestations on the yield of wheat. *Weed Research*, 1979, **19**, (3), 193–199.

814 WILSON, B J and CUSSANS, G W. The effects of herbicides, applied alone and in sequence, on the control of wild-oats (*Avena fatua*) and broad leaved weeds, and on yield of winter wheat. *Annals of Applied Biology*, 1978, **89**, (3), 459–466.

819 WILSON, B J and TAYLOR, W A. Field trials with the controlled drop application of barban and difenzoquat for the control of wild oats (*Avena fatua* L.) in spring barley. *Weed Research*, 1978, **18**, (4), 215–221.

WONG, C H and OSBORNE, D J. Ethylene-induced enlargement of positionally differentiated target cells in flower buds of *Ecballium elaterium* and the indentification of these cells by their content of endoreduplicated nuclear DNC. *Planta*, 1978, **149**, 103–111.

WRIGHT, M and OSBORNE, D J. Gravity-regulation of cell elongation in nodes of the grass *Echinochloa colonum*. *Biochemie und Physiologie der Pflanzen*, 1978, **171**, 479–492.

WRIGHT, M, MOUSDALE, D M A and OSBORNE, D J. Evidence for a gravity-regulated level of endogenous auxin controlling cell elongation and ethylene

production during geotropic bending in grass nodes. *Biochemie und Physiologie der Pflanzen*, 1978, **172**, 481–496.
YULE, A H, MAY, M J and SMITH, J. The prospects for improved weed control in sugar beet on organic soils. *Annual Review Arthur Rickwood Experimental Husbandry Farm*, 1979, 48–52.

ANNOTATED BIBLIOGRAPHIES 1978–79

(Apply to Information Department for current conversion of price codes)

		Price Code
117	Selected references to the biology and control of *Bromus* (*Anisantha*) species, 1958–1978 (176 references).	I
118	Selected references to factors affecting herbicide application, 1975–1978 (454 references).	L
119	Selected references to the biology and control of *Echinochloa crus-galli*, biology 1956–1977, control 1966–1977 (663 references).	N
120	Selected references to the biology and control of *Apera spica-venti* 1967–1977 (135 references).	H
121	Selected references to weed control in sports turf. 1968–1978 (40 references).	E
122	Selected references to the control of gorse (*Ulex europaeus*) 1968–1978 (108 references).	H
123	Selected references to the biology and control of *Equisetum* spp. 1968–1978 (84 references).	G
124	Selected references to water hyacinth (*Eichhornia crassipes*) 1973–1978 (313 references).	K
125	Selected references to the biology and control of *Phalaris brachystachys, P canariensis, P minor* and *P paradoxa,* 1956–1978, (98 references).	G
126	Selected references to the biology and control of *Convolvulus arvensis* (an addendum to bibliography no. 95), 1975–1978, (66 references).	F
127	Selected references to herbivorous fish (replacing bibliographies No. 31 and 103) 1957–1978 (238 references).	J
128	Selected references to the biology and control of *Sporobolus* species, 1958–1978, (67 references).	F
129	Selected references to weed control in ornamental trees, shrubs and ground cover plants 1973–1978 (208 references).	J
130	Selected references to the biology and control of *Chondrilla* juncea—skeleton weed 1956–1979 (149 references).	H
131	Selected references to control of groundkeeper potatoes. 1959–1978 (73 references).	F
132	Selected references to the use of MCPA mecoprop and dichlorprop in forestry, 1955–1978 (74 references).	F
133	Selected references to the biology and control of Orobanchaceae. (A supplement to bibliographies Nos. 23, 49, 77, & 107), 1977–1979, (91 references).	G
134	Selected references to the biology and control of hemiparasitic Santalales and Scrophulariacea (including Striga) (A supplement to bibliographies nos. 17, 50, 74, 86 and 108), (59 references), 1977–1979.	F
135	Selected references to the biology and control of Cuscuta species (A supplement to bibliographies nos. 32, 51 and 100), 1976–1979, (69 references).	F

136 Selected references to the biology and control of mistletoes (Loranthaceae and Viscaceae) (A supplement to bibliography no. 67), 1974–1979, (111 references). G

137 Selected references to weed control in oil seed rape, 1973–1978, (88 references). G

138 Selected references to the biology and control of *Salvinia* spp. 1953–1979, (145 references). H

139 Selected references to minimum cultivation in cereals. (A supplement to bibliography no. 84), 1974–1979, (129 references). H

140 Selected references to minimum cultivation in perennial fruit crops, 1974–1979, (33 references). E

141 Selected references to the biology and control of *Commelina* species, 1972–1979, (94 references). G

STAFF OF THE ARC WEED RESEARCH ORGANIZATION

As at 31st December 1979

Director and Visiting Professor, University of Reading
J. D. Fryer, C.B.E., M.A., F.I.Biol.

Institute Secretary
B. A. Wright, MBIM

Secretary to Director
Mrs. M. E. Weedon

WEED CONTROL DEPARTMENT

Head of Department: J. G. Elliott, M.A.

ANNUAL CROPS GROUP

Leader: G. W Cussans, B.Sc.

Scientific Staff

P. Ayres
C. J. Bastian
P. J. W. Lutman, B.Sc., Ph.D.
M. J. May
S. R. Moss, B.Sc.
F. Pollard, B.Sc.
M. E. Thornton
D. R. Tottman, B.Sc.
B. J. Wilson, B.Sc.

Assistants

Miss J. E. Birnie
R. A. P. Denner
Miss F. L. Hemmings
A. W. Lovegrove
Miss S. J. Norris
P. A. Phipps
Miss L. A. Surman
S. L. Woolliams

GRASS AND FODDER CROPS GROUP

Leader: R. J. Haggar, B.Sc., Ph.D.

Scientific Staff

A. K. Oswald
N. R. W. Squires, B.Sc.
F. W. Kirkham

Assistants

P. G. Smith
Miss C. Standell, B.Sc.

Post-Graduate Research Student
N. Boatman, B.Sc.

Student
G. Hodge

PERENNIAL CROPS GROUP

Leader: J. G. Davison, B.Sc., Ph.D.

Scientific Staff

J. A. Bailey
D. V. Clay, B.Sc.

Assistants

Miss K. J. Cleave
*Mrs. S Jacques

*Part-time

SPECIAL SERVICES

M. E. Thornton — Mrs. C. M. Smith*

FARM

Farm Director: J. G. Elliott, M.A.
Farm Manager: R. J. Dale

F. A. Penfold — C. G. Woodhams

Secretarial Staff

Personal Secretary: Miss B. E. Watson

Mrs. L. M. Marsland* — Mrs. G. M. Pratley*

WEED SCIENCE DEPARTMENT

Head of Department: K. Holly, B.Sc., Ph.D.

HERBICIDE PERFORMANCE GROUP

Leader: J. Holroyd, B.Sc.

Scientific Staff

I. D. Clipsham
M. P. C. Loader, B.Sc.
W. G. Richardson, B.Sc.
H. F. Taylor, B.Sc., Ph.D.
W. A. Taylor
D. J. Turner, B.Sc., Ph.D.

Assistants

Miss J. M. Heritage
Miss P. G. Owen
Miss W. Thomas
T. West
G. P. White

ENVIRONMENTAL STUDIES GROUP

Leader: J. C. Caseley, B.Sc., Ph.D.

Scientific Staff

A. M. Blair, B.Sc., M.Phil.
D. Coupland, B.Sc., Ph.D.
C. R. Merritt, M.I. Biol.
R. C. Simmons, B.Sc.
K. E. Pallett, B.Sc., Ph.D.

Assistants

Miss K. M. Pitson — Miss D. F. Wyatt

CHEMISTRY GROUP

Leader: R. J. Hance, B.Sc., Ph.D.

Scientific Staff

T. H. Byast
E. G. Cotterill
S. J. Embling
P. D. Smith

Assistants

Mrs. P. M. Baden — M. Law

MICROBIOLOGY GROUP

Leader: M. P. Greaves, B.Sc.

Scientific Staff

Mrs. S. L. Cooper
Mrs. H. A. Davies, B.Sc.
J. A. P. Marsh
G. I. Wingfield, B.Sc., M.Sc.

Assistants

S. J. Hills — Miss J. M. Johnson

*Part-time

WEED BIOLOGY GROUP

Leader: R. J. Chancellor, M.A.

Scientific Staff

R. J. Froud-Williams, B.Sc.
Miss J. Hilton, B.Sc.
N. C. B. Peters, B.Sc.
E. D. Williams, B.Sc.

Assistant

Mrs. P. A. Simmons

SPECIAL SERVICES

R. Porteous
S. L. Burbank
R. H. Webster

Secretarial Staff

Personal Secretary: Mrs. D. L. Gawne

Mrs. J. Wallsworth

EXTRA-DEPARTMENTAL SCIENCE GROUPS

AQUATIC WEEDS and UNCROPPED LAND GROUP

Leader: T. O Robson, B.Sc.

Scientific Staff

P. R. F. Barrett, B.Sc.
Miss M. C. Fowler
E. J. P. Marshall, B.Sc., Ph.D.

Assistants

S. Hanley
Ms. K. E. Murdoch

Secretarial Staff

Mrs. M. F. Cox*

DEVELOPMENTAL BOTANY GROUP

Leader: Daphne J. Osborne, B.Sc., M.Sc., Ph.D., D.Sc.

Scientific Staff

R. J. Hooley, B.Sc., Ph.D.
J. A. Sargent, B.Sc., Ph.D.
M. Wright, B.Sc., Ph.D.

Assistant

Mrs. R. Y. Cole*

Post-Graduate Research Student

Miss M. M. McDonald, B.Sc.

Secretarial Staff

Mrs. M. E. Cook, B.A.

ODA TROPICAL WEEDS GROUP

Leader: C. Parker, M.A.

Scientific Staff

P. J. Terry, B.Tech. (Home based post)
(*Seconded to ODA*)
Mrs. D. C. Reid
Mrs. A. K. Wilson, B.Sc.*

Assistants

Miss K. M. Chadwick
Miss D. Stringer

Secretarial Staff

Mrs. J. Souch

*Part-time

ARC LETCOMBE LABORATORY/WRO JOINT BIOMETRICS GROUP

B. O. Bartlett, M.A., Dip. Math. Stat.*

W. Jenkins, B.Sc., ARIC.* C. J. Marshall, B.Sc.

Assistant

M. J. Loach* D. Smith

INFORMATION DEPARTMENT

Head of Department: J. E. Y. Hardcastle, O.B.E., B.Sc., D.A.S., D.T.A., M.I.Inf.Sci.

Editor, 'Weed Abstracts': W. L. Millen, B.A., A.L.A.

Information Staff

Mrs. H. R. Broad, B.Sc.* P. J. Kemp, B.A. J. L. Mayall

Ms. N. Kiley, B.Sc. Mrs. M. Turton, M.A.*

Librarian: Mrs. B. R. Burton, A.L.A.

Secretarial and Clerical Staff

Personal Secretary: Miss K. P. M. Hedges

Mrs. D. Blackburn Mrs. S. Dale*

Mrs. J. A Cox Mrs. P. M. Loveridge*

ADMINISTRATION DEPARTMENT

Secretary and Head of Department: B. A. Wright, M.B.I.M.

Assistant Secretary: L. G. Young

Administration Officer: Mrs. A. J. Dick

Clerical and Typing Staff

Mrs. P. M. Appleton* Mrs. S. Higgs* Miss T. McLoughlin

Mrs. S. Cox Mrs. B. Hunter* Mrs. D. Robson

Mrs. M. Cox* Mrs. H. Jordon* Mrs. J. Tonkin*

Mrs. C. Green* Mrs. M. C. Leach Mrs. H. R. Wills*

Photography

R. N. Harvey, A.I.I.P. S. G. Bebb Mrs. J. Kilcoyne*

Workshop Supervisor: R. Kibble-White, B.A.

A. D. Bland D. Elvidge W. Macklin

J. A. Drinkwater R. Foddy

Building Maintenance Supervisor: A. W. H. Gardner

C. Day L. S. Goodgame A. Worth

Vehicle Maintenance Supervisor: P. A. Savin

P. Wickson

Electronics Engineer: C. J. Stent, B.A.

Stores: T. H. Evans

Cleaning Staff

Supervisor: Mrs. J. Martin*

Mrs. S. Buswell* Mrs. J. Penfold* Mrs. J. West*

Mrs. M. Jakeman* Mrs. J. Robinson* T. West*

Mrs. E. N. Luke* Mrs. M. Robinson*

* Part time

ATTACHED STAFF

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

Agricultural Development and Advisory Service Liaison Officers
J. H. Orson, B.Sc. (Agriculture)
A. G. Jones, C.D.H. (Horticulture)

Agricultural Chemicals Approval Scheme Liaison Officer
R. J. Makepeace, B.Sc.

Secretarial Staff

Miss S. Langdon   Mrs. D. G. M. Roberts   Mrs. C. Wheeler*

SOIL SURVEY OF ENGLAND AND WALES

J. Hazelden, B.A.

CHANGES IN RESEARCH, TECHNICAL AND ADMINISTRATIVE STAFF

NEW APPOINTMENTS

C. J. Bastian	SO	Annual Crops Group	1.4.78
(on internal promotion)			
M. J. Ashdown	SO†	Aquatic Weeds Group	8.5.78
Miss S. E. Milner	SO†	Aquatic Weeds Group	8.5.78
H. F. Taylor	PSO	Herbicide Group	1.9.78
(on transfer from ARC Unit of Systemic Fungicides)			
K. E. Pallett	SO†	Herbicide Group	11.9.78
Mrs. A. J. Dick	EO	Administration Department	2.1.79
R. J. Hooley	SO	Developmental Botany Group	8.1.79
Miss M. Dolan	SO†	Aquatic Weeds Group	19.3.79
E. J. P. Marshall	SO†	Aquatic Weeds Group	22.3.79
S. J. Embling	SO	Chemistry Group	1.4.79
(on internal promotion)			
J. A. Drinkwater	PTO4	Administration Department	1.4.79
(on internal promotion)			
E. J. P. Marshall	HSO†	Aquatic Weeds Group	10.9.79

RESIGNATIONS

M. J. Ashdown	SO	Aquatic Weeds Group	29.9.78
A. D. Whelton	EO	Administration Department	6.10.78
Miss S. E. Milner	SO	Aquatic Weeds Group	23.10.78
Miss M. Dolan	SO	Aquatic Weeds Group	7.9.79
E. J. P. Marshall	SO	Aquatic Weeds Group	7.9.79
J. H. Fearon	HSO	Information Department	30.9.79

†Temporary   *Part-time

STAFF VISITS OVERSEAS

Overseas visits have been undertaken by members of staff in the period covered by this report as follows:—

1978		
January	G. W. Cussans P. J. W. Lutman	Belgium, for discussion between EWRS/ EAPR Working Group and Monsanto Ltd on control of groundkeeper potatoes; sponsored by Monsanto.
	T. O. Robson	Netherlands, for EWRS.
February	J. D. Fryer	United States to attend Weed Science Society of America Annual Meeting; sponsored by Monsanto.
	T. O. Robson	Netherlands, for EWRS.
March	J. D. Fryer J. G. Elliott P. R. F. Barrett	Spain, to attend Mediterranean Symposium of Herbicides; sponsored by Monsanto.
April	R. J. Hance M. P. Greaves	Germany, for EWRS.
	C. Parker	India to advise United Planters Association of South India on weed control in tea, for ODA.
May	J. D. Fryer R. J. Hance J. E. Y Hardcastle B. A. Wright	Belgium, for EWRS (JDF, JEYH, BAW) and for RJH to present paper at International Symposium on Crop Protection, Ghent.
July	R. J. Hance	Switzerland, to attend 4th International Congress of Pesticide Chemistry.
	K. Holly	Switzerland, to present invited paper at 4th International Congress of Pesticide Chemistry; sponsored by organisers.
	C. Parker	Nigeria, to attend International Weed Science Conference on behalf of ODA.
August	J. D. Fryer	India, to attend 17th All India Wheat Research Workers' Workshop and in advisory capacity on behalf of ODA.
	M. P. Greaves	Germany, to attend International Workshop on Side Effects of Pesticides; and International Congress of Phytopathology; partly sponsored by EWRS.
September	J. D. Fryer T. O. Robson P. R. F. Barrett Miss M. C. Fowler	Netherlands, to attend 5th International Symposium on Aquatic Weeds; sponsored by EWRS (JDF TOR) and Duphar Midox Ltd. (MCF).
	J. D. Fryer	France, to attend EPPO Conference on Weed Problems; sponsored by EPPO.
	C. Parker	Senegal, to attend 3rd COLUMA Tropical Weed Symposium and Sierra Leone to advise on weed research in mangrove swamp rice, for ODA.

October	C. Parker	Sudan, to attend the University of Sudan/ IDRC *Striga/ Orabanche* Workshop, on behalf of ODA.
November/ December	P. J. Terry	Kenya, Tanzania and Zambia to collect material for ODA sponsored project to prepare weed control handbook for East Africa.
1979		
January to December	D. Coupland	United States, to undertake investigations on the chemical control of field horsetail at, and sponsored by, Washington State University.
January	R. J. Hance	Germany, on behalf of EWRS.
February	R. J. Hance	United States, to attend meetings of Weed Science Society of America and International Weed Science Society on behalf of EWRS.
March	J. D. Fryer	India, to follow up visit made in August 1978 on behalf of ODA.
	R. J. Hance	Germany, on behalf of EWRS.
	K. E. Pallett	Germany, to present paper at Conference; sponsored by University of Konstanz.
April	J. D. Fryer C. Parker R. J. Hance J. C. Caseley	Switzerland, on behalf of Ciba/Geigy.
	T. O. Robson	Netherlands, on behalf of EWRS.
	C. Parker	Switzerland, to visit Ciba/Geigy laboratories at the invitation of the company.
	C. Parker	Indonesia, to assist BIOTROP with a training course and to discuss research on *Imperata cylindrica*, for ODA.
April to June	Miss D. J. Osborne	Israel, as Churchill Visiting Professor at The Technion, Haifa sponsored by the British Technion Society.
May	J. D. Fryer	Germany, sponsored by Hoechst.
	J. E. Y. Hardcastle	France, to attend meeting of International Standards Organisation TC.81.
	P. J. Kemp	Canada and United States to visit libraries and relevant laboratories; funded privately.
May to April 1980	P. J. Terry	The Gambia, on secondment to conduct weed research project for ODA.
June	J. D. Fryer	France, on behalf of EWRS.
July	G. W. Cussans R. J. Hance	France, to liaise with staff of ITCF and INRA, partly sponsored by ITCF.
	T. O. Robson P. R. F. Barrett	United States, to attend Aquatic Plant Management Society Annual Conference, and to visit Eli Lilly Research Laboratories and their ICI field experiments. Sponsored partly by EWRS and Eli Lilly (TOR) and ICI and Eli Lilly (PRFB)

July	C. Parker	USA, to attend 2nd International Symposium on Parasitic Weeds, on behalf of ODA.
September/ October	C. Parker	Upper Volta, Niger, Nigeria, Sudan to study and advise on *Striga* research with team sponsored by USAID.
October	J. D. Fryer J. C. Caseley J. G. Elliott M. P. Greaves J. E. Y Hardcastle R. J. Chancellor G. W. Cussans B. J. Wilson P. J. W. Lutman	Germany, to attend EWRS Symposium and meetings, for J. D. Fryer to receive the Otto Appel Medal, and for GWC, BJW, and RJC to discuss current research at Hohenheim University; sponsored by EWRS (JDF, GWC, RJH, JEYH, MPG).
	J. C. Caseley	Netherlands, to visit CABO, Wageningen.
	R. J. Hance	Italy, to attend meetings on soil pollution in University of Pisa; sponsored by Consiglio Nazionale Delle Richerche.
November	Miss D. J. Osborne	United States, to visit University of Califorina as 1979 Ruth Storer Lecturer; sponsored by the Ruth Storer Lectureship Committee.
December	C. Parker	France, to attend EWRS discussion on formation of tropical weed group; on behalf of ODA.

STAFF COMMITTEE SERVICE

Members of WRO have served on the following Committees:

ACAS Scientific Advisory Committee

ADAS Pesticide Committee

ADAS/WRO
- Liaison Group
- Working Party on Systematic Control of Wild Oat and Associated Grass Weeds

Agricultural Research Council
- Secretary's Policy Advisory Committee (SPAC)
- Working Party on Suitability of Soils for Direct Drilling
- Working Party on Information Services via Computer-based Networks
- Fruit Weed Control Group

Annals of Applied Biology
- Editorial Board

Aquatic Botany
- Editorial Panel

Aquatic Weed Control Training Working Party

Association of Applied Biology
- Weed Group Committee

British Crop Protection Council
- Application Symposium Programme Committee
- Board of Management
- Conference 1980 Consultative Group
- Council
- Finance and General Purposes Committee
- Education and Communications Committee
- Programme Committee—Weeds
- Programme Policy Committee
- Publications Committee
- Research and Development Technical Committee
- Research and Development Technical Sub-Committee (Weeds)

British Grassland Society
- Executive Council
- Grass as a Crop Group

British Standards Institution Technical Committee PCC/1

Department of the Environment
- Standing Committee of Analysts Working Group 6-3

European Weed Research Society
- Council
- Editorial Board *Weed Research*
- Education Committee
- Executive Committee
- Scientific Committee
- Research Group on Annual Grass Weeds
- Research Group on Aquatic Weeds
- Research Group on Herbicide Application
- Research Group on Herbicides/Soils
- Symposia Organizing and Programme Committees

EWRS/EAPR Volunteer Potato Working Group

Herbage Seeds (Weed Control) Working Party

International Standards Organization Technical Committee TC/81

International Parasitic Seed Plant Research Group

International Weed Science Society
- Executive Committee

JCO Arable Grass and Forage Board
- Cereals Committee
- Plant Science Committee

Ministry of Agriculture, Fisheries and Food
- Agriculture Chemicals Approval Scheme Science Advisory Committee
- Grass Carp Field Trials Steering Committee
- National Wild Oat Advisory Programme Steering Committee
- NIAE Consultative Group on Cultivation

MAFF/ARC
- Users Group on Cultivation

ODA Sub-Committee on Pesticide Application Overseas

Oxfordshire Agricultural Trust

Oxford College of Further Education Science and Mathematics Advisory Committee

Royal Society Environmental Biology Sub-Committee

Society of Chemical Industry
- Editorial Board of *Pesticide Science*
- Pesticides Group Committee
- Physiochemical and Biophysical Panel
- Publications Committee

Sugar Beet Research and Education Committee
- Weed Beet Sub-Committee

University of Reading Plant Sciences Joint Committee

POST GRADUATE RESEARCH STUDENTS AT WRO 1978–79

Name	*Universtity and Higher Degree*	*Estimated Period at WRO*	*Topic of Research*
D. Cole	Bath; Ph.D (CASE award)	1977–79	Mode of action of glyphosate
B. Kowalczyk	Oxford; D.Phil (ARC award)	1977–79	Effect of pre-spraying environment on herbicide performance
N. D. Boatman	Reading; Ph.D (ARC award)	1977–80	Factors affecting the establishment of white clover
B. Cragg	UWIST: Ph.D (Univ. Wales award)	1977–80	The role of bacteria in the deoxygenation of water treated with herbicides
P. J. Mudd	Bath, Ph.D (CASE award)	1977–80	Degradation of isoproturon in rhizosphere of winter wheat
S. W. Adkins	Reading; Ph.D (CASE award)	1978–81	Factors affecting seed dormancy in wild-oats

A. Matin	Univ. St Andrews M.Sc. (British Council award)	1978–81	The effect of light, temperature and the herbicide terbutryne on the photosynthesis of some submerged aquatic plants
M. M. McDonald	Oxford; D.Phil (ARC award)	1978–81	Factors regulating perennation and regeneration of plant parts in potato groundkeepers
P. Whitehouse	Bristol; M.Sc (ARC award)	1978–81	Factors affecting the activity of wild-oat herbicides applied to different positions on the plants
S. Adalla	Reading; Ph.D	1979–82	Factors affecting the performance of soil applied herbicides in winter cereals
P. D. Pateman	Reading; Ph.D (ARC award)	1979–82	Vegetative regeneration in selected grassland species
A. Pinho	Reading; M.Phil	1979–82	Factors affecting tolerance of soil-acting herbicides by perennial crops

VISITING RESEARCH WORKERS AND OVERSEAS TRAINEES AT WRO 1978–79

Name and Origin	*Estimated Period at WRO*	*Topic of Research*
Miss E. Y van der Velde Wageningen	1978 (5 months)	Weed biology techniques
Dr. D. G. Swan Washington State University, USA	1978–79 (12 months)	Biology and control of *Convolvulus arvensis*
Dr. D. W. Koch University of New Hampshire, USA	1979 (6 months)	Establishment of red clover by slot-seeding
Dr. Yoram Fuchs Volcani Institute, Israel	1979 (2 months)	Physiological research techniques
Mrs M. Schönfeld Wageningen	1979 (5 months)	Movement and induced dormancy in grass seeds
Dr G. S. Hassawy Foundation of Technical Institutes, Baghdad, IRAQ	1979/80 (12 months)	Effect of temperature and soil water stress on diclofop activity in wild-oats and wheat
O U Okereke University of Nigeria Nsukka, Nigeria	1979/80 (12 months)	Isoproturon activity against *Bromus sterilis* and *Phalaris minor*
Dr P. Chow Agriculture Canada Brandon Research Station, Canada	1979/80 (12 months)	Mode of action of herbicide mixtures

GLOSSARY OF CHEMICALS MENTIONED IN THIS REPORT

An asterisk (*) signifies a common name approved by the British Standards Institution.

alloxydim-sodium*	2-[(1-*N*-allyloxyamino)butylidene]-4-methoxycarbonyl-5,5-dimethyl=cyclohexane-1,3-dione
asulam*	methyl (4-aminobenzenesulphonyl)carbamate
atrazine*	2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine
barban*	4-chlorobut-2ynyl *N*-(3-chlorophenyl)carbamate
bentazone*	3-isopropyl-2,1,3-benzothiadazin-4-one 2,2-dioxide
benzoylprop-ethyl*	ethyl-*N*-benzoyl-*N*-(3,4-dichlorophenyl)-2-aminopropionate
bromoxynil*	3,5-dibromo-4-hydroxybenzonitrile
butam	*N*-benzyl-*N*-isopropyl-2,2-dimethyl propionamide
butralin*	*N*-s-butyl-4-t-butyl-2,6-dinitroaniline
carbetamide*	D-*N*-ethyl-2-(phenylcarbamoyloxy)propionamide
chlortoluron*	*N*'-(3-chloro-4-methylphenyl)-*N*,*N*-dimethylurea
2,4-D*	2,4-dichlorophenoxyacetic acid
dalapon*	2,2-dichloropropionic acid
dichlobenil*	2,6-dichlorobenzonitrile
diclofop-methyl*	methyl 2-[4-(2,4-dichlorophenoxy)phenoxy] -propionate
difenzoquat*	1,2-dimethyl-3,5-diphenyl-pyrazolium
diquat*	9,10-dihydro-8a, 10a-diazoniaphenanthrene
diuron*	*N*'-(3,4-dichlorophenyl)-*N*,*N*-dimethylurea
EPTC*	*S*-ethyl *N*,*N*-dipropyl(thiocarbamate)
ethofumesate*	2-ethoxy-2,3-dihydro-3,3-dimethylbenzofuran-5-yl methylsulphonate
flamprop-isopropyl*	isopropyl (±)-2-(*N*-benzoyl-3-chloro-4-fluoroanilino) propionate
fluometuron*	*N*'-(3-trifluoromethylphenyl)-*N*,*N*-dimethylurea
fluridone*	l-methyl-3-phenyl-5-(3-trifluoromethylphenyl)-*N*,*N*-dimethylurea
glyphosate*	*N*-(phosphonomethyl)glycine
ioxynil*	*N*-hydroxy-3,5-di-iodobenzonitrile
isopropalin*	4-isopropyl-2,6-dinitro-*N*,*N*-dipropylaniline
isoproturon*	*N*'(4-isopropylphenyl)-*N*,*N*-dimethylurea
lenacil*	3-cyclohexyl-6,7-dihydro-1*H*-cyclopentapyrimidine-2,4-(3H,5H)dione
mecoprop*	(±)2-(4-chloro-2-methylphenoxy)propionic acid
metamitron*	4-amino-3-methyl-6-phenyl-1,2,4-triazin-5(4H)-one
methabenzthiazuron*	*N*-(benzothiazol-2-yl)-*N*,*N*'-dimethylurea
metoxuron*	*N*'-(3-chloro-4-methoxyphenyl)-*N*,*N*-dimethylurea
metribuzin*	4-amino-6-t-butyl-3-(methylthio)-1,2,4-triazin-5(4H)-one
nitrofen*	2,4-dichlorophenyl 4-nitrophenyl ether
oxadiazon*	3-(2,4-dichloro-5-isopropoxyphenyl)-5-*t*-butyl-1,3,4-oxadiazolin-2-one
oxyfluorfen*	2-chloro-4-trifluoromethylphenyl 3-ethoxy-4-nitrophenyl ether
paraquat*	1,1'-dimethyl-4,4'-bipyridylium
pendimethalin*	*N*-(1-ethylpropyl)-2,6-dinitro-3,4-xylidene

perfluidone*	4′-(phenylsulphonyl)trifluoromethylsulphono-*o*-toluidide
prodiamine*	2,6-dinitro-*N*′,*N*′-dipropyl-4-trifluoromethyl-*m*-phenylene diamine
propachlor*	α -chloro-*N*-isopropylacetanilide
propyzamide*	3,5-dichloro-*N*-(1,1-dimethylpropynyl)benzamide
simazine*	2-chloro-4,6-bisethylamino-1,3,5-triazine
TCA*	trichloroacetic acid
terbuthylazine*	2-chloro-4-ethylamino-6-t-butylamino-1,3,5-triazine
terbutryne*	4-ethylamino-2-methylthio-6-t-butylamino-1,3,5-triazine
tri-allate*	*S*-2,3,3-trichlorallyl *N*,*N*-di-isopropyl(thiocarbamate)
triclopyr*	3,5,6-trichloropyridyloxyacetic acid
trifop-methyl*	methyl [4-(4-trifluoromethylphenoxy)phenoxy] propionate

INSTITUTES FOR AGRICULTURAL RESEARCH IN GREAT BRITAIN

The research programmes of all the following Research Institutes, supported from public funds, are co-ordinated by the Agricultural Research Council. Most of them publish reports annually and copies can be obtained from the Secretaries of the Institutes concerned.

ARC Institutes

Animal Breeding Research Organization	West Mains Road, Edinburgh, EH9 3JQ
Animal Research Station	307 Huntingdon Road, Cambridge, CB3 0JQ
Food Research Institute	Colney Lane, Norwich, NR4 7UA
Institute of Animal Physiology	Babraham, Cambridge, CB2 4AT
Institute for Research on Animal Diseases	Compton, Newbury, Berks. RG16 0NN
Letcombe Laboratory	Letcombe Regis, Wantage, Oxfordshire, OX12 9JT
Meat Research Institute	Langford, Bristol, BS18 7DY
Poultry Research Centre	King's Buildings, West Mains Road, Edinburgh, EH9 3JS
Weed Research Organization	Begbroke Hill, Yarnton, Oxford, OX5 1PF

State-aided Institutes in England and Wales

Animal Virus Research Institute	Pirbright, Woking, Surrey, GU24 0NF
East Malling Research Station	East Malling, Maidstone, Kent, ME19 6BJ
Glasshouse Crops Research Institute	Worthing Road, Rustington, Little-hampton, Sussex, BN16 3PU
Grassland Research Institute	Hurley, Maidenhead, Berks, SL6 5LR
Houghton Poultry Research Station	Houghton, Huntingdon, PE17 2DA
John Innes Institute	Colney Lane, Norwich, NR4 7UH
Long Ashton Research Station	Long Ashton, Bristol, BS18 9AF
National Institute of Agricultural Engineering	Wrest Park, Silsoe, Bedford, MK5 4HA
National Institute for Research in Dairying	Shinfield, Reading, RG2 9AT
National Vegetable Research Station	Wellesbourne, Warwick, CV35 9EF
Plant Breeding Institute	Maris Lane, Trumpington, Cambridge, CB2 2LQ
Rothamsted Experimental Station	Harpenden, Herts, AL5 2JQ
Welsh Plant Breeding Station	Plas Gogerddan, Aberystwyth, Dyfed, SY23 3EB
Wye College, Department of Hop Research	Ashford, Kent, TN25 5AH

State-aided Institutes in Scotland

Animal Diseases Research Association	Moredun Institute, 408 Gilmerton Road, Edinburgh, EH17 7JH
Hannah Research Institute	Ayr, Scotland, KA6 5HL
Hill Farming Research Organization	Bush Estate, Penicuik, Midlothian, EH26 0PH
Macaulay Institute for Soil Research	Craigiebuckler, Aberdeen, A89, 2QJ
Scottish Institute of Agricultural Engineering	Bush Estate, Penicuik, Midlothian, EH26 0PH
Rowett Research Institute	Greenburn Road, Bucksburn, Aber-deen, AB2 9SB
Scottish Horticultural Research Institute	Invergowrie, Dundee, DD2 5DA
Scottish Plant Breeding Station	Pentlandfield, Roslin, Midlothian, EH25 9RF

Published by the
AGRICULTURAL RESEARCH COUNCIL
and obtainable from
HER MAJESTY'S STATIONERY OFFICE
at the following addresses:
49 High Holburn, London, W.C.1
13a Castle Street, Edinburgh, 2
109 St. Mary Street, Cardiff, CF1 1JW
2 Brazennose Street, Manchester, M60 8AS
50 Fairfax Street, Bristol, BS1 3DE
238 Broad Street, Birmingham, 1
Chichester House, Chichester Street, Belfast
or through any bookseller

ISSN 0511 4128 ISBN 0 7084 0164 3

Printed by Bocardo Press, Cowley, Oxford
in 10/12 Baskerville with Univers headings