Proceedings 12th British Weed Control Conference (1974)

CORRELATIONS BETWEEN CLIMATIC FEATURES OF THE PLANT'S ENVIRONMENT AND GERMINATION RESPONSES TO TEMPERATURE

P. A. Thompson

Royal Botanic Gardens, Wakehurst Place, Ardingly, Sussex

Summary Plant populations in any part of the world persist according to their capacity to take advantage of seasons favourable for growth and development and to survive periods of unfavourable conditions. The season at which seeds germinate is a major factor predetermining prospects of survival since it is directly related to the nature of climatic conditions experienced during the vulnerable early seedling stage, as well as levels of exposure to predators and infection by pathogens.

Natural hazards and climatic pressures on survival vary from one phyto-geographical region to another in ways which may be broadly correlated with season of germination and subsequent prospects of successful completion of a full life cycle. Plant germination processes may be selectively modified in two major forms in response to different environmental pressures. One, by variations in the proportions of seeds which germinate or remain dormant, the other, by changes, often quite small ones, in the range of temperatures favourable to germination.

Examples of such responses are presented for different populations, and their significance in relation to the biological control of weed populations is briefly discussed.

INTRODUCTION

The survival of any plant population depends on its capacity to replace itself through successive generations, and this replacement in its turn depends on the survival of individuals and their eventual production of seed. In a long term stable situation the proportion of surviving individuals need be no more than sufficient to balance the loss of their parents; in other words one offspring from each plant of monoecious and hermaphrodite taxa and two from each female plant of dioecious taxa. This low level of survival contrasts markedly with very large numbers of seeds normally produced by many species.

Evidently the balance between seed production and loss from all factors is a very fine one, and one which is potentially susceptible to manipulation by man as a means of reducing plant populations. Indeed, the main factors leading to the eruption of certain species as weeds are small changes in favour of survival arising from modifications to the environment by man. Hofsten (1947), for example, had demonstrated very large differences in the germination patterns of cornfield weeds according to whether stubbles were ploughed in the spring or the autumn. It is not unreasonable to propose that other relatively small changes in management or technique would reverse the favourable balance and produce a reduction in the weed population to a point where the species ceased to be a problem. Such techniques depend on a close understanding of the factors affecting survival, and the ability to make an informed assessment of the consequences of any deliberately imposed modification to the plant's environment.

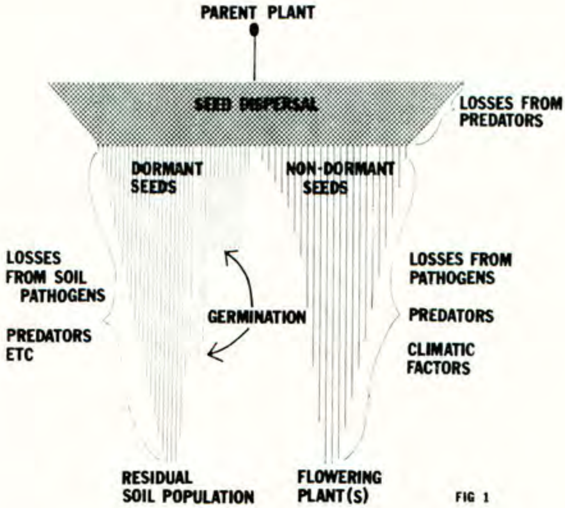

FIG 1

Fig. 1. Diagrammatic representation of the progressive destruction of the progeny of an individual plant before and after germination of the seeds

Figure 1 summarised diagrammatically the progressive loss of the siblings which comprise the progeny of a single individual. Losses occur during seed dispersal, during the time seeds lie in the soil prior to germination and throughout the growth phase of the plants life cycle. Populations of many species display polymorphisms in the responses of individuals which result in variable proportions of seeds germinating or remaining dormant in the soil both at harvest time and at successive seasons thereafter. One result of the presence of these dormant seeds is that a large proportion and often a great majority of any plant population may consist of ungerminated seeds distributed in the soil beneath the more conspicuous but numerically inferior population of growing, flowering and fruiting plants.

CLIMATIC CONDITIONS AND SEED GERMINATION

The proportions of seed which germinate or remain dormant after dispersal may be variable from one population of a species to another, and even as in Rumex species (Cavers and Harper, 1966) from plant to plant within a single population. Similarly, great variations may occur in the incidence of predation, pathogenic infestation, and loss of life due to climatic extremes. The seasons at which seeds germinate critically affect their chances of survival and satisfactory completion of their life cycles by altering the significance and nature of factors influencing survival. Thus, the time of germination is directly related to the climatic conditions experienced during the vulnerable seedling stage which follows germination; it governs the nature of exposure to predators and pathogens and the duration of such exposures; and it may critically affect the timing of plant growth and development which regulate plant maturation and floral development. Went (1949) and Went, Juhren and Juhren (1952) have demonstrated ways in which germination responses of particular species of desert annuals are related to subsequent life history and winter and summary composition of the natural flora.

In certain phyto-geographical zones the season at which seeds germinate predetermines, almost absolutely, prospects of survival and maturation. Species of annuals, biennials and short-lived perennials in particular within such zones typically possess recognisably characteristic germination patterns which respond to the natural succession of climatic factors so as to produce seedlings at those seasons which are favourable for ultimate survival. The main climatic factors involved in these responses are temperature and precipitation, although important effects may also result from changes in photoperiod or light quality. Figures 2, 3 and 4 summarise climatic patterns of mean monthly temperatures and precipitation in different parts of Europe, derived from Rumney (1968), in relation to the seasons when seeds mature on the plant or germinate in the soil.

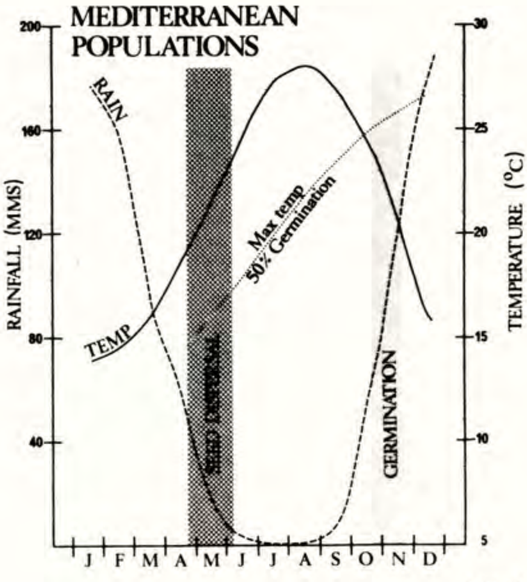

FIG 2

Fig. 2. Climatic features of the Mediterranean basin in relation to the seasons of seed dispersal and germination. Changes in the maximum temperature for 50% germination from the time ripe seed matures are also indicated. (Meteorological records represent mean monthly temperatures and precipitation from Beirut, Lebanon).

Populations of species which grow around the Mediterranean basin (Fig. 2) flower during the spring at the end of the winter growing season and seed is shed during early summer at the start of long, intensely arid summers. The presence of residual soil moisture when seed is being shed, and the occurrence of summer thunderstorms may provide intermittent periods of high soil moisture levels followed by lengthy periods of extreme drought, which would destroy any seedlings present. Survival within this region depends on the evolution of selective responses which prevent seeds from germinating during transient periods of high soil moisture during the summer. This is achieved by after-ripening requirements which restrict the proportions of seeds germinating immediately after harvest, and by high temperature dormancy mechanisms such as have been described for Aegilops ovata by Datta, Evenari and Gutterman (1970) and for Silene secundiflora by Thompson (1970). The maximum temperature at which germination occurs may be as low as 15°C immediately after the seed is shed, but these increase progressively to c.30°C as after-ripening proceeds. During the autumn natural temperatures fall to levels favourable for germination, at about the same time as the first heavy winter rains. Characteristically, very high proportions of seeds germinate almost synchronously at this time, and seedlings develop rapidly in the warm soil temperatures of mid to late autumn.

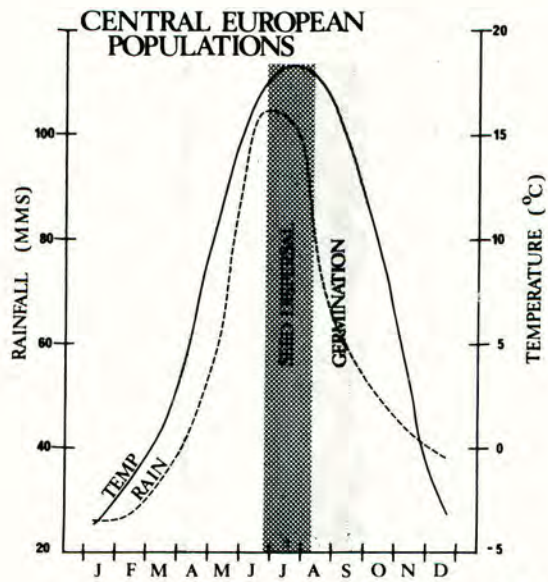

FIG 3

Fig. 3. Climatic features of continental areas of central Europe in relation to the seasons of seed dispersal and germination. (Meteorological records represent mean monthly temperature and precipitation from Lvov, Poland).

Species which grow naturally in central Europe (Fig 3) experience totally different climatic regimes with quite different implications for plant survival. Winter temperatures fall below the levels at which plant growth occurs, and moderate rainfall provides good conditions for plant growth during the summer. Short periods of drought may occur in late summer but soil moisture deficits are seldom severe and are eliminated as temperatures decrease in early autumn. Plant survival during the winter of hardy species may even be facilitated by the low temperatures which decrease predator and pathogen activity, and by moderately low levels of precipitation much of it as snow which provides protection. Populations of many of the taxa which grow in this region shed their seed in late summer, and characteristically possess few restrictions on germination imposed either by post-harvest dormancy or narrowly defined temperature requirements. As a result seed may germinate soon after dispersal to produce small seedlings which overwinter as young plants and are well established by the spring and early summer, which consitute the most favourable seasons for plant development.

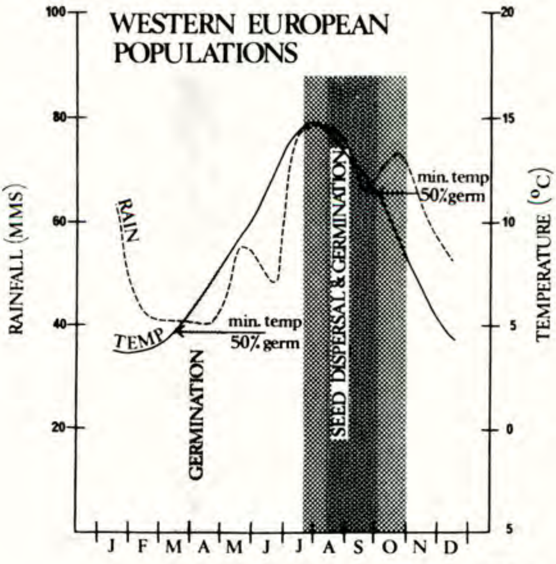

FIG 4

Fig. 4. Climatic features of western, oceanic Europe in relation to the seasons of seed dispersal and germination. (Meteorological records represent mean monthly temperature and precipitation from Edinburgh, Scotland).

Western Europe, exposed to moderating oceanic influences, experiences notably varied climatic patterns, not only from year to year but within seasons. Irregular and unpredictable sequences of cold, or drought, or wet, especially during the winter, pose special hazards to plant survival, both from attacks by predators and pathogens which may be active for long periods when regenerative plant growth is at a minimum, and from the direct effects of wind and cold usually unmitigated by any appreciable snow cover. Germination responses of populations growing naturally within this region also tend to be complex and many species possess highly developed dormancy mechanisms which reduce levels of germination at any particular season. In the simplest situation, all seeds display deep post-harvest dormancy, which prevents germination at any temperature and is only removed by a low temperature chilling treatment of the imbibed seed. Under natural conditions this requirements would normally be satisfied during the winter (Fig. 4), and seeds would germinate soon after temperatures started to rise again in the springtime. Even after a chilling treatment, a minimum temperature can frequently be identified, below which seeds will not germinate and this provides protection against premature germination during transient mild periods in the winter.

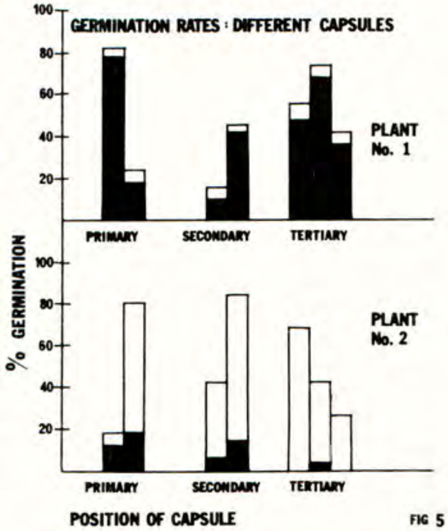

Fig. 5. Variations in germination responses of seeds collected from different capsules on two plants of Silene dioica. Shaded areas represent germination within five days of sowing; final counts were made after thirty-eight days.

One major disadvantage of this response is that seedlings produced in the spring are less able than larger plants to take full advantage of good growing conditions during late spring and early summer. An alternative strategy is for seeds to germinate in late summer and early autumn. This ensures that seedling stages are completed during fine weather and high soil temperatures in the autumn and advances the growth stage of the plant so that it is well established and well able to grow responsively by the following summer. Species growing in the area are therefore faced with a choice of strategies each with particular advantages and disadvantages. Unpredictable winter weather with varying levels of hazard from year to year prevents an unequivocal resolution of this conundrum, and very many species from western oceanic regions of Europe, including Anagallis minima and Lythrum hyssopifolia (Salisbury, 1965) appear to have developed germination polymorphisms which split populations of seeds annually into those which germinate in autumn and those which germinate in the spring. Levels of post-harvest dormancy, and hence the proportion of individuals germinating soon after seed is shed in the autumn may be extremely variable from population to population, from plant to plant and even from capsule to capsule from the same plant. (See Fig. 5)

RESPONSES OF DIFFERENT POPULATIONS

The nature and extent of these variations is a matter for analysis, and marks the point where a detailed understanding of the magnitude and direction of changes required for survival in different geographical locations may provide instances where methods of weed control by modifications to existing agricultural practices become possible. As an example patterns of variation between populations of a species from western and central Europe are illustrated in Figure 6. Seeds, freshly harvested from populations of *Lychnis flos-cuculi* L., the ragged robin, collected originally from different locations in Europe, were sown at different temperatures between 6 and 31°C. Variations in the proportions of dormant seeds produced large variations in the percentage of seeds which germinated, but all the populations shared optima around 21 to 26°C, all showed reduced germination rates at 31°C and 16°C, and none germinated well at 6° or 11°C. Thus the populations examined here shared qualitative responses

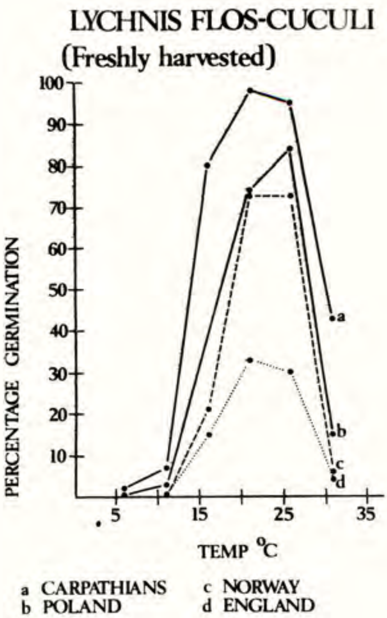

Fig. 6. Germination responses of freshly harvested seeds from four different origins of Lychnis flos-cuculi tested at temperatures between 6° and 31°C.

to temperature in spite of quite wide variations in geographical origin, but displayed obvious differences in the proportions of seed capable of immediate germination and by implication, those which would have remained dormant until the following spring.

If these results may be interpreted in relation to natural conditions they display a logic closely in line with the contrasting conditions described earlier for species growing in oceanic Europe and in central more continental regions. Levels of dormancy of the four populations, as well as minimum temperatures favouring germination display an ordered succession in which the most restricted position is occupied by the species from England (from an extreme oceanic part of Europe) and the least restricted from the Carpathians and Poland (areas with very marked continental climates). Thus germination during the late summer and autumn would appear to be much more probable in the populations from eastern Europe than in ones from western Europe, in which high proportions of seed, and almost all late shed seed, might be expected to remain dormant until after exposure to winter chilling conditions during the winter.

Weedy species are characterised by their ability to colonise in the wake of man's activity, which may result in enormous extensions to their natural range in association with particular crops or cropping systems. One species which once spread in this way, and whose spread is relatively well documented is the corn-cockle (Agrostemma githago, L.). Our understanding of the chronology of the distribution of this species arises partly because it has large easily identified seeds which sometimes persist amongst deposits on archaeological sites and partly because the flower is unusually conspicuous and the seed, which is exceedingly poisonous, is a well known and dangerous contaminant of cereal grains. The species arrived in Europe, probably from the eastern Mediterranean, very early in the history of cultivation on the continent as evidence by the occurrence of its remains in deposits from Swiss lake dwellings (Herr, 1866), and was certainly present in Neolithic times more than 4,000 years B.P. It has now become a very rare species over much of the continent and there is little doubt that in recent years this decline has been accelerated by the use of selective herbicides. However, in the more advanced agricultural countries the species started to decline during the late nineteenth century before the introduction of selective chemicals, and appears to have been virtually eliminated in many areas by improvements in seed cleaning techniques which removed its seeds from samples of seed grain and prevented annual recruitment of field stocks from seed sown by man with his grain (c.f. Fryer and Chancellor, 1970, and Perring, 1970). Figure 7 shows the maximum range of this species and also the locations of a number of populations which were used in tests to examine germination responses.

The results of these tests of which a few are illustrated in Figure 8 and which are described in detail elsewhere (Thompson 1973), showed that all these populations, whatever their immediate origin, possessed a germination character, typical of their original home in the Mediterranean with few if any recognisable characteristics attributable to selective adaptation during their period in alien parts of Europe. Few, if any significant and consistent differences in response occurred at temperatures between 0 and 25°C, and variations in positions of maxima could not be correlated with geographical location or particular climatic features. As it happens, particular qualities of the Mediterranean germination response are admirably pre-adapted to the requirements of a cultivated plant. These include the ability to germinate at low temperatures when sown in the spring, and the normal pattern of rapid synchronous germination of a very high proportion of the population on exposure to favourable conditions. In this case therefore a germination response, well suited to a particular pattern of agricultural techniques had been instrumental originally in the development of the species as a weed, and during, perhaps, five thousand generations in northern Europe no selective pressures had operated with sufficient intensity to create modifications to the germination response sufficient to permit independent establishment of truly feral populations. Consequently, the species declined and practically

Fig. 7. Maximum extent of range of Agrostemma githago as a cornfield weed, and the location of populations included in tests to examine the effects of cultivation on germination responses.

died out as soon as it was deprived of the support of annual harvesting and resowing by man.

RESPONSES TO TEMPERATURE AND DORMANCY

There are two main components of variation in the germination responses to temperature. One is the proportion of seeds which remain dormant at any temperature, the other is the temperature range over which germination occurs. The germination responses of populations of Lychnis flos-cuculi shown in Figure 6 illustrate both types of variation, and draw attention to the considerable differences in levels of dormancy which contrast with rather narrow variations in the range of temperatures favourable to germination. This is a typical pattern and one which is frequently found in comparisons between the germination responses of different populations of a taxon. The significance of large variations in the proportions of dormant individuals is one which is easily perceived and its bearing on the pattern of seasonal germination and on the level of the soil borne weed seed population is readily imagined. The significance of relatively small differences in the range of favourable temperatures may be less obvious. Tests over a wide range of temperatures

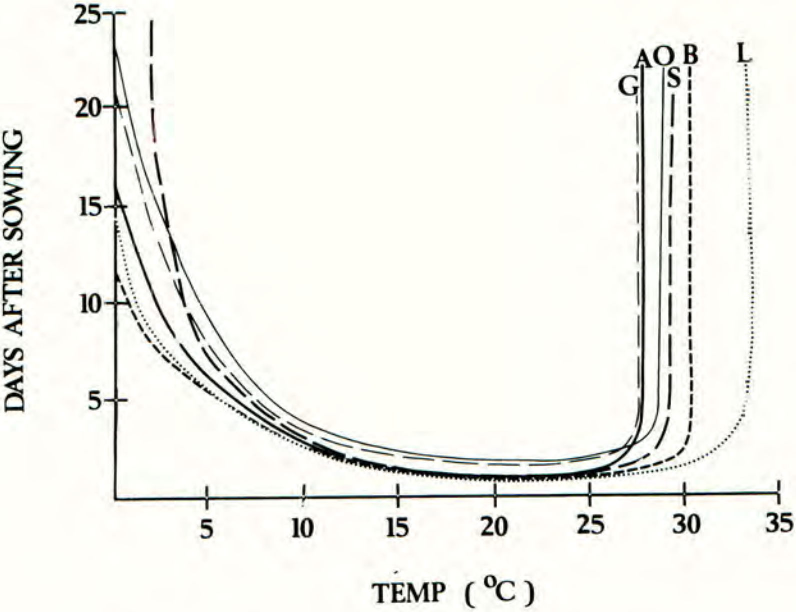

Fig. 8. Germination responses, expressed as maximum and minimum temperatures on successive days resulting in 50% of maximum germination for six populations of Agrostemma githago obtained from different parts of Europe. (Identifying letters beside graphs, refer to locations indicated in Fig. 6).

may indicate, as with L. flos-cuculi broad qualitative similarities, and narrow qualitative differences. However, if the latter occur at temperatures which correlate with natural conditions they may be, ecologically, highly significant. This could certainly be the case with L. flos-cuculi, in which the responses to temperature illustrated in Figure 9 display maximum differences at c. 16°C. A position which is very close to the temperatures which occur in moist soil in its natural geographical range at the season of the year when seed is being shed.

Particular aspects of the germination response may therefore be correlated with the distribution of different species, and with the distribution of different populations of a taxon. These would appear to be adaptive responses which effectively permit survival of the minimum number of individuals necessary to maintain a plant population. Variations between the responses of different populations, even from widely separated geographical locations may be quite minor, deriving from changes in the proportions of individuals germinating or remaining dormant at particular times, and in changes, perhaps only of one or two degrees centigrade in the range of temperatures favouring germination. There is as yet no way of assessing how critically such changes may affect the chances of survival of a population.

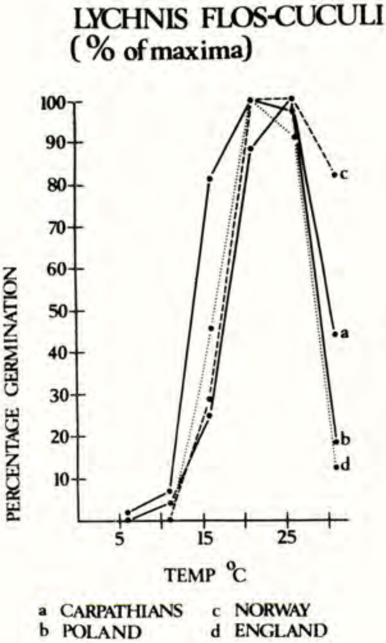

Fig. 9. Germination responses of freshly harvested seed of Lychnis flos-cuculi. Values are plotted, for each population separately, as percentages of final maximum number of seeds in order to remove the effects of variations in numbers of dormant individuals from one population to another.

The situation would appear to offer prospects for the biological control of weed populations provided enough is understood about the germination biology of a species and its contribution to survival, quite small changes in techniques including cultivation, and the timing of herbicide applications might be expected to affect survival rates critically. At present most examples of such effects have been on the debit side when plant populations have increased and weeds become more serious as a result of changes in agricultural techniques, techniques which also, of course, act favourably or otherwise on processes other than germination. Examples, such as Agrostemma githago where improved techniques have in fact led to the elimination of a weed, and this is only one amongst a number of cornfield weeds similarly affected, provided reason for optimism to the extent that the genetic changing circumstances, appears to have been quite small. Spread of the species as a weed and its maintenance as a weed for many centuries evidently derived directly from particular aspects of its natural germination response, and when altered techniques, such as improved seed cleaning, altered the balance of advantage against the survival of individuals using this strategy the species ceased to play any effective role as a weed of cultivation.

References

CAVERS, P. B. and HARPER, J. L. (1966) Germination polymorphism in Rumex crispus and Rumex obtusifolius. J. Ecol. 54, 367-382

DATTA, S. C., EVENARI, M. and GUTTERMAN, Y. (1970) The heteroblasty of Aegilops ovata L. Israel J. Bot. 19, 463-483

FRYER, J. D. and CHANCELLOR, R. J. (1970) Herbicides and our changing weeds in 'The Flora of a Changing Britain' ed. F. Perring, Classey ltd., Middx.

HEER, O. (1866) In 'Die Pflanzen der Pfahlbautern'. Neujahrsbl. Naturf. Ges. Zurich

HOFSTEN, C. G. von (1947) Investigations of germination biology in some weed species. Pub. Inst. Plant Husbandry, Royal Agric. College, Sweden, 2, 91-107

PERRING, F. (1970) Changes in plant distribution following changes in local climate. In 'The Flora of a Changing Britain' ed. F. Perring, Classey Ltd., Middx.

RUMNEY, G. R. (1968) In 'Climatology and the World's Climates'. The MacMillan Co., New York, Collier MacMilland Ltd., London.

SALISBURY, E. J. (1965) The reproductive biology and occasional seasonl dimorphism of Anagallis minima and Lythrum hyssopifolia. Watsonia, 7, 25-39

THOMPSON, P. A. (1970) Changes in germination responses of Silene secundiflora Otth. in relation to the climate of its habitat. Physiol. Pl., 23, 739-746

THOMPSON, P. A. (1973) Effects of cultivation on the germination character of the corncockle (Agrostemma githago L.) Ann. Bot., 37, 133-154

WENT, F. W. (1949) Ecology of desert plants. II. The effect of rain and temperature on germination and growth. Ecology, 30, 1-13

Proceedings 12th British Weed Control Conference (1974)

WIND DISPERSAL OF WEED SEEDS

F.M. Burrows

School of Mathematics and Computer Science, University College of North Wales, Bangor.

Summary A variety of seeds and fruits suitably shaped for making use of winds for dispersal is discussed in general aerodynamic terms and species are grouped according to the flight styles they employ during aerial movement. The salient features of these differing styles are outlined briefly and the importance of vertical wind velocities in affecting dispersal range and both natural and forced deposition is indicated.

INTRODUCTION

Quite a wide variety of seeds and fruits are suitably shaped for making use of winds for assisting dispersal and it is not difficult to make a preliminary classification of some of these into fairly well defined groups which are distinguished from one another by aerodynamic rather than by botanical features. In the aerodynamic sense seeds and fruits are simply shapes of differing mass and geometry so that a botanical classification as complete as that used by Ridley (1930) is perhaps not needed in discussing species which are capable of quite different forms of aerial movement. Once the equations of motion for the different groups have been established calculation of their aerial movement becomes possible, and whilst this has been done for plumed seeds (Burrows, 1973), and for dust seeds, spores and pollens (Burrows, 1974a), a number of other species remain to be considered.

When the wind is blowing on a dry clear day aerial movements are seen not directly as the motion of the air itself but indirectly as the effect of this motion on suspended, but not necessarily buoyant, objects which are opaque at least to some extent. Natural winds are rarely steady in time and because of this there are differences between the flow stream lines, the paths taken by single marked particles of air, and the streak lines delineated by a succession of particles at a particular instant in time following release from a single point in space at earlier times (Prandtl & Tietjens, 1957). Non-buoyant particles of different materials like seeds and fruits always move relative to the air when in flight so that the particle paths and streak lines for these differ from those for the air particles in the same flow. Smoke issuing from a chimney is perhaps the most familiar of all groups of streak lines whilst, on a smaller scale, a number of dust seeds or spores released successively from a single point in space forms an isolated streak line. Every single particle moving freely and without propulsive thrust in a gravitational field is always falling relative to the air at every moment of its flight even though it may be observed to be rising away from the ground, a situation which arises when the air moves upwards faster than the body can fall in still air. When the fall is vertical and in absolutely still air the steady speed reached eventually is the terminal velocity and this quantity is of importance in discussing wind-borne seed movement.

When a flow is specified in the aerodynamic sense the velocity distribution in space and time is known so that the flow stream lines and particle paths for individual air particles can be deduced together with the streak lines for particular instants in time when these are needed. The next step is to determine the aerodynamic forces and moments which act upon a seed and fruit during aerial motion. These, together with the environmental force and moment field, lead to the equations of aerial motion and solutions of these equations state where a seed or fruit will be at a particular instant in time and with what speed it moves following either release or projection into the environment elsewhere at an earlier time. The aerial path described between the position of release and the position of initial contact with the ground has been defined as the primary trajectory (Burrows, 1973), and although there is always the possibility of some seeds and fruits which have alighted on the ground at an earlier time being whisked up into the air again, so that other trajectories may exist, the primary trajectory is perhaps of greatest importance in studies of this sort. Examination of single particle trajectories is perhaps the only satisfactory means for providing an understanding of the mechanics of response to changing airflow even though the ultimate goal of predicting population dynamics and possible control of species must of necessity involve statistical statements of position at given times.

The present discussion need not be considered restricted to weed seeds and fruits and is an abridged version of a more complete and general work by the author (Burrows, 1974b).

AERODYNAMIC CLASSIFICATION OF SEED AND FRUIT GROUPS

A preliminary classification of seed and fruit groups which is based substantially, if not almost entirely, on aerodynamic rather than botanical features leads to the following list :-

(a) dust seeds, spores and pollens;
(b) plumed seeds and fruits and woolly seeds and fruits;
(c) plain winged seeds and fruits with a central or more less central concentration of mass;
(d) winged seeds and fruits which rotate when falling;
(e) seed-carrying tumble weeds, and
(f) aerodynamically unimportant seeds and fruits.

Each one of the groups of seeds and fruits in this list requires its own distinct set of equations to describe aerial motion. For group (a) the combinations of slow flight speeds and small physical sizes are such that movement is dominated by aerodynamic drag forces which are proportional to the speed of movement relative to the air. Group (b) members tend to move at rather greater relative speeds and the aerodynamic drag which is the dominant force developed is proportional to the square of the relative speed. In contrast, aerodynamic lift forces are usually dominant for groups (c) and (d), but the quite different modes of motion associated with the lift production mean that a separate classification of these two groups is essential. Group (e) is a rather difficult one to deal with because, unlike all of the others, the probable geometry of tumble weeds during movement on the wind may not be easy to specify and on this count the group will not be discussed further. Group (f) includes all species for which the weight is relatively large compared with any aerodynamic force which can be developed and thus needs no discussion at all. The first four groups are now dealt with separately.

DUST SEEDS, SPORES AND POLLENS

Although many of these tiny particles have densities of the same order of mag-

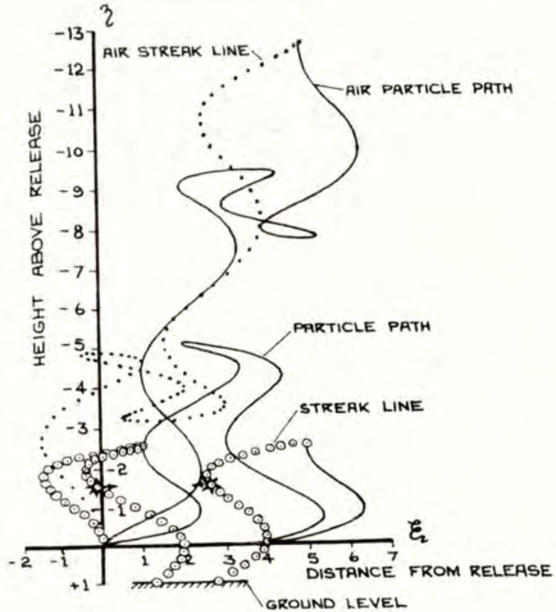

FIG. 1.

Particle paths and streak lines for air particles and dust seeds in a simple fluctuating wind following release at $\xi = 0$, $\eta = 0$. $\xi = x/h$; $\eta = y/h$; h = plant height; x = horizontal distance from plant; y = vertical distance (+ve downwards). All of the particles in the streak line between and below the starred ones ✵ will have passed below ground level at earlier times.

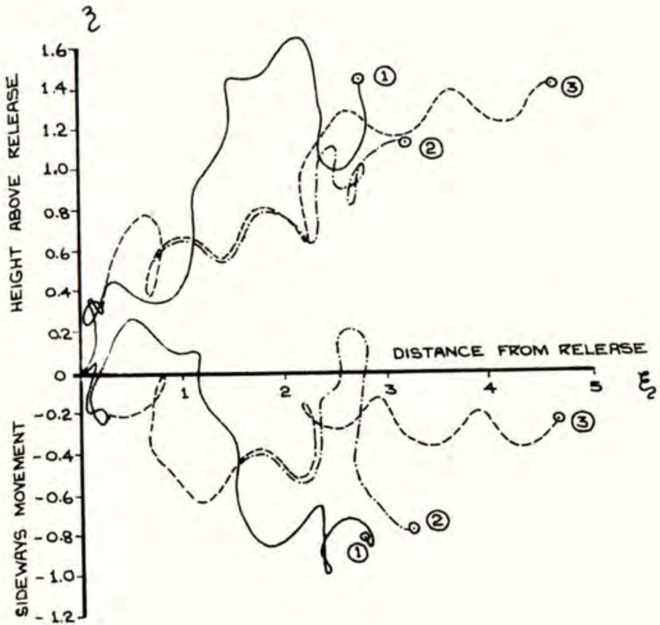

FIG. 2.

Single particle trajectories for dust seeds released into pseudo-turbulent wind from adjacent co-ordinates. Legend as for Fig. 1 and with $\zeta = z/h$; z = lateral distance from plant. Release co-ordinates ①, (0,0,0); ②, (0.1,0,0); ③, (-0.1,0,0); particle trajectories: ①, ——— ; ②, —·—·—; ③, - - - - - -.

nitude as that of water (for spores see for example: Gregory, Table III, 1973) the terminal velocities of fall in still air are very small and usually less than 100 mm/s. This means that the trajectories followed by them in practice become very sensitive to similarly small fluctuations in wind and convection velocities and these can occur even in the small eddies which exist in many environments which appear to be tranquil. Steady mean velocities in excess of the terminal velocities are achieved frequently in diurnal convection and when this happens dust seeds and spores can become elevated to very great altitudes so that vast carriage distances are possible in favourable horizontal winds (Ridley, 1930; Ingold, 1971).

Equations describing the motion of these species when represented by spherical particles moving without collisions in a gravitational field can be solved for environments which vary in time, in space, and in both time and space (Burrows, 1974a). Since the solutions of these define particle trajectories they can be used, for example, to detect possible coincidence with particular co-ordinates as would occur in deposition. Specimen solutions for fluctuating winds are given in Figs 1 & 2 and the first of these figures shows clearly the differences between the particle paths and streak lines for air particles and for seeds. The second figure shows trajectories calculated for a space and time dependent environment and demonstrates roughly the kind of effect which might be expected to occur in a turbulent wind. The quite different ultimate positions of migration of seeds released from positions close to one another indicates the sort of spread which might well occur, for example, during the early life of a spore cloud.

The sensitive response of small particles of this kind to the sort of eddying motion which occurs in turbulent boundary layer flows permits an explanation for their arrival at the positions of under-surface deposition mentioned by Gregory (1973) and also for the possible accumulation of deposited particles in the flows adjacent to surfaces with marked changes of contour (Burrows, 1974a).

PLUMED SEEDS AND FRUITS AND WOOLLY SEEDS AND FRUITS

Plumed seeds and fruits and woolly seeds and fruits of the kind shown in Fig. 3 (a) - (d), and not counting those with either long tails (e) or other limbs (f), amount to devices with parachutes of varying porosity which may tend to close up and work less effectively with increase in atmospheric humidity (Sheldon & Burrows, 1973).

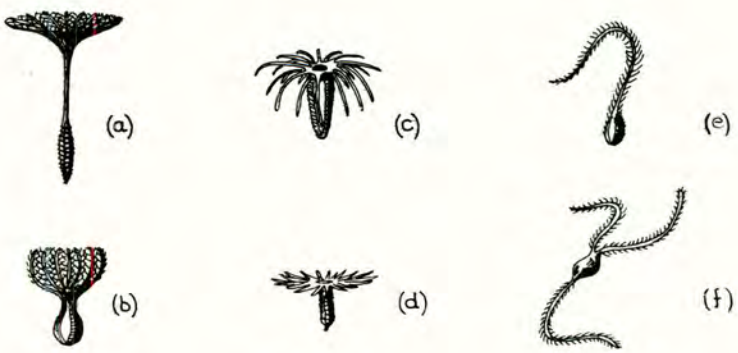

FIG. 3.

Representative forms of plumed seeds and fruits

Two kinds can be distinguished (Burrows, 1973) on the basis of the parachute acting as either a drag producing device or as a guiding device. When the parachute is either or both very small and porous it most likely acts as a guide parachute (Hoerner, 1958) which serves to orientate the seed during fall in preference to ensuring the small rates of descent common to other seeds of this group so that the achievement of a significant dispersal range may depend on a catapulting action being available at the time of release. For those with parachutes of larger size and small porosity low terminal velocities of fall are reached rapidly subsequent to release into still air. When the axial symmetry of the seed and its parachute are not quite perfect axial rotations can and do occur in flight.

All of the arrangements shown in Fig. 3 (a) - (d) amount dynamically to the first one of the group in that they consist of a fairly concentrated mass to which is attached a parachute of some sort. Equations for plane motion in steady winds have been derived for them (Burrows, 1973) and admit of a fairly wide range of useful and practical solutions which can be used to account for seed behaviour in aerial flight. Fig. 4 shows some calculated trajectories for seeds which move through a region which includes rapid changes of convection flow and indicates that care is needed in making approximate calculations based on the assumption that such seeds always fall relative to the air at their steady terminal velocities.

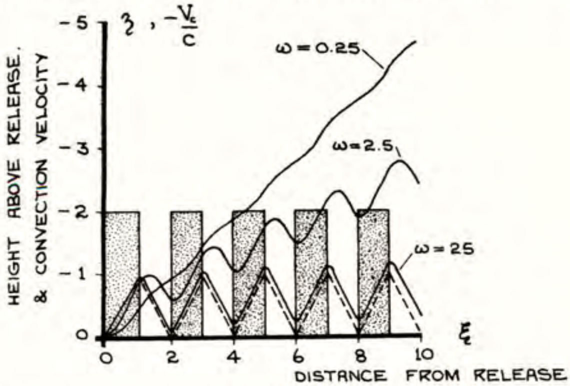

FIG.4.

Trajectories for plumed seeds moving across a series of convection pulses of unit width and spacing. - - - - - - - Approximate trajectory; ———— true trajectories. Stippled areas, convection pulses, V_c max = 2c. c = terminal velocity of fall; V_c = convection velocity, $\omega = hg/cU_w$, h = plant height, g = acceleration due to gravity, U_w = horizontal wind velocity, $\xi = x/h$, $\eta = yU_w/hc$, x = horizontal distance from release, y = vertical distance (+ve downwards).

PLAIN WINGED SEEDS WITH A CENTRAL OR MORE OR LESS CENTRAL CONCENTRATION OF MASS

Of the various winged and plumed arrangements this type is perhaps alone capable of an extensive linear trajectory in regular flight in still air with a substantial range from the point of release provided that it has that perfect geometry which is consistent with such stable flight. The asymmetry which is almost inevitable with uneven ripening of the wing membrane may lead to curved flight paths of the kind shown in Fig. 5(a) and in some circumstances the flight may be very irregular, involving apparently erratic movements of the type indicated in Fig. 5(b) and which are probably wholly unpredictable.

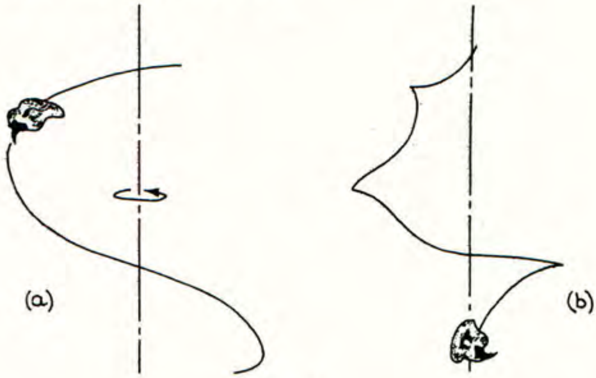

FIG. 5.

Possible still air flight paths for plain winged-seed

Regular flight of seeds of this kind is only possible when aerodynamic lift is developed and when all of the aerodynamic forces act in such a way that stable trim is possible. When the amount of lift is very much greater than the drag produced in the motion very moderate rates of descent can be achieved during gliding flight in still air. If a straight glide is begun down-wind the ground coverage can become very great in terms of the release height, particularly when the structural arrangement and mass distribution is such that equilibrium with the aerodynamic loads developed is established in flight attitudes corresponding to the minimum possible rates of sink which are the usual measure of best gliding performance. Flight paths for straight glides in still air and in steady winds are indicated in Fig 6.

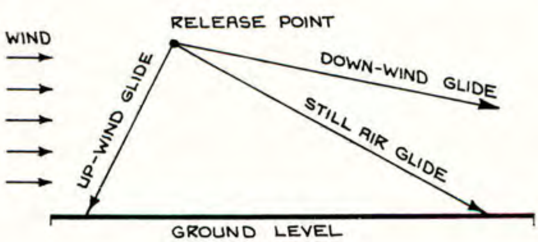

FIG. 6.

Straight glide paths for plain winged-seed

The aerodynamics of seeds of this type does not appear to have been discussed in the literature but as they are, to some extent, not unlike aeroplanes much of what is well established for these machines in un-powered flight (Durand, 1963) may be applicable to the motion of such seeds when proper allowance has been made for the relative scales of these motions.

Norberg (1973) has discussed some aspects of the mechanics of flight of single winged seeds which rotate when falling using well established analysis of helicopter theory (Shapiro, 1955), and has shown that, for falls in still air, two trajectories of the kind indicated in Fig. 7 are possible.

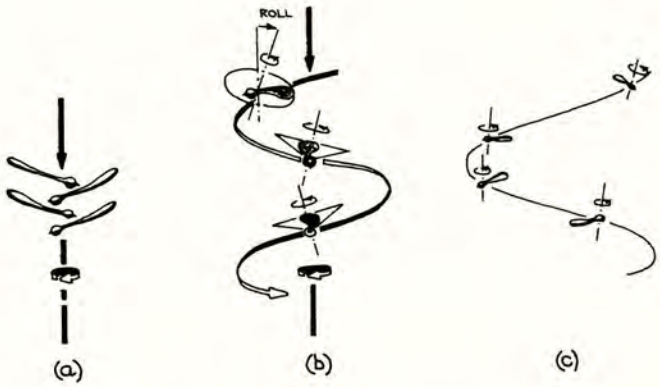

FIG. 7.

Still air trajectories for rotating winged-seed. (a) Single helical trajectory. (b) Compound helical trajectory. (c) Compound helical trajectory with large lateral dimensions.

Fig. 7 (a) shows the most familiar case in which the centre of mass of the seed descends roughly in a straight vertical line and the wing tip describes a helical path. For the second of these two trajectories, Fig. 7 (b), the deviation of the flight path from the vertical occurs if the wing tip path plane during rotation is inclined to the horizontal and flight equilibrium is established in a side-slipping motion with stable autorotation. Because of the side-slip the amount of lift developed on the wing is increased or decreased according as it is advancing or retreating along the direction of the side-slip and this, together with the gyroscopic effects of the rotating mass, causes the rolling motion which results in the compound helical trajectory shown in Fig. 7 (b). A most interesting feature of this motion is that the direction of the rotation of the helical path described by the centre of mass of the seed is opposite to that of the rotation about the centre of mass. When sudden cross-winds of sufficient strength are encountered the seed is easily toppled out of either one of these two comparatively stable states. This can happen also when winged seeds are given an initial velocity of projection which is sufficiently large to establish autorotation and such that the axis of rotation is horizontal or nearly so. Seeds moving in this way slow down to a stop and fall out of the initial trajectory and into one of the two types described earlier. Seeds projected with sufficient speed in downward directions closer to the vertical can be observed to move along compound helical trajectories of relatively large lateral dimensions as indicated in Fig. 7 (c).

Calculation of the trajectories for winged seeds of this kind is a complicated business if transients are not to be ignored because there are six degrees of freedom to be accounted for. On the other hand if steady rotational flight is assumed, together with steady relative fall at the terminal velocity, approximate calculations are no more difficult than for the plumed seeds discussed elsewhere (Burrows, 1973).

CONCLUDING REMARKS

In wind-borne seed movement convection velocity variations are of particular importance because of their direct effect on gravitational sedimentation and they have a decisive influence on the dispersal range which might be achieved in a given horizontal wind blowing away from the point of release. Since vertical currents can be induced in otherwise horizontal winds by the introduction of suitably shaped obstacles the attractive notion of inducing a certain amount of forced deposition, even for the larger and heavier species, may define a possibility which can be developed. Fig. 8 shows, for example, the sort of effect transverse obstructions of differing degrees of porosity, like fences and hedgerows, have on the flow and where deposition concentrations may perhaps be induced by them.

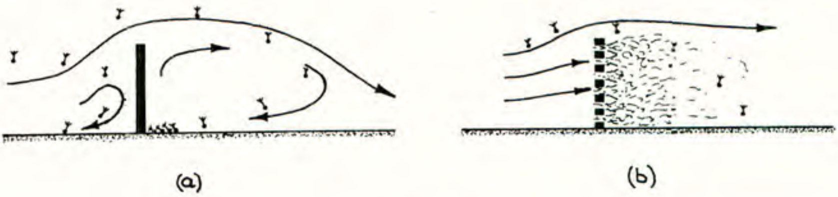

FIG. 8.

Flow with transverse obstructions.
(a) Non-porous obstruction with regions of reversed flow.
(b) Porous obstruction with region of flow of reduced speed downstream but without the substantial re-circulation induced by obstruction (a).

When the aerodynamic response of any species is known precisely wind separation from other species and material particles having a different response by immersion in a properly controlled airstream is theoretically possible. Whilst this is none other than the usual winnowing process it is the possible refinements to it which can follow an understanding of the aerodynamic response of species which may be of immediate interest.

Acknowledgement

The author is most grateful to Professor J.L. Harper for his very kind help during the preparation of this paper.

References

BURROWS, F.M. (1973) Calculation of the primary trajectories of plumed seeds in steady winds with variable convection. New Phytologist, 72, 647-664.

BURROWS, F.M. (1974a) Calculation of the primary trajectories of dust seeds spores and pollens in unsteady winds. Unpublished.

BURROWS, F.M. (1974b) Wind-borne seed and fruit movement. Unpublished.

DURAND, W.F. (Editor) (1963) Aerodynamic Theory, Vol. $\overline{v}$. Dover Publications, Inc., New York.

GREGORY, P.H. (1973) The Microbiology of the Atmosphere. Leonard Hill.

HOERNER, S.F. (1958) Fluid-Dynamic Drag. Hoerner, New York.

INGOLD, C.T. (1971) Fungal Spores. Clarendon Press, Oxford.

NORBERG, R.A. (1973) Autorotation, self-stability, and structure of single-winged fruits and seeds (samaras) with comparative remarks on animal flight. Biological Reviews, 48, 561-596.

PRANDTL, L. & TIETJENS, O.G. (1957) Fundamentals of Hydro- and Aeromechanics. Dover Publications, Inc., New York.

SHAPIRO, J. (1955) Principles of Helicopter Engineering. Temple Press Limited. London.

SHELDON, J.C. & BURROWS, F.M. (1973) The dispersal effectiveness of the achene-pappus units of selected compositae in steady winds with convection. New Phytologist, 72, 665-675.

Proceedings 12th British Weed Control Conference (1974)

SEEDS IN RUDERAL SOILS, THEIR LONGEVITY AND CONTRIBUTION TO THE FLORA OF DISTURBED GROUND IN DENMARK

Søren Ødum

The Royal Veterinary & Agricultural University, Botanical Institute, Rolighedsvej 23, 1958 Copenhagen V, Denmark

INTRODUCTION

This paper summarizes a comprehensive investigation of buried seeds in Danish ruderal soils carried out mainly in 1969-1972. It continues on from a previously published study of the presence of dormant seeds in old culture deposits (Ødum 1965), in which stress was laid on the possibility of dating seeds by archaeological methods, as well as explaining the occurrence of certain rare species.

The investigations were confined to environments where the ecological and phytosociological aspects of the problem were obviously significant. The aim of the study was to investigate the composition of the seed bank, i.e. the dormant seeds in ruderal soils, and the extent to which they contribute to the earliest stages of plant succession after soil disturbance. The term ruderal soil is used here in the widest sense as a collective term for uncultivated soils within and around existing or abandoned human settlements. The study included material from field observations and results from experimental plots and soil samples.

The significance of the seed bank and the longevity of buried seeds in relation to the weed populations on cultivated soil has long been recognized. Recent publications on this subject are, in Denmark by Jensen (1969), in England by Thurston (196o) and Roberts (197o) and in France by Guyot (196o). A comprehensive literature review, including more natural ecosystems, is by Mayor & Pyott (1966). Buried seeds in successional field and forest stands in Massachusetts have been studied by Livingstone & Allessio (1968). The significance of the seed bank in population studies has been discussed by Harper (1960) and by Sagar (1970). Studies on the physiology of buried seeds have been carried out by Wesson & Wareing (1967, 1969a, 1969b).

METHODS AND MATERIALS

1. Plant lists from disturbed soil. Plant lists were made at 59 excavations in towns, after house demolitions, or in archaeological excavations, etc. Only species germinated from seeds were recorded. The sites were infinitely variable. In some instances the occurrence of certain species could be related to easily recognized environmental factors.

2. Soil samples. Soil samples were taken from 78 localities, each was about 1o kg. The major part of each sample was spread in a 3-4 cm thick layer in boxes in an

unheated greenhouse To avoid contamination, the samples were watered with a manually-operated drip-watering system. A small number of samples was placed outdoors under frames as described below. A layer of unimpregnated rock-wool (Olsen 1970) and a fine-meshed nylon net separated the samples from the soil beneath. The samples were watered through the nets by hose and sprinkler. Some samples were divided and placed partly in the greenhouse and partly outdoors. The samples were frequently inspected and the numbers of each species were counted. Almost all the seedlings appeared within 3 weeks after the samples were laid out, but the experiment was continued much longer.

3. Experimental plots. Experimental plots were successfully established at 74 localities. These were in undisturbed ruderal communities covering an area of greater size and dominated by a closed vegetation of perennials. Having noted the specific composition of the vegetation on the locality chosen, the plot was established as follows. On an area of about 150 x 250 cm, the upper 10–20 cm thick layer of soil was removed. The floor of the plot was locally grubbed up, and as some loose soil from the removed upper layer usually fell down, the exposed soil on the plot represented soil from a vertical zone of about 5–30 cm. One half of the plot was then covered by a 100 x 140 cm frame with a fine-meshed ($<$ 0.4 mm) nylon net. The outside lower part of the frame was covered with soil. Rain passed easily through the net, and light was only slightly reduced. No artificial watering was given. On one or several later visits the germinated species were noted on both halves of the plot. Seedling grasses were generally not identified. On most plots the frames were taken up in late autumn of the same year, but on a few plots the frames were kept through the winter. The localities were chosen to cover a very wide range of conditions from town centres to former farmland.

RESULTS AND DISCUSSION

The plant lists from the localities with recently disturbed soil had very many species. Furthermore most of the species were not present in the surrounding area, where conditions prior to the disturbance were unsuitable for them. The same was true for most of the experimental plots. The many species common to the plant lists, the experimental plots and the soil samples, suggest that the seed bank is an important contributor to the earliest stages of successions on disturbed ruderal soils.

Species that have frequently been recorded from disturbed soil and from soil samples are summarized and grouped in Table 5. The table indicates the relative frequency of various species in disturbed ruderal soils in Denmark. However, on other sites and with larger samples the specific composition and relative frequency of species might have been different.

Plant lists at some localities agree well with the germinations from their soil samples, but at others there are discrepancies. The same occurred on covered and uncovered parts of the experimental plots. Table 6 shows, however, that these differences are on the whole being equalized, and they appear to be due to local variations in the seed bank. Covered parts of plots germinated slightly more plants than uncovered parts, which is probably due to a greenhouse effect and to protection from hazards. Of the species in Table 6, only Senecio vulgaris and Taraxacum vulgare appear to have occasionally invaded the plots from outside, while Ulmus glabra appears to have done so invariably. The successional stages on the plots in the second and third year show generally a rapid decline in number and size of non-perennial species.

Suitability of the methods. The frames on the experimental plots have with few exceptions proved satisfactory for protecting the covered part of the plots against invading seeds. Among the species which appeared on the covered part of the plots, only Epilobium montanum, Gnaphalium uliginosum, Sagina procumbens and Stellaria media have seeds measuring less than 0.4 mm across, and so might have entered through the nylon net. The time of their appearance should indicate whether they are contaminants or not. On dry sites exposed to full daylight, the uncovered part of the plots was usually more sparsely populated than the covered part where plants were more vigorous. In the very dry summers of 1969 and 1970 the effect of drought was particularly pronounced on plots established late in summer. On shaded plots, on the other hand, fewer plants appeared in the covered part, and they were weak and died early. The techniques used in the greenhouse were generally satisfactory. One of the main problems was maintaining equal moisture conditions among soils of different textures, but this could be regulated by altering the number of drip feeders. Under frames outdoors, the rock wool substratum made daily watering essential.

The compilation of data. On cultivated soils the uniform mechanical treatment permits estimation of the total seed population because dormant seeds are more or less evenly distributed, cf. Jensen (1969), and Roberts (1970). However, in ruderal soils as in the present study and the case histories in Ødum (1965), the seed bank may vary considerably, both quantitatively and qualitatively even within short horizontal and vertical distances. Any attempt to determine the number of viable seeds of the various species per unit area would therefore be misleading. Even data such as volume or weight of the soil samples investigated give little real information, for the distribution of the seeds in the soil is unknown. These circumstances also restrict the conclusions that can be drawn about differences between the covered and uncovered parts of the experimental plots.

The selective effects of the techniques employed on germination and development of the plants have not been considered. Furthermore, for practical reasons it has not been possible to carry out continuous observations of the plots and soil samples, and consequently some seedlings or plants may have gone unrecorded. The duration of experiments with the soil samples was probably long enough to permit germination of almost all viable seeds present in the soil. All plants appeared within three weeks. Therefore, according to the terminology proposed by Harper (1957), it seems as if enforced dormancy predominated. It may have been desirable to have prolonged the observations on the experimental plots, especially in dry localities. Only a small number of plots were followed into the second and third summer.

The origin of the seed bank. To determine the possible origin of the seeds in the seed bank at each locality would generally be impossible. Anyway, movement of seeds by earthworms, and other soil disturbances, would limit the drawing of correct conclusions. Such movement is clearly evident where seeds from recently introduced weeds are present in old deposits, e.g. Galinsoga parviflora (two instances). Seeds of species growing on or near the investigated localities and seeds from species with effective dispersal (see Table 7) may accumulate continuously where the soil is not covered by buildings, etc. It appears from Table 6 that such species are not numerically important contributors to the seed bank.

The presence of seed of other species would result from either or both of the following possibilities. (1) The seeds were carried to the locality actively or accidentally by various means, perhaps incorporated in soil. (2) The seeds were shed by plants that had grown there after previous disturbance. The last possibility is more likely. In many instances the seed populations faithfully reflect previous known conditions. Where experimental plots have been established close to each other on sites almost equally exposed to seed invasion from outside, marked differences in the results probably do reflect different previous uses.

Longevity aspects and dating possibilities. The composition of the seed bank at most of the localities emphasize that the seeds of many species, especially annuals and biennials, are able to retain their viability for many years when buried in the soil. If those species that occur frequently in stabilized ruderal environments, and that are common species with effective wind dispersal, and that were only recorded at one locality, are omitted, one is left with species whose occurrence in ruderal environments is mainly determined by the longevity of their seeds (Table 8).

The species in Table 7 are not dependent to the same extent on the longevity of their seeds. Even though these species are common on more stable ruderal soils, or are effectively dispersed by wind or birds, their frequency on disturbed soil is probably mainly due to accumulated dormant seeds. Aegopodium podagraria, Anthriscus silvestris, Cirsium arvense, Galium aparine, and many other common ruderal perennials, on the contrary, have short-lived seeds.

A number of rare species the seedlings of which are restricted to disturbed soils would hardly have survived if their seeds were not able to remain dormant in the soil for very long periods. These are, Artemisia absinthium, Conium maculatum, Euphorbia lathyris, Hyoscyamus niger, Leonurus cardiaca, Oenothera biennis, Onopordon acanthium, Verbascum thapsiforme, and V. thapsus, and maybe also Malva spp., and others.

A dating of buried dormant seeds by direct methods would be highly desirable. Sufficient evidence for the longevity of buried seeds might be obtained by radiocarbon dating of seed coats from germinating seeds washed out from well-defined deposits (Godwin 1968). Attempts to obtain enough quantities of dormant seeds for that purpose have not been made during the present period of fieldwork. Nevertheless, considerations based on old-fashioned indirect methods such as observations and experiments with soil samples may lead to the determination of the minimum age of the seeds of some species in certain localities. Indirect datings have been possible on disturbed sites, where the local distribution of a species is clearly determined by horizontal or vertical boundaries representing previous limiting factors or buried surface layers that can be dated archaeologically or geologically. To discover localities where that kind of observation can be made involves, however, a good deal of luck, and definite examples are rare. The distribution of Verbascum thapsus in the excavation of Asmild Bishop House, as described by Ødum (1965), is a good example of this.

In the present investigations the following examples yield a convincing basis for minimum datings of dormant seeds. Table 9 summarizes such datings. Locality Simrishamn in SE-Skåne, Sweden. The church square, SW of the mediaeval church in the centre of Simrishamn, is covered by lawns with trees and walks and surrounded by paved streets and storeyed houses. In 1964 Gustav Åberg, Curator of Österlens Museum in Simrishamn, told me that Hyoscyamus niger had appeared on disturbed soil in the square after pipe-laying. I visited the locality on September 28, 1964, and observed that many rosettes of Hyoscyamus niger were growing on the eastern half of the filled-in excavation, but none at all along the western stretch. The limit of Hyoscyamus was sharply defined, for the density did not decline at the edge. On April 28, 1965 an excavation was made 1 m. south of the limit. It became apparent that the limit corresponded with foundation-stones situated 35-4o cm below the present surface. Gustav Åberg later told me that a cemetery wall was built here before the middle of the 15th century at the latest, at the same time as the church tower, and that it was demolished and the square levelled in 1846 as a new cemetery had been in use since 1835. Soil samples were taken at different depths east and west of the foundation-stones, and only the sample taken inside the foundation-stones from 55-1oo cm below the present surface contained viable *Hyoscyamus* seeds.

Discussion: The seeds of *Hyoscyamus* on the locality must be at least 118 years old, but are probably much older. The local frequency of the *Hyoscyamus* plants on the disturbed soil after the excavation, and the detection of the western limit of its distribution as parallel with the foundation of the wall demolished in 1846, show clearly that the seeds were not shed later on the site. Further, the contents of *Hyoscyamus* seeds in the soil sample taken east of the foundation-stones at a low level verify this fact. Whether the seeds were shed by plants growing inside the cemetery wall, or whether they were buried with people is hard to tell.

Locality Hirsholm. The small island Hirsholm NE of Frederikshavn, Jylland, is the only inhabited island in a little group of islands 6 km from the main-land. A survey of their flora is given by Ødum (1961), and records of some annuals and biennials occurring in excavations and soil samples are given by Ødum (1965). Because of the small size of the island and its well-known history, it was considered suited for further investigations. As there have been very few inhabitants since 1900, most ruderal areas are densely covered by perennials, so many experimental plots were established and many soil samples taken. One locality chosen was an overgrown refuse dump that had not been used since 1936. The amount of refuse indicated that the original surface was buried long ago. The middle and eastern part of the heap was removed in spring 1970.

Vegetation on the undisturbed part was comprised of *Aegopodium podagraria*!, *Agropyron repens*, *Anthriscus silvestris*!, *Cirsium arvense*, *Convolvulus arvensis*! and *Urtica dioeca*!. (! = common or dominant.) Plant-list from the disturbed soil, max. depth 8o cm below the top of the heap, July 21, 1970, was *Chenopodium album*!, *Euphorbia peplus*, *Geranium pusillum*, *Hyoscyamus niger*!, *Lamium amplexicaule*, *Malva neglecta*, *M. silvestris*, *Medicago lupulina*, *Papaver somniferum*, *Polygonum convolvulus*, *Sisymbrium officinale*, *Sonchus oleraceus*!, *Stellaria media*, *Taraxacum vulgare*, *Verbascum thapsus*.

Soil. The 8o cm section through the heap showed alternating layers of sand and refuse including much *Zostera*, probably mattress filling. At the bottom, sandy soil without refuse, indicating the original soil surface. Soil samples were taken behind the profile surface (July 22nd 1970) at 1: 10-15 cm, 2: 35-55 cm, 3: 80-100 cm.

Experimental plots were established July 22, 1970. Upper plot: on the top of the heap, 30 cm behind the surface. Lower plot: at base of the cross-section after removal of 5-10 cm soil.

Table 1. Result of soil samples Sept. 18, 197o.

	1	2	3
Artemisia vulgaris	2		
Chenopodium album	2		
Hyoscyamus			12
Malva silvestris	1		

(Table 1. continued)

	1	2	3
Urtica dioeca	many	14	3
Grass	2		

Table 2. Result on the plots Oct. 7, 1970 (+ = few plants, ++ = many plants)

Upper plot	+ net	– net
Chenopodium album	+	
Malva silvestris	+	+
Urtica dioeca	+	+
Lower plot	**+ net**	**– net**
Hyoscyamus niger	++	++
Malva neglecta	+	+
Stellaria media		+
Urtica dioeca	+	+

Discussion: Seeds of Hyoscyamus were present in the lowest soil sample only, and many germinated with Malva neglecta in the lower plot. The soil on that level was surface soil before the area was used as a dump. The area has remained undisturbed since 1936, and considering that the layer of refuse is very thick, it is not unreasonable to assume these seeds are at least 6o years old. They are probably much older.

Locality Vesborg. Above a steep cliff at the SW coast of the island Samsø stands the remains of the mediaeval fortification Vesborg. It was probably abandoned and pulled down before 1400, and most of the buildings have fallen into the sea. A part of a wall is still to be seen in the cliff. The unused area between the lookout station of the lighthouse and the cliff is covered by a closed vegetation dominated by Anthriscus silvestris, Avena elatior, Festuca rubra, Knautia arvensis, Plantago lanceolata and Ranunculus bulbosus. Around the lookout station the vegetation is kept cut.

Observations, June 1, 1969: in 1968 a barbed wire fence had been set up along the upper edge of the cliff. On the disturbed soil around almost all of the fencing posts many rosettes of Onopordum acanthium were growing. By July 14, 1970 the Onopordum plants were flowering and the soil around the posts was covered by grass. Only a single weak Onopordum rosette had appeared by one of the posts.

Soil samples. A. At the experimental plot June 1, 1969, A_1: 3–1o cm, brown sandy soil. A_2: 2o–4o cm, light brown soil or filling. B. 1 m from the pole farthest to the west, July 14, 197o, B_1: 3–15 cm, soil and filling. B_2: 15–35 cm, filling. B_3: 35–65 cm, filling with rubble. Experimental plot established June 1, 1969, 6 m N of the fence.

Table 3. Result of the soil samples. A: July and Aug. 1969. B: Sept. and Oct. 197o

	A_1	A_2	B_1	B_2	B_3
Arenaria serpyllifolia			1	2	
Artemisia vulgaris			1		
Atriplex patula	3		9	1	

(Table 3. continued)	A_1	A_2	B_1	B_2	B_3
Capsella bursa-pastoris			2		
Cerastium casepitosum	6				
Daucus carota	1				
Juncus bufonius	1				
Lathyrus sp.	5				
Malva silvestris				1	1
Medicago lupulina				1	
Onopordum acanthium					6
Rumex acetosella		4			
Taraxacum vulgare			1		
Veronica hederifolia	2				

Result on the plot. Aug. 23, 1969: on the covered part Atriplex patula, Lathyrus sp., Sonchus asper and Trifolium repens; on the uncovered part Achillea millefolium, Lathyrus sp. and Trifolium repens. In July 1970 it was covered by grasses and Convolvulus arvensis, Centaurea scabiosa and Taraxacum vulgare.

Discussion: the appearance of the many Onopordum plants around the deeply-placed poles and the fact that the seeds are present in deep-lying deposits only, and not in the upper samples or in the more superficial plot, indicate that the seeds are at least 55o years old.

Locality Uggeløse. The mediaeval church in the village Uggeløse in N Sjælland is situated on top of a sandy hill. During the summer of 1970 the National Museum carried out archaeological excavations under the church floor. From a mediaeval grave under the floor in the tower a sample of sandy grave-filling was taken on May 16, 1971, at a depth of $1\frac{1}{2}$ m. The grave is dated to the 11th century and has not been disturbed since then. By July 20,1970,a single plant of Verbascum thapsiforme had germinated.

Discussion: the deep-lying and well-protected soil from where the sample was taken certify that the viable Verbascum thapsiforme seed is at least 850 years old.

Locality Jægersborg Dyrehave, Fortunens Indelukke. This is in a forest north of Copenhagen. On the 17th of October 1967 a hurricane blew down a 91 year-old plantation of Fagus silvatica mixed with a few Quercus robur and Larix decidua. The trees were 24-28 m high. After the most valuable timber had been taken out, the area was left undisturbed for studies on plant succession. On a northern slope with sandy subsoil, numerous Calluna vulgaris plants appeared in 1968. The nearest known locality of Calluna is 6 km away. Their pattern of distribution was remarkable for they were restricted to the inclined surface of the tipped stumps exposed to erosion, and to the margins of the stumps and stump-holes. In 1969 and 1970 many Calluna plants flowered and produced seeds. By 1971 most of the plants were very weak or shaded to death by dense growth of Betula verrucosa, B. pubescens, Sambucus racemosa and Rubus idaeus.

Soil samples:

A. July 17, 1969. After removal of about 5 cm Fagus litter and Fagus moor a 2 kg sample of sand with humus was taken. Result in Sept. 1969: a great number of Calluna seedlings.

B. July 17, 1969. A 15 cm thick and 30 cm high block of soil was taken up, placed on one side, and scraped clean of loose particles. Result in Sept.

1969: 1 Calluna seedling had appeared from a depth of 12 cm.

C. A continuous series of samples was taken on June 3, 1970, from an undisturbed place. C_1. 0–2 cm, 1200 g. Partly decomposed litter, mainly Fagus leaves. C_2. 2–4 cm, 1400 g. Fagus peat (moor) with scattered grains of sand. C_3. 4–7 cm, 2300 g. Sand with humus. C_4. 7–13 cm, 2900 g. Sand with humus. C_5. 13–23 cm, 24oo g. Sand with humus, getting lighter downwards.

Table 4. Results Sept. 8, 1970

	C_1	C_2	C_3	C_4	C_5
Arenaria trinervia	1				
Calluna vulgaris			7	5	
Carex pilulifera	2	1	3	2	
Juncus bufonius				1	
J. effusus		1	1		
Stellaria media				1	
Veronica officinalis			2		
Grass	3				

Discussion: a few years after the establishment of the Fagus plantation the Calluna, if present, was undoubtedly shaded out. The Calluna seeds are therefore at least 80 years old. The distribution pattern of Calluna and the presence of seeds in the soil samples from beneath the Fagus moor confirm this. A map of 1764 shows that the area was then treeless and grazed, and Calluna was probably at that time a component of the vegetation.

In addition to these more certain datings, the minimum age of seeds of some species at other localities can be estimated, see Table 10. Longevity of seeds seems to be the most obvious explanation of the appearance of the plants. The circumstances of dating these are abandoned farmland, gardens or settlements, now covered by woodland or closed perennial vegetation, soil samples from under old or demolished houses of known age and the last excavation of mounds or restoration of ruins, etc.

On many other of the investigated localities, the minimum age of seeds germinating from soil samples or on disturbed soil is less certain. The evidence always seems strongest for species that can rarely if ever have met favourable conditions of growth at the localities. The abundance of seeds of non-perennial species which, for instance, are found in the soil on Hirsholm (mentioned above) may have been produced and buried during the period 1680–1880 when the island was inhabited by about 200 people. The soil surface and vegetation was probably then more unstable. Today only 10–15 people are living on the island.

CONCLUDING REMARKS

The results of tests on buried seeds (Madsen 1962, Toole & Brown 1946, and Darlington & Steinbauer 1961) show that the rate at which viability is lost varies from species to species, and maybe from strain to strain. There are marked differences between species in the proportion of their seeds that are long-lived. The proportion is obviously large in seeds of Verbascum thapsus, Onopordum acanthium, Datura stramonium and Solanum nigrum, while it is small in Brassica campestris, Medicago lupulina and Trifolium repens. The occurrence of biologically different groups in the seeds of Chenopodium album has been described by Williams & Harper (1965). The local abundance occasionally met with in some localities, of Verbascum thapsus, Onopordum acanthium and Hyoscyamus niger, may well reflect the occurrence of large proportions of long-surviving seeds.

To the range of plant life forms might be added that of "seed survivor". In the concepts and terminology of pioneer vegetation and colonizing species, "seed survivors" and "invaders" should be clearly distinguished. Among the transitory species or strains of species occurring in unstable environments, the "seed survivor" type of life form obviously exists, and may have developed as a physiologically-adapted ecotype which guards against local extinction for decades or even centuries. A considerable longevity of a proportion of the seeds, together with self-compatibility and plasticity in individual size and reproductive capacity are probably the most vital biological characteristics of the majority of species that compose the earliest stages of plant succession on disturbed ruderal soils.

Alien species are constantly being introduced, and of the transitory species which lack effective seed-dispersal, the length of life of their seeds will probably determine whether they can become fully established in ruderal environments.

The biology of seeds, the composition of the seed bank, and the character of present and previous mechanical disturbances, together with other known and unknown historical circumstances, seem to be the factors which determine the vegetation of a given ruderal habitat. These factors therefore have to be considered when attempts are made to interpret ecological, phytosociological and phytogeographical influences in ruderal, and possibly other, unstable environments.

In a climatically humid region like Denmark the ruderal communities are, from an ecological and phytosociological point of view, to be regarded as discontinuous dynamic systems, where more or less stabilized vegetation patterns are covering a rather different and unpredictable "potential vegetation" in the form of dormant seeds, which may manifest itself as temporary eruptions.

References

DARLINGTON, H.T. & STEINBAUER, G.P. (1961) The eighty-year period for Dr. Beals seed viability experiment. American Journal of Botany, 48, 321-325.

GODWIN, H. (1968) Evidence for longevity of seeds. Nature, 22o, 708-709.

GUYOT, L. (196o) Sur la présence dans les terres cultivées et incultes de semences dormantes des espèces adventices. Bulletin du Service de la Carte Phytogéographique, Series B, 5, 197-254.

HARPER, J.L. (1957) The ecological significance of dormancy and its importance in weed control. Proceedings 4th international Conference of Plant Protection, Hamburg, 415-420.

HARPER, J.L. (1960) Factors controlling plant numbers. The Biology of Weeds, Symposium of British Ecological Society, 119-132.

JENSEN, H.A. (1969) Content of buried seeds in arable soil in Denmark and its relation to the weed population. Dansk Botanisk Arkiv, 27, 2.

LIVINGSTONE, R.B. & ALESSIO, M.L. (1968) Buried viable seed in successional field and forest stands, Harvard Forest, Massachusetts. Bulletin Torrey Botanical Club, 95, 58-69.

MADSEN, S.B. (1962) Germination of buried and dry stored seeds, III, 1934-60. Proceedings international Seed Testing Association, 27, 920-928.

ØDUM, S. (1961) Hirsholmenes vegetation. Botanisk Tidsskrift, 57, 53-61.

ØDUM, S. (1965) Germination of ancient seeds. Floristical observations and experiments with archaeologically dated soil samples. Dansk Botanisk Arkiv, 24, 2.

OLSEN, O. B. (1970) Stenuld som dyrkningssubstrat. Gartnertidende, 87, 115-116.

ROBERTS, H.A. (1970) Viable weed seeds in cultivated soils. Report National Vegetable Research Station 1969, 25-38.

SAGAR, G.R. (1970) Factors controlling the size of plant populations. Proceedings 10th British Weed Control Conference, 965-979.

THURSTON, J.M. (1960) Dormancy in weed seeds. The Biology of Weeds (ed. J.L. Harper), Symposium of British ecological Society, 69-82.

TOOLE, E.H. & BROWN, E. (1946) Final results of the Duvel buried seed experiment. Journal of Agricultural Research, 72, 201-210.

WILLIAMS, J.T. & HARPER, J.L. (1965) Seed polymorphism and germination. I. The influence of nitrates and low temperatures on the germination of *Chenopodium album*. Weed Research, 5, 141-150.

Table 5. The number (from five upwards) out of 152 localities at which each species has been recorded. Grasses are not included. ! = Species frequent on at least 1/4 of the localities, and ! ! on at least 1/3 of the localities, when present on 10 localities or more.

On 5-9 localities:

Acer pseudoplatanus, Artemisia absinthium, Brassica campestris, Carex muricata, Chenopodium glaucum, Chrysanthemum parthenium, Epilobium hirsutum, Glechoma hederacea, Lappa minor, Linaria minor, Lycopersicum esculentum, Melandrium album, Potentilla reptans, Sisymbrium altissimum, Spergula arvensis, Tanacetum vulgare, Thlaspi arvense, Tussilago farfara, Verbascum thapsiforme, Veronica hederifolia.

On 10-19 localities:

Achillea millefolium, Anagallis arvensis, Anchusa arvensis, Anthriscus silvestris, Arenaria serpyllifolia, Artemisia vulgaris, Ballota nigra, Chamaenerion angustifolium, Chenopodium hybridum !, Chenopodium polyspermum !!, Chenopodium rubrum, Erigeron canadensis, Galeopsis tetrahit, Galinsoga parviflora, Geranium molle, Geranium pusillum, Gnaphalium uliginosum, Juncus bufonius, Lamium amplexicaule, Oxalis stricta, Panicum sp., Papaver somniferum, Plantago lanceolata, Rumex crispus, Sagina procumbens, Sinapis arvensis, Sisymbrium sophia, Sonchus asper, Stachys silvatica, Trifolium pratense, Ulmus glabra, Verbascum nigrum, Verbascum thapsus, Vicia angustifolia.

On 20-29:

Atriplex patula!!, Cerastium caespitosum, Chelidonium majus!!, Epilobium montanum, Euphorbia helioscopia, Lamium album !, Malva neglecta !!, Myosotis arvensis, Papaver dubium, Veronica persica.

On 30-39:

Carduus crispus, Fumaria officinalis, Hyoscyamus niger!, Matricaria matricarioides, Polygonum persicaria, Ranunculus repens, Rumex obtusifolius, Sambucus nigra, Sisymbrium officinale, Urtica urens, Viola arvensis.

On 40-49:

Artemisia vulgaris, Lamium purpureum, Lapsana communis, Malva silvestris, Matricaria inodora, Medicago lupulina, Polygonum convolvulus, Senecio vulgaris, Trifolium repens.

On 50-59:

Plantago major, Polygonum aviculare, Sonchus oleraceus.

On 60-69:

Aethusa cynapium !!, Capsella bursa-pastoris, Euphorbia peplus !, Solanum nigrum !

On 70-79:

Stellaria media, Taraxacum vulgare, Urtica dioeca !!

On 100–109:

Chenopodium album !!

<u>Table 6. This table is based on the data from 60 localities</u> (a total of 52 plots and 36 soil samples). It indicates how many times a species has been recorded from a covered and an uncovered part of a plot and from a soil sample. ( ) indicates that the species formed part of the vegetation on or around the locality in question. Species recorded less than 4 times are not included.

	plots + net	plots ÷ net	Soil samples
Aethusa cynapium	12	8	8
Anagallis arvensis	5	4	1
Anchusa arvensis	5	7	2
Anthriscus silvestris	(5)	(6)	(1)
Arenaria serpyllifolia		2	2
Artemisia absinthium	2	1	2
Artemisia vulgaris	9+(6)	6+(4)	2+(3)
Atriplex patula	6	5	1
Ballota nigra	4+(2)	4+(2)	1
Capsella bursa-pastoris	11	11	5
Carduus crispus	8	5	4
Carex muricata		1	2+(1)
Cerastium caespitosum			5
Chelidonium majus	7+(3)	8+(3)	4+(3)
Chenopodium album	25	24	17
Chenopodium hybridum	1	2	1
Chrysanthemum segetum	3	3	
Epilobium montanum	5	5	1+(1)
Euphorbia helioscopia	4	4	
Euphorbia peplus	19	15	8
Fumaria officinalis	1	2	5
Galeopsis tetrahit	4+(1)	6	1
Galinsoga parviflora	2	2	
Galium verum	(1)	(1)	1+(2)
Geranium molle	5	5	2
Glechoma hederacea	(2)	(1)	1
Gnaphalium uliginosum	6	5	3
Hyoscyamus niger	5	5	5
Juncus bufonius	1	1	4
Lamium album	4+(6)	2+(5)	(2)
Lamium amplexicaule	3		2
Lamium purpureum	17	13	2
Lappa minor	2	3	
Lapsana communis	20+(1)	17+(1)	8+(1)
Leonurus cadiaca	2	2	2
Malva neglecta	5	5	5
Malva silvestris	16	15	9

	plots + net	plots ÷ net	Soil samples
Matricaria inodora	9	7	4
" matricarioides	5	5	2
Medicago lupulina	9	4	3+(1)
Myosotis arvensis	8	7	3
Onopordum acanthium	2	2	1
Oxalis stricta	6	3	
Plantago lanceolata	2	2	1+(1)
Plantago major	7+(1)	4+(1)	7+(2)
Polygonum aviculare	4	8	7
Polygonum convolvulus	5	5	6
Polygonum persicaria	5	6	
Potentilla reptans	1+(1)	2	(3)
Ranunculus repens	5+(6)	6+(5)	6+(4)
Rubus idaeus	2	1	1
Rumex crispus	2+(1)		2+(1)
Rumex obtusifolius	4+(5)	6+(1)	5+(2)
Sagina procumbens	1		5
Sambucus nigra	5+(4)	4+(4)	
Senecio vulgaris	2	5	1
Sinapis arvensis	6	5	1
Sisymbrium officinale	4	3	5
Solanum nigrum	12	12	9
Sonchus oleraceus	11	7	6
Spergula arvensis	2	2	1
Stachys silvatica	2+(4)	2+(2)	1
Stellaria media	13	11	8+(2)
Taraxacum vulgare	9+(10)	13+(10)	2+(5)
Thlaspi arvense	2	3	1
Trifolium repens	2+(1)	2+(2)	1+(1)
Ulmus glabra		(10)	
Urtica dioeca	2+(23)	3+(23)	7+(16)
Urtica urens	6	4	3+(1)
Verbascum nigrum	1+(1)	1+(1)	(1)
Veronica persica	7	7	4
Vicia angustifolia	5	2	6
Viola arvensis	5	8	2

Table 7. Common species from rather stable ruderal communities and species with effective wind dispersal whose dormant seeds obviously accumulate in the soil

Artemisia vulgaris	Poa pratensis
Ballota nigra	Polygonum aviculare
Cerastium caespitosum	Potentilla reptans
Chelidonium majus	Ranunculus repens
Epilobium montanum	Rubus idaeus
Glechoma hederacea	Rumex crispus
Gnaphalium uliginosum	Rumex obtusifolius
Lamium album	Sagina procumbens
Matricaria matricarioides	Sambucus nigra
Medicago lupulina	Sonchus oleraceus
Plantago lanceolata	Stellaria media
Plantago major	Taraxacum vulgare
Poa annua	Trifolium repens
	Urtica dioeca

Table 8. Species, whose presence in the investigated disturbed ruderal environments is supposed to be due mainly to the longevity of their seeds.

Aethusa cynapium	Euphorbia helioscopia	Onopordum acanthium
Anagallis arvensis	Euphorbia peplus	Oxalis stricta
Anchusa arvensis	Fumaria officinalis	Panicum spp.
Arenaria serpyllifolia	Galeopsis tetrahit	Papaver dubium
Artemisia absinthium	Galinsoga ciliata	Papaver rhoeas
Artemisia vulgaris	Galinsoga parviflora	Papaver somniferum
Atriplex patula	Geranium molle	Phytolacca americana
Ballota nigra	Geranium pusillum	Polygonum convolvulus
Brassica campestris	Hyoscyamus niger	Polygonum persicaria
Bryonia alba	Juncus bufonius	Sinapis arvensis
Buddleia davidii	Lamium amplexicaule	Sisymbrium altissimum
Calendula officinalis	Lamium purpurea	Sisymbrium officinale
Carduus acanthoides	Lapsana communis	Sisymbrium sophia
Carduus crispus	Leonurus cardiaca	Solanum nigrum
Cerastium caespitosum	Linaria minor	Spergula arvensis
Chelidonium majus	Lycopersicum esculentum	Stachys silvatica
Chenopodium album	Malva moschata	Stellaria media
Chenopodium glaucum	Malva neglecta	Thlaspi arvense
Chenopodium hybridum	Malva pusilla	Trifolium repens
Chenopodium polyspermum	Malva silvestris	Urtica urens
Chenopodium rubrum	Matricaria inodora	Verbascum nigrum
Chrysanthemum leucanthemum	Medicago lupulina	Verbascum thapsiforme
Chrysanthemum parthenium	Melandrium album	Verbascum thapsus
Chrysanthemum segetum	Melissa officinalis	Veronica persica
Conium maculatum	Myosotis arvensis	Vicia angustifolia
Diplotaxis muralis	Oenothera biennis	Viola arvensis

Table 9. The minimum age of dormant seeds attributed on the basis of convincing distribution patterns or other pertinent data, cf. text.

Calluna vulgaris	8o years	Papaver somniferum	1oo years
Chenopodium album	25o "	Sarothamnus scoparius	8o "
Hyoscyamus niger	16, 118 and 25o years	Spergula arvensis	25o "
Malva neglecta	6o years	Trifolium repens	25o "

(Table 9. continued)

Malva neglecta/silvestris	loo years	Verbascum thapsiforme	85o years
Onopordum acanthium	55o "	Verbascum thapsus	65o "

Table lo. The probable minimum age of seeds from 2o years upwards, cf. text.

Aethusa cynapium	25	Matricaria inodora	2o, 25
Anagallis arvensis	2o, 3o, 15o	Medicago lupulina	2o, 25, 3o, 8o
Anchusa arvensis	2o, 3o, 15o	Melandrium album	7o
Artemisia absinthium	7o	Melissa officinalis	3oo
Artemisia vulgaris	3o, 92	Myosotis arvensis	3o
Bryonia alba	3oo	Oenothera biennis	3o
Calendula officinalis	3o	Oxalis stricta	25
Carduus crispus	2o, 25, 3o, 4o	Papaver dubium	5o
Cerastium caespitosum	92	Papaver somniferum	3o
Chenopodium album	2o, 3o, 5o, 8o, 15o, 3oo, 6oo	Plantago major	3o
Chenopodium glaucum	loo	Polygonum aviculare	2o
Chenopodium polyspermum	2o, 3o, 8o	Polygonum convolvulus	3o, 5o, 3oo
Conium maculatum	5o, 15o	Polygonum persicaria	3o, 3oo
Euphorbia helioscopia	3o	Ranunculus repens	8o
Euphorbia peplus	2o, 25, 3o, loo	Sinapis arvensis	2o, 25, 8o
Fumaria officinalis	25, 6oo	Sisymbrium officinale	3o
Galeopsis tetrahit	25, 3o	Sisymbrium sophia	2o, 3o
Galinsoga parviflora	2o	Solanum nigrum	2o, 5o, 8o
Geranium molle	3o	Sonchus oleraceus	15o
Geranium pusillum	2o, 3o	Spergula arvensis	3o
Gnaphalium uliginosum	2o, 3o, loo	Stellaria media	2o, 3o, 92
Hyoscyamus niger	2o, 4o, 45, 7o, 75, 15o, 25o	Urtica urens	2o, 5o, loo
Juncus bufonius	3o, 3oo	Verbascum nigrum	25, 3o, loo
Lamium amplexicaule	25, 3o	Verbascum thapsiforme	loo, 5oo
Lamium purpureum	2o, 3o	Verbascum thapsus	3o, 4o, 15o
Linaria minor	3oo	Veronica arvensis	3o
Malva neglecta	7o, 15o	Veronica persica	2o
Malva silvestris	2o, 25, 3o, 15o	Veronica serpyllifolia	3o
		Vicia angustifolia	2o
		Viola arvensis	3o, 3oo

Proceedings 12th British Weed Control Conference (1974)

EFFECT OF LONG-TERM WEED CONTROL MEASURES ON VIABLE WEED SEEDS IN THE SOIL

K. Hurle

Abteilung für Herbologie, Universität Hohenheim, 7 Stuttgart 70, Federal Republik of Germany.

Summary The numbers of viable weed seeds were determined in the soil of plots of a field experiment in which 12 consecutive years of various annual weed control measures in cereals had been carried out. The reduction in total weed seeds by the different control measures was in the order: DNOC > 2,4-D > calcium cyanamide ≈ MCPA > "rotation" > harrow. "Rotation" was a rotation of MCPA, DNOC, calcium cyanamide, and harrowing. The species composition of weed seeds in the soil reflects the effectiveness of the different control measures on the weed species present. The changes in the relative abundance of viable seeds of individual species in the soil are given. Observations were made on malformed seedlings emerging from soil of the MCPA and 2,4-D-treated plots and the possible reasons for them are discussed.

INTRODUCTION

The soil is a great reservoir of weed seeds and the main source of weed infestations. Weed control in crops, especially with suitable applications of herbicides, reduces the number of weeds so that only a few of them escape and develop seeds or other propagules. Species that are not affected by the weed control measure, however, may develop with time into a severe infestation. This causes the well-known shifts in the weed flora, which occur particularly when the same type of herbicide is used for a long period. The amount of weed seeds in the soil is therefore influenced by the weed control measure, the influence depending upon its effectiveness. This effect may be relatively small if the control measure is only carried out from time to time, for there are large numbers of seeds present in the soil (seldom 5,000, up to 300,000 seeds/m^2; see Kropáč, 1966; Koch, 1969; Roberts, 1970), and the seeds of many weed species are relatively long-lived. However, when weed control is carried out every season, as it is in many crops, the control measure will reduce the amount of seed. Although complete exhaustion of weed seeds can not be expected, a reduction may be of some value in limiting weed infestations.

The purpose of the work reported here was to demonstrate the effects of different cereal weed control measures applied annually for twelve years on the viable weed seeds in the soil. The occurrence of malformed seedlings, obviously caused by the previous use of herbicides, is also reported on.

METHOD AND MATERIALS

The soil, a sandy loam, was taken from an experimental field of the University of Hohenheim, Stuttgart, Germany, where spring cereals had been grown since 1957; with the exception of 1957, 1959, and 1962 when winter cereals were grown.

Size of plots was 10 x 5 m and each treatment was replicated four times.

The following weed control measures were applied annually to the same plots at the optimal time: (1) No weed control. (2) MCPA-dimethylamine, 1.5 l/ha U 46 M Fluid, 48% a.i. (3) 2,4-D-dimethylamine, 1.5 l/ha U 46 D Fluid, 49% a.i. (4) DNOC, 4 kg/ha Raphatox, 50% a.i. (5) Calcium cyanamide, 143 kg/ha. (6) "Rotation", i.e. a rotation of MCPA, DNOC, calcium cyanamide and harrowing; the last in 1968. (7) Harrowing.

Five cubes of soil, 20 x 20 cm to a depth of 25 cm, i.e. the depth of ploughing were taken in 1968 after harvest from each plot. The samples from each plot were bulked, thoroughly mixed and then carefully sieved. Five sub-samples consisting of 2.1 kg (d.wt) were transferred to shallow pots (25 x 25 cm, depth of soil c. 5 cm) giving 20 pots per treatment. The pots were kept in the greenhouse most of the time (mean temp. 20°C) and the seedlings were identified and recorded on emergence. The soil was disturbed periodically, and to enhance germination the pots were exposed to lower temperatures (5 to -12°C) and to periods of dryness. The experiment was terminated after four years, when seedling emergence had virtually ceased.

RESULTS

(1) Changes of weed seed populations in the soil

All weed control measures reduced the number of viable weed seeds in the soil (Table 1). DNOC had the greatest effect, reducing the number of seedlings to 40%, and 2,4-D, calcium cyanamide, and MCPA reduced it to about 2/3 of the untreated control. The "rotation" treatment and harrowing had least effect.

The effect of the different treatments on the presence of seeds of the prevalent species parallels their effectiveness in controlling these weeds (Table 2). In the soil of the MCPA and 2,4-D plots *Sinapis arvensis*, and *Thlaspi arvense* were reduced to a similar extent, while 2,4-D gave a greater reduction of *Lamium purpureum*. In soil from the DNOC treatment *S. arvensis*, *L. purpureum*, *Stellaria media* and *T. arvense* were greatly reduced. The DNOC treatment also had most influence on the occurence of the dominant species, *Veronica persica*. Calcium cyanamide reduced the number of *V. persica*, and also reduced the amount of *S. arvensis*, *S. media* and *L. purpureum* seeds. In the "rotation" treatment only *T. arvense* was significantly reduced. Harrowing had little effect on any of the species.

In Table 3 all species which occurred are listed and their relative abundance in the soil of the different treatments is given so that the shift in species composition can be seen. *V. persica* which was the most frequent species in the control plots, remained so under all treatments with the exception of DNOC. *Sinapis arvensis* was generally reduced: to the greatest extent by the phenoxy herbicides and least by harrowing. *T. arvense* remained the same in the "rotation" treatment and in harrowed plots. It was reduced by MCPA and 2,4-D; but in the DNOC and the calcium cyanamide treatments, seeds of this species increased relatively, and in the DNOC-treated plots it became the most frequent species. The propor-

Table 1

Effect of 12 consecutive years of annual weed control measures in cereals on the total number of viable weed seeds in the soil

Treatment	Viable weed seeds per m^2 (related to 25 cm depth of ploughing)	
	Total	Percentage of No weed control
No weed control	43 778	100
MCPA	27 820	64
2,4-D	24 596	56
DNOC	17 712	40
Calcium cyanamide	26 764	61
"Rotation"	34 159	78
Harrow	37 778	68

tion of Rumex crispus was reduced in the MCPA and 2,4-D plots, but increased portionally in the DNOC ones. The relative abundance of S. media and L. purpureum did not change much but Matricaria recutita increased relatively, particularly in the MCPA plots. Because of the low numbers obtained for the other species, no conclusions can be drawn from their occurrence.

(1.1) Malformation of seedlings in the soil treated with 2,4-D and MCPA

At nearly every assessment from the beginning of the experiment some seedlings of V. persica, Sinapis arvensis, and Polygonum convolvulus in the soil of the MCPA and 2,4-D plots, were deformed. V. persica had connate cotyledons, P. convolvulus had funnel-shaped first true leaves and Sinapis arvensis had fused funnel-shaped cotyledons. Such plants usually died one or two weeks after emergence. These effects were observed only in the soil of the phenoxy herbicide treatments and only in these three species.

In a separate experiment soil was taken from the control plot and different concentrations up to 1 ppm (w/w) of 2,4-D and MCPA were added. Some seedlings of the three species, but not all, showed similar symptoms to those of deformed plants from the field plots. When the experiment was terminated after nine weeks malformed plants were still emerging.

DISCUSSION

The data presented here have been obtained by counting seedlings as they emerge and therefore cannot represent the real total number of viable seeds in the soil. The numbers of some species are certainly underestimated, even though the experiment was run for four years. The statistical variance of the data is also restricting to the conclusions.

Table 2

Effect of 12 consecutive years of annual weed control measures in cereals on the level of weed seed in the soil of the most frequent weed species (> 1 000 viable seeds per m^2). "No weed control" = 100%

Species	MCPA	2,4-D	DNOC	Calc. cyan.	"Rotation"	Harrow
Veronica persica	85	85	20[a]	64[b]	91	72
Sinapis arvensis	9[c]	6[b]	16[c]	24[c]	28	58
Thlaspi arvense	37[a]	34[a]	62[b]	102	76[b]	98
Rumex crispus	8	9	74	45	71	95
Stellaria media	90	99	55[b]	37[b]	86	81
Lamium purpureum	64	43[c]	29[b]	34[b]	73	103
Matricaria recutita	282	98	91	83	138	159

Values marked with a, b, and c are significantly different from "no weed control" at the 1%, 5%, and 10% level respectively.

Table 3

Relative abundance of viable weed seeds in the soil after 12 consecutive years of annual weed control measures (total number of seeds in each treatment = 100)

Species	No weed control (%)	MCPA (%)	2,4-D (%)	DNOC (%)	Calc. cyan. (%)	"Rotation" (%)	Harrow (%)
Veronica persica Poir.	35,9	48,3	54,2	17,6	37,4	41,8	30,1
Sinapis arvensis L.	17,2	2,4	1,7	7,0	6,6	6,2	11,6
Thlaspi arvense L.	16,8	9,8	10,2	25,8	28,0	16,4	19,1
Rumex crispus L.	7,1	+	1,1	12,9	5,2	6,5	7,8
Stellaria media (L.) Vill.	5,7	8,1	10,1	7,8	3,4	6,3	5,3
Lamium purpureum L.	5,5	5,5	4,2	3,9	3,0	5,1	6,5
Matricaria recutita L.	3,6	15,8	6,2	8,1	4,9	6,3	6,6
Poa annua L.	1,2	+	3,2	4,6	1,7	2,0	1,3
Polygonum persicaria L.	1,2	1,8	1,4	1,0	+	1,2	+
Sonchus arvensis L.	1,1	3,1	2,3	2,1	2,0	2,5	1,8
Vicia tetrasperma (L.) Schreb.	1,0	+	+	1,3	2,2	2,0	3,4
Vicia hirsuta (L.) S.F. Gray	+	+	+	+	1,3	1,1	+
Alopecurus myosuroides Huds.	+	1,0	2,3	4,1	1,6	1,0	2,0
Chenopodium album L.	+	+	+	+	+	+	+
Polygonum convolvulus L.	+	+	+	+	+	+	+
Capsella bursa-pastoris (L.) Med.	+	+	+	+	+	+	+
Papaver rhoeas L.	+	+	+	+	+	+	+
Galium aparine L.	+	+	1,4	+	+	+	+

Table 3 cntd

Relative abundance of viable weed seeds in the soil after 12 consecutive years of annual weed control measures (total number of seeds in each treatment = 100)

Species	No weed control (%)	MCPA (%)	2,4-D (%)	DNOC (%)	Calc. cyan. (%)	"Rotation" (%)	Harrow (%)
Geranium dissectum L.	+	+	+	+	+	+	+
Fumaria officinalis L.	+	+	+	+	-	+	+
Senecio vulgaris L.	+	+	+	+	+	-	+
Myosotis arvensis (L.) Hill	+	+	-	+	-	+	+
Atriplex patula L.	-	+	+	+	-	+	+
Plantago sp.	-	-	+	+	+	-	+
Polygonum aviculare L.	-	+	-	+	-	-	+
Ranunculus arvensis L.	+	-	-	-	-	+	+
Vicia angustifolia (L.) Gaud.	+	-	-	-	+	-	+
Avena fatua L.	+	-	-	-	-	+	+
Cirsium arvense (L.) Scop.	-	-	-	+	-	-	+
Veronica hederaefolia L.	-	-	+	-	-	-	-
Viola tricolor L.	-	-	+	-	-	-	-
Apera spica-venti (L.) Beauv.	+	-	-	-	-	-	-
Galeopsis tetrahit L.	-	-	+	-	-	-	-
Rumex obtusifolius L.	-	-	+	-	-	-	-
Lithospermum arvense L.	-	-	-	-	-	-	+
Unidentified	+	+	-	+	+	+	+

+ stands for: respective species $<1\%$, - stands for: species not present

However, despite these limitations, this method may be regarded as appropriate for a comparison of the influence of different weed control measures on the numbers of viable seeds in the soil.

The total number of viable weed seeds in the soil where no weed control has been carried out for 12 years may be regarded as a moderate infestation. The effect of the different treatments on the total number of seeds in the soil was much as expected, considering the composition of the weed flora and the relative effectiveness of the various control measures. However, the effect of the sequence of different treatments in the "rotation" treatment was lower than expected, demonstrating that one weak link (harrowing) enabled more plants to survive than with other treatments and consequently more seeds were added to the soil, thereby diminishing the effect of the previous control measures.

The changed weed seed populations in the soil show the potential for future weed infestations. Species relatively abundant after 12 years of treatment supposedly will keep or even increase their relative magnitude in the weed flora under the same cropping conditions. It is a challenging task to undertake a prediction of the future weed infestation as has been done by Rademacher et al. (1970) for this field experiment on the basis of annual weed counts. The tendency in the composition of the weed population as shown by Rademacher is about the same as shown by the data presented here, except in case of Cirsium arvense whose seeds in the soil do not of course represent its potential in the weed flora of the experiment. However, if the abundance of the different weed species, as recorded in only one year are compared with the total number of their viable seeds actually present in the soil, there are great differences. This can be demonstrated by the effects of weed control measures in 1968 when the order of weed frequency was quite different from that of seeds present in the soil: MCPA > 2,4-D > DNOC > "rotation" > calcium cyanamide > harrow. The relative abundance of the individual weeds was also somewhat different from that of their seeds in the soil, in fact the number of counted weeds represented only c. 1% of the total viable seeds in the soil. This clearly demonstrates that "the plants actually growing in a field represent only the tip of the iceberg" as Roberts (1970) has pointed out.

The malformations of V. persica, Sinapis arvensis, and P. convolvulus seedlings occurring in the soil of the MCPA and 2,4-D plots must have been caused by these herbicides, for no similar plants were observed in the soil of the other treatments. For an explanation of this phenomenon there are two possibilities: (1) At the time of spraying weed seeds lying on the soil surface were contaminated and penetrated by the herbicide. Seedlings of such seeds could show malformations. This theory is supported by the result of the additional experiment described, for although low concentrations of 2,4-D and MCPA are degraded very rapidly under greenhouse conditions, deformed plants were still emerging after several weeks. The fact that only these three species and only a few of their seedlings were deformed, could possibly be due to the quality of their seed coats or to general differences in susceptibility. (2) At the time of application some plants were contaminated with sublethal doses and the herbicide and/or metabolites were translocated into their developing seeds. Plants from these seeds could show malformations. This explanation is supported by the findings that phenoxy herbicides can be translocated into seeds (Bevenue, 1962), and that seeds of treated mother plants can produce abnormal daughter plants (McIlrath et al., 1951; Aamisepp, 1966). Both possibilities are thought to contribute to the deformities.

Although some seeds, affected by normal field sprayings with 2,4-D and MCPA, do develop into malformed seedlings and do not survive, they probably contribute little to practical weed control, but it is still an interesting phenomenon.

Acknowledgments

The technical assistance of R. Lexow and Mrs Benthaus is much appreciated. I thank Mr R.J. Chancellor for his help with the English text.

References

AAMISEPP, A. (1966) Klorerade fenoxiättiksyrors verkan på besprutade plantor och dessas avkomma - Studir i korn, lin och ärter. Växtodling (Plant Husbandry), 22, pp. 147.

BEVENUE, A., ZWEIG, G., NASH, N.L. (1962) Residue determination of 2,4-dichlorophenoxyacetic acid in dry crops and walnuts. Journal of the Association of Official Analytical Chemists, 45, 990-993.

KOCH, W. (1969) Einfluß von Umweltfaktoren auf die Samenphase annueller Unkräuter insbesondere unter dem Gesichtspunkt der Unkrautbekämpfung. Arbeiten der Universität Hohenheim, 50, pp. 204. Verlag Eugen Ulmer Stuttgart.

KROPÁČ, Z. (1966) Estimation of weed seeds in arable soil. Pedobiologia, 6, 105-128.

McILRATH, W.J., ERGLE, D.R., DUNLAP, A.A. (1951) Persistence of 2,4-D stimulus in cotton plants with reference to its transmission to the seed. Botanical Gazette, 112, 511-518.

RADEMACHER, B., KOCH, W., HURLE, K. (1970) Changes in the weed flora as the result of continuous cropping of cereals and the annual use of the same weed control measures since 1956. Proceedings 10th British Weed Control Conference, 1-6.

ROBERTS, H.A. (1970) Viable weed seeds in cultivated soils. Report of the National Vegetable Research Station for 1969, 25-38.

Proceedings 12th British Weed Control Conference (1974)

HERBICIDE USAGE IN MAINCROP POTATOES IN GREAT BRITAIN

C. P. Hampson and J. A. H. Taylor

Potato Marketing Board, London.

Summary Surveys carried out by the Potato Marketing Board provide much information on technical aspects of potato production including weed control.

In 1963, control of weeds was still effected almost entirely by post planting cultivations. At that time, only 1% of the maincrop potato acreage was treated with chemical herbicides. By 1973, 67% of the maincrop potato acreage in Great Britain was treated with one or other of a wide range of herbicidal compounds and mixtures for the purpose of chemical weed control. Herbicides are now the accepted standard treatment for the control of weeds. With the introduction of safe and effective chemicals that can be used to control weeds after the emergence of the crop, a further increase in the use of herbicides on the potato crop in Great Britain is likely to occur.

'Surveys of Maincrop Potatoes' carried out by the Potato Marketing Board in collaboration with the Survey Section of the National Institute of Agricultural Engineering and the Statistical Department of Rothamsted Experimental Station in 1958, 1963 and 1968 and published in the form of three reports by the Potato Marketing Board entitled Report on the Survey of Maincrop Potatoes, 1958, 1963 and 1968, provide information on husbandry practices up to and including harvesting and storage. The Potato Marketing Board's crop production surveys, entitled 'Crop Check Weighing Surveys - Annual Reports', in the years from 1970, supplement this information.

The frame from which the 1973 survey sample was drawn consisted of the acreage returns of all maincrop potatoes made by Registered Producers in Great Britain growing more than three acres of any maincrop variety. The eligible acreage records were then sorted by administrative area and variety and within these groupings by the total potato acreage grown on the farm. From these sorted lists, farms to be included in the survey were selected to give a representative sample covering all potato varieties and sizes of potato enterprises within each PMB administrative area. In consequence, areas with large potato acreages tended to have sample lists reduced, while those with low potato acreages had theirs increased to give sufficient numbers at thr area level.

The number of farms surveyed in relation to the number of registered producers and total acreage of maincrop potatoes in each Potato Marketing Board division are shown in the following table.

Table 1

Division	No. of Farms Surveyed	Total No. of Registered Producers	Total Acreage of Maincrop Potatoes
South West	111	4,403	17,010
South East	153	3,407	41,500
West Midland	179	5,034	40,760
East Midland	315	6,607	82,910
East Anglia	285	6,602	83,830
North	255	6,383	66,430
Scotland	352	6,180	63,610
Total	1,650	38,616	396,050

In all cases, the producers included in the survey were visited by Potato Marketing Board field officers to obtain information on the herbicides that were used on the selected crops.

In 1958 chemical sprays were not used for weed control and in 1963 1% was treated with dinoseb and MCPA. Weed control was part of traditional post-planting mechanical cultivations.

Since 1965 when details of the then new techniques of herbicide spraying were first collected with crop check weighing yield data the percentage of the potato acreage treated with herbicides has followed the pattern shown in Table 2.

Table 2

		Percentage of Maincrop Acreages treated with Herbicides				
		1965	1967	1969	1971	1973
England and Wales	Maincrop Acreage	407,410	407,820	345,930	366,000	331,090
	% Treated	16.0	33.0	46.0	55.5	67.0
Scotland	Maincrop Acreage	109,410	100,710	77,450	76,230	64,260
	% Treated	7.0	37.0	46.0	56.0	70.0

In 1973 as in earlier years a greater proportion of acreage was treated in the West and Wales than elsewhere, followed by the South East, the North, Midlands and North West and the East, (Table 3), in that order.

Table 3

Regional Use of Herbicides in England and Wales

% of total checked acreage treated with herbicides

Year	West & Wales	South East	North	Midlands & N.W.	East
1965	41	29	12	18	10
1967	63	46	34	27	25
1969	75	55	40	50	44
1971	93	50	60	71	49
1973	92	84	72	71	57

This is more or less in the reverse order of their importance, as maincrop potato producing areas. A number of theories suggest themselves. Although the Eastern region is looked upon as being the area which uses most herbicides in general, farmers in this region are very prudent in deciding which crops to spray. On the other hand, weed growth is perhaps more of a certainty in the wetter West region and for that reason, chemical sprays are used more routinely. Also it may be that growers in the West and Wales are influenced by their proximity to areas of early potato production which quickly took up the technique of chemical weed control.

The percentages of the maincrop potato acreage in England and Wales, and Scotland treated with different types of herbicides are shown in Table 4.

Table 4

Percentage of total maincrop acreage treated with various herbicides

	England and Wales				
Herbicide	1965	1967	1969	1971	1973
Bipyridils (diquat, paraquat)	41.5	53.5	54.7	52.0	47.3
Dalapon	0.7	0.3	0.2	0.6	-
MCPA	5.7	2.6	0.4	1.5	1.0
Dinoseb	12.4	3.0	2.6	2.8	1.3
Triazines (ametryne, prometryne & simazine)	7.9	10.7	4.0	3.0	1.4
Ureas (linuron, monolinuron)	28.9	25.1	15.8	14.1	16.0
Bipyridil/urea/triazine mixtures and others	2.9	4.8	22.8	26.0	32.0
	100	100	100	100	100
Paraquat + linuron				21.2	16.6
Linuron + triazine				0.5	5.8
Metribuzin				-	3.1

Table 4 (cont.)

Percentage of total maincrop acreage treated with various herbicides

Herbicide	Scotland 1965	1967	1969	1971	1973
Bipyridils	31.7	48.8	65.2	61.9	63.6
Dalapon	3.7	0.1	-	1.1	-
MCPA	9.2	0.2	-	1.7	-
Dinoseb	8.2	2.8	2.2	1.4	0.4
Triazines	-	2.8	-	1.0	1.0
Ureas	17.1	11.5	2.2	-	2.4
Bipyridil/urea/triazine mixtures and others	30.6	33.8	30.4	32.9	32.6
	100	100	100	100	100
Paraquat + linuron				30.2	26.0
Metribuzin				-	4.4

\- = nil acreage recorded

The contact herbicides (diquat, paraquat and mixtures of the two) are still the most frequently used treatments. With 47.3% of the treated acreage in England and Wales and 63.6% in Scotland, their position is pre-eminent. Triazine compounds (ametryne and prometryne) are more popular in England and Wales than in Scotland. The continued decline in the use of dinoseb is no doubt a reflection of its handling problems. The use of MCPA has practically disappeared and nowadays it is probably only used where there is a specific requirement for the control of late germinating and MCPA susceptible weeds such as fat hen.

In its first year of commercial use, in 1973, metribuzin gave very satisfactory results and this impression combined with the ability to apply the chemical as a post-emergence treatment and to use it as a "long-stop" to control a second crop of weeds that might appear after using a cheaper pre-emergence treatment, would indicate that it has a big usage potential. 3% of the maincrop acreage of potatoes in England and Wales and 4% in Scotland were treated with metribuzin in 1973.

The apparent drop in the use of straight urea compounds in England and Wales is accounted for by the use of urea bipyridil mixtures for contact plus residual weed control action.

The extent to which the different types of herbicides are used in different regions in Great Britain is shown in Table 5.

Table 5

Herbicide Usage by Different Regions - Great Britain, 1973

% of Treated Acreage receiving different chemicals.

Region	EPTC	Linuron	Mono-linuron	Paraquat	Paraquat with *	Linuron+ Trietazine	Metri-buzin	Others
South West	2	13	4	37	19	4	1	20
South East	3	9	2	44	14	9	2	19
West Midland	5	9	16	39	9	5	4	13
East Midland	3	10	12	44	9	5	3	14
East Anglia	1	16	-	44	7	9	4	19
North	5	6	1	61	12	3	3	9
Scotland	2	17	-	71	3	-	4	2
Great Britain	3	12	5	51	9	5	3	12

* paraquat with linuron and monolinuron.

The pre-eminence of paraquat and paraquat containing mixtures in all regions will again be noticed.

The extent to which different maincrop potato varieties are treated with herbicides is shown in Table 6.

Table 6

Herbicide Usage by Variety - Great Britain, 1973

VARIETY	ACREAGE		
	Total Acreage of Variety	Acreage Treated	% Treated
Desiree	28,561	20,000	70
King Edward	75,606	48,400	64
Majestic	28,372	16,200	57
Maris Piper	41,541	23,300	56
Pentland Crown	100,892	68,600	68
Pentland Dell	44,715	33,100	74
Pentland Ivory	16,058	11,200	70
Record	31,507	23,900	76
Golden Wonder	2,544	2,000	78
Kerr's Pink	3,573	2,400	66
Redskin	4,970	3,700	74
Others	17,011	11,900	70
Total - All Main-Crop Varieties	395,350	264,700	67

The lower usage of herbicides on the Majestic and Maris Piper acreage may in part be explained by the fact that Majestic tends to be grown widely by the small scale producer and Maris Piper tends to be lifted earlier than other maincrop varieties and for this reason, the need for weed control may be less.

Following the rapid adoption of herbicides in 1964 and 1965, they have been increasingly used each year to the extent that in 1973, 67% of the maincrop potato acreage in Great Britain was treated with one or more of the 66 different proprietary products, based on 30 or more different compounds and mixtures marketed in that year.

It is clear that the majority of farmers no longer regard herbicides as an alternative or an adjunct to cultivations and that now they have accepted these chemicals as the standard treatment for the control of weeds. Compared with the extent to which chemicals are used for the control of blight, where over 84% of the maincrop potato acreage is treated with fungicides, there would still appear to be scope for a further increase in the use of herbicides. To what extent this will result from the introduction of safe and efficient herbicides for use as post-emergence treatments is yet to be revealed.

The overall picture of herbicide usage is that farmers have become increasingly aware of the broad benefits of chemical weed control in potatoes. Regional differences in herbicide usage appear to be associated with geographical and climatological factors rather than with the intensity of production or the more specific requirements of particular varieties. Shifts in the relative importance of different types of compounds reflect not only the availability of new materials but the recognition that weed control is concerned not only with the destruction of weeds present before the emergence of the crop, but also with the need to control weeds that develop later after the emergence of the crop. The available evidence suggests that there is scope for the continued expansion of herbicide usage in the potato crop in Great Britain.

Proceedings 12th British Weed Control Conference (1974)

THE EFFECTS OF WEEDS ON FRUIT AND ORNAMENTAL CROPS

H.M. Lawson

Scottish Horticultural Research Institute, Invergowrie, Dundee DD2 5DA.

INTRODUCTION

Most of the work on weed control in fruit and flower-bulb crops in the last 20 years has concentrated on herbicides, their safety, efficacy, application and persistence. Investigations have also been carried out (particularly in fruit) into the managerial aspects of replacing cultivations with herbicides and into the opportunities thereby provided of examining new systems of crop husbandry. Because of limited acreages and the multitude of varieties and strains involved, ornamental crops other than flower bulbs have received relatively little attention with respect to weed control. Few research projects have been specifically designed to measure the direct and indirect effects which weeds can have on fruit and ornamental crops, or the stages of development and times of year at which the crops are particularly vulnerable. For these reasons much of the information presented in this review has had to be derived from experiments on herbicide performance or crop management. This apparent lack of interest by research workers in studying the effects of weeds on fruit and ornamental crops may be due in part to an earlier assumption that the 'weed-free' crop was both technically attainable and economically feasible, so that weed studies were unnecessary. However, the rapid adaptation of weed flora in response to changes in herbicide practice, reduced opportunity for weed control by soil cultivation due to closer planting, scarcity of labour and ever-increasing costs have necessitated the consideration of acceptable levels of weed control rather than complete weed removal. In this context it is particularly important to establish exactly when and how weeds may affect the growth and yield of fruit and ornamental crops, so that the best use may be made of available resources.

Adverse effects of weeds may be grouped as follows:

1) Competition for light, water and nutrients a) during establishment, b) in the established crop.
2) Interference with routine management operations.
3) Interference with harvesting operations, handling and quality.
4) Weeds acting as hosts for pests and diseases, giving shelter to vermin or diverting pollinating insects.

Beneficial effects are of course a possibility, the most obvious of which is assistance in the prevention of soil erosion, but there are more efficient ways of achieving this objective.

Information available on the above factors is summarised below under various crop headings.

TOP FRUIT

Comparisons between bare soil and grass swards, in terms of fruit production and ripening, have been the subject of detailed investigations in temperate top fruit crops by research workers in several countries. In many ways the presence of a grass sward around the trees would have a similar effect to that of weeds and in fact the sward is often composed of 'weeds' rather than specially sown grasses. Many growers who use grass swards prefer to maintain a bare soil strip around the trees and it is in this area that weed species can become a problem.

Competition in young crops

Several workers have demonstrated that top fruit crops are particularly vulnerable to direct interference by weeds during the establish-ment phase. Fisher (1965), evaluating herbicide treatments on newly-planted apples (cv. Red Delicious), noted that shoot production by the crop was closely correlated with weed growth. Even relatively few weeds had a detrimental effect and competition for water was thought to be the main factor involved. Mellenthin et al (1966) reported that maximum retardation of apple tree growth (measured in terms of tree trunk circumference) due to weeds occurred in the first growing season, but that adverse effects also occurred in the third and fourth year of growth, indicating the need for continued weed control. White & Holloway (1967) found that competition from a 50% ground cover of weeds around young apple trees (cv. Cox's Orange Pippin) produced severe reductions in shoot length in the first year of growth compared with clean control plots. The reduction of growth persisted in the following 2 years, was not reduced by the application of extra nitrogen and was attributed mainly to moisture stress. Müller (1969) found that the growth and development of fruit trees up to the fifth year after planting was markedly improved by keeping an area of one square metre around the trees free from weeds. Such trees had twice the trunk girth of unweeded trees. Although there are therefore quite a number of examples of weeds affecting the growth and yield of young trees, there is very little systematic information on the effects of different levels and species of weed on growth and on the time of year when the crop is most vulnerable. Davison (personal communication) is, however, current-ly examining the effects of different times of removal of annual weeds around newly-planted apple trees at Oxford. This work should provide very useful quantitative data on the subject.

Competition in established crops

Information on effects of weeds on tree growth and yield in established orchards is less readily found from published data, and the situation is complicated by interactions between herbicide efficacy and crop tolerance, between soil cultivation and tree root disturbance, and by the presence or absence of grass swards. However, several reports suggest the need for continued weed control beyond the establishment phase. Raese et al (1974) imposed herbicide treatments in previously unweeded 4-year-old pear trees (cv. d'Anjou) in 1970 and maintained these treatments for three years. This was compared against herbicide treatments imposed for the first time in 1972. Herbicide treatment gave effective control of the main weed species (*Taraxacum officinale*). Commencing weed control treatments at 4-years old rather than at 6-years old greatly increased tree vigour (in terms of trunk circumference) and resulted in higher yields of larger fruit in 1972. Trees on regularly weeded plots bloomed earlier than those on initially weedy plots. However, the latter produced fruit which ripened earlier, coloured better and had softer flesh than plots with more vigorous trees. Stott (1973) has reported that Cox's Orange Pippin and Worcester Pearmain apple trees maintained in a weed-free situation without soil cultivation from their 16th to their 21st year after planting consistently produced higher yields but fewer first grade fruit than weedy trees. He also noted that trees on weed-free plots regularly blossomed earlier than those on weedy plots, had less well coloured fruit and that the fruit was more susceptible to rotting in store. These effects were related to a significant increase in nitrogen uptake and hence increased tree growth on clean as opposed to weedy plots. Curtis (1965) found that 5 years of treatment in an established apple orchard with herbicides for the control mainly of Agropyron repens resulted in the development of a wide range of densities of infestation of this major weed species. Tree girth and apple yield increased markedly as the density of weed cover decreased. Dermine & Detroux (1966) reported that where good weed control was obtained, tree growth in apples invariably increased, but suggested that complete weed control was not necessary since the best tree growth was obtained in partly-weedy situations. Goddrie (1969) noted that while pears (cv. Conference) appeared to benefit from permanent weed control with herbicides, as opposed to a system in which herbicides were used to maintain weed-free conditions until late July only, this was not the case with apples (cv. Golden Delicious).

More detailed information on the effect of different densities and durations of weed growth in established orchards is not currently available.

Other effects of weeds

Interference by weeds with routine orchard management is probably limited to requiring cultivation in situations intended for non-cultivation or further herbicide application beyond that originally planned. However, perennial weeds around the tree base, such as Convolvulus spp, Urtica spp and Cirsium arvense may make hand-picking difficult or unpleasant. They may also provide shelter for vermin. In this context, Curtis (1965) reported severe injury to apple tree trunks by mice when a dense cover of weeds was left around the base of the trees, while Stalder et al (1969) noted that a clean strip along fruit tree rows gave protection against winter damage by voles. An unusual aspect of competition between weeds and fruit trees has been reported by Free (1968) who found that pollen of Taraxacum officinale could be more attractive to bees than apple and plum pollen at blossom time so that the elimination of this weed from orchards was desirable in order to increase the pollinating efficiency of honey-bee colonies.

Weeds may act as hosts for pests and diseases of top fruits, but a search of the literature has not revealed any quantitative assessments of the importance of this aspect of the weed/crop situation.

SOFT FRUIT

Here also, much of the recent research has been devoted to herbicide evaluation and to studies of the effects of reductions in soil cultivation on crop growth.

Competition in young crops

Effects of different levels and durations of weediness in newly-planted raspberries are reported elsewhere in these Proceedings by Lawson & Wiseman (1974a). Competition from dense infestations of annual weeds in late spring and early summer resulted in up to 70% loss of planting material and severe reductions in numbers of canes produced. More detailed investigations on spring-planted raspberries at SHRI (Lawson & Wiseman, 1972a) showed that the presence of annual weeds until early June did not reduce cane numbers but did result in a 60% reduction in average length of canes produced. Delaying weeding for a further 4 or 8 weeks reduced cane numbers by 28% and 77% respectively. Shading during the emergence and early growth of young canes was thought to be a major factor contributing to the death of planting material and to reduced cane numbers. Effects of first-year competition persisted into the second and third years of the plantations. Wood et al (1960) recorded severe reductions in cane numbers and shorter canes due to heavy weed cover in late spring/early summer in the year of planting. This resulted in over 50% less fruit being picked on originally weedy plots in the second year. In a cane-nursery experiment, (Sutherland & Stephens, 1960), dense weed cover in the summer of the first year resulted in only 93 canes (50% first grade) being harvested from untreated plots at the end of the second year compared with 181 canes (78% first grade) on plots originally treated with simazine after planting.

Information on the effects of weeds on newly-planted bush fruit crops is not available from the literature.

In spring-planted strawberries, studies on competition between crop and annual weeds in the establishment year (Lawson & Wiseman, 1973) showed that failure to control weeds for the first 8 weeks after planting resulted in a loss of fruit yield of 13% in the following year compared with weed-free plots. The loss increased to 34% when weeding was delayed a further 6 weeks. Both crown and runner production in the first year were affected by competition from weeds. Crops intended to be grown as matted rows would therefore have been more severely affected than rows maintained as individual plants. As with raspberries, shading by weed foliage was thought to be an important competitive factor. A search of the literature has revealed no other relevant information from weed competition or herbicide experiments in spring- or autumn-planted strawberries.

Competition in established crops

Losses of crop growth and yield due to weed competition in established bush and cane fruit have been reported by various workers. This information relates mainly to experiments with herbicides for the control of dense stands of perennial weeds. The removal in spring, even temporarily, of competition from Agropyron repens resulted in increases of 30-40% in cane production in raspberries (Lawson & Rubens, 1970). Myram and Forrest (1970) found cane production increased by 40% and 60% at two sites where spray treatment with bromacil was effective in controlling this weed. Experiments with dichlobenil in gooseberries and blackcurrants (Spencer-Jones & Wilson, 1968) showed that successful treatment of A. repens in October or November greatly increased the total new growth of gooseberries at the end of the following year, while treatment in March or April had less effect. This was attributed to the earlier release of the crop from competition on autumn-treated plots. Similar but less marked beneficial effects resulted from treatments in blackcurrants. Sumpter (1970) in experiments on the control of _A. repens_ in strawberries with propyzamide, found considerable increases in subsequent yield as a result of effective weed control treatments applied in autumn. Rath and O'Callaghan (1972) also reported increased yield of strawberries as a result of control of _A. repens_ with terbacil.

There is no published information on the effects of annual weeds on established soft fruit crops, and data on perennial weeds other than _A. repens_ is very limited. Davison (personal communication) has studied the establishment of _Convolvulus arvensis_ and _Heracleum sphondylium_ in blackcurrants. _Convolvulus arvensis_ grew poorly under the bushes and had little effect on crop growth and yield whereas _H. sphondylium_ consistently reduced crop growth and yield.

Other effects of weeds

Davison (1974) found that _Convolvulus arvensis_ because of its climbing growth habit had serious indirect effects on bush fruit. Time taken for pruning and picking was increased and picking efficiency was reduced where this weed was present. Information on weed species interfering with the management or handling of other soft fruit crops is lacking, but weeds such as _Urtica_ spp and _Cirsium arvense_ may be expected to discourage pickers, thereby possibly reducing harvested yields, while _Galium aparine_ can have the same general effect as _Convolvulus_ spp. At a time when the labour force available for harvest-ing is diminishing, unpleasant conditions underfoot or inability to pick quickly because of weeds, may divert pickers to pleasanter and more remunerative plantations. Also, pick-your-own customers are less likely to return to weed-infested plantations. These are, however, observations rather than quantitative assessments.

Interference by weeds with routine management of soft fruit plantations can be of several kinds. Non-cultivation may have to be abandoned because of the spread of weeds resistant to herbicide treatment, with possible harmful effects on crop root-systems. Loss of planting material due to weed competition will require expensive replacement planting. Weeds may obstruct routine pest and disease spraying and absorb much of the spray. Scarce labour may have to be diverted to hand-hoeing along rows. The development of a resistant flora may require the use of more expensive herbicides than were originally necessary and spot treatment of perennial weeds may be possible only at the risk of local injury to the crop.

Weeds act as hosts for a range of nematode, fungal and virus diseases of soft fruit crops, and may therefore contribute to the spread of disease through the crop (Thomas, 1969).

FLOWER BULBS

Competitive effects

Information is available on direct effects of weeds on the growth, yield and quality of narcissus and tulip crops both from competition studies and from herbicide experiments carried out in the United

Kingdom. Published reports from Kirton Experimental Horticulture Station (Wood & Howick, 1958; Wood et al 1960; Turquand, 1962, 1964, 1966; Briggs, 1972) contain data showing reductions due to weeds of between 4% and 17% in the fresh weight of narcissus bulbs lifted after one season. In several cases, when evenly-graded narcissus bulbs were forced, bulbs from weedy plots produced fewer first grade flowers and more smaller flowers than those from cultivated or hand-weeded plots. Tulips did not generally show yield reductions or adverse effects on forcing quality due to weeds, despite relatively high levels of weediness on unweeded plots, but Briggs (1972) has recorded a reduction in total bulb yield of 15% on unweeded tulip plots relative to cultivated controls in one experiment. The comparison is complicated by possible effects of cultivation in itself.

Lawson & Wiseman (1972b) reported on herbicide evaluation experiments on narcissus (cv. Carlton) in which uncultivated weedy and weed-free plots could be directly compared. Spring-germinating weeds reduced overall yield of bulbs lifted after one year by 5% in one experiment and by 17% in another. Yield differences were due mainly to a greater proportion of bulbs falling in the larger size grades on weed-free plots. When evenly-graded bulbs were later forced, those from weedy plots emerged later and mean shoot height was for some time less than on weed-free plots. By flower-harvest these effects had largely been outgrown in the first experiment but in the second experiment the effects of weed competition in the field persisted, reducing flower size and delaying flowering. Flower numbers were not affected. In the dry spring and early summer of 1973, competition from spring-germinating weeds in a similar experiment reduced bulb yield by 36% (Lawson & Wiseman, 1974b).

Detailed studies of the effects of autumn and spring-germinating weeds on narcissus (cv. Carlton) were reported by Lawson (1971). Plots totally unweeded from planting in September until the following August suffered a 24% reduction in yield of bulbs compared with weed-free plots, while on plots on which only spring-germinating weeds were allowed to grow, yield was reduced by only 10%. However, both sets of plots produced over 20% fewer flowers in the field in the following spring than did weed-free plots, and despite freedom from weeds throughout the second year, lower yields were still recorded on originally weedy plots when sample areas were lifted at the end of two year's growth.

Removal of weeds from narcissus plots at intervals during the growing season showed that the presence of dense weed growth had no adverse effects on flowering in the first spring after planting or on weights of foliage and bulbs until after flowering. However, continued weed presence during the period of maximum bulb growth and flower initiation did lead to severe competition, reducing total yields and resulting in a lower proportion of bulbs in the larger size grades. The 'critical period' for narcissus weed competition was therefore between the end of flowering and the onset of senescence. Unpublished data (Lawson & Wiseman) suggests that a similar situation obtains with tulips.

Since, as with several vegetable crops, yield of certain size grades of the harvested part of the crop is more important than gross yield, relatively small differences in total yield of bulbs may mask serious effects of weed competition on yields of marketable bulbs. The evidence suggests that the potential flowering quality of these bulbs may also be affected by the presence of weeds.

No published information has been traced on the competitive effects of weeds in other bulb crops.

Other effects of weeds

The presence of overwintered weeds at flowering time might possibly interfere with picking efficiency, and removal of weeds by mechanical means could damage crop roots. Jeff (1960) noted that the root disturbance associated with weeding operations in anemones affected flower production. Plots hand-weeded regularly gave slightly more marketable flowers than those given minimal weeding, but less frequently weeded plots produced more flowers in total.

The main interference by weeds with routine management is however at lifting time, when even weeds germinating in late spring can obstruct the passage of harvesting machinery (Briggs, 1970).

No quantitative information is available on effects of weeds as hosts of pests and diseases of bulb crops.

WOODY ORNAMENTALS, HERBACEOUS AND ANNUAL PLANTS

There is almost no published information on weed competition in these crops. Most weed control experiments have dealt solely with crop tolerance to herbicides, often scored visually, with weeds removed by hand or by hoe. Comparison of weedy and clean plots is therefore seldom possible.

Competitive effects

Woody ornamentals may be expected to suffer from weed competition in a similar manner to newly-planted tree or bush fruit. Some relevant data can be drawn from experiments in forest nurseries. For example Hanschke (1968) found that *Calamagrostis epigeios* or *Agrostis tenuis* covering as little as 10% of the ground area in rows of planted Scots pine caused nearly 25% and 50% mortality respectively in the year of planting. Heavier weed infestations gave almost complete mortality.

Herbaceous plants or transplanted annuals may be reduced in size or smothered by weeds. This situation is probably analagous with that of transplanted vegetable crops, while sown annuals may reasonably be compared with direct-drilled vegetable crops which can be completely eliminated by dense weed growth (King, 1972). However, the range of herbicides available for use in these ornamental crops is very limited. A further problem in these ornamental crops is that weeds may affect plant shape and hence reduce sales value.

Other effects of weeds

The herbicide treatments developed for use in woody ornamentals are normally those found successful in fruit crops. However, the use of these herbicides in nurseries for control of perennial weeds may be restricted by the need to avoid the persistence of residues of such herbicides as atrazine and terbacil in the soil (Kelly, 1970; Roberts & Harris, 1972). Perennial weeds may therefore be of greater importance in disrupting routine management than is the case in fruit crops. On the other hand, since possible effects of herbicides on food quality are not involved, the grower of ornamental crops can experiment with a wider range of herbicides than is possible with food crops. The need for more research into weed control in nursery stock was noted by Humphries & Sheard (1964), and in recent years there is evidence of increased effort in terms of herbicide evaluation by both official and commercial agencies. The major problem is the diversity of species and strains of ornamental plants and the amount of development work required to establish firm recommendations for relatively minor uses of herbicides. The readiness with which growers are prepared to risk herbicide treatment in their crops because of the scarcity and increasing cost of labour (Cox 1972), illustrates their recognition of the potential crop losses which may result from weeds. Where nurseries are open to the public, weedy fields or standing areas for container-grown ornamentals may also create an adverse impression with potential customers.

CONCLUSIONS

Factual information on many aspects of the effects of weeds on top fruit crops is patchy. It is however well-documented that these crops are most vulnerable in the first few years after planting. Unfortunately the range of herbicides available for use during the establishment phase is often limited by inadequate crop tolerance. Many top fruit herbicides are restricted to crops established for two and in several cases at least four years (Fryer & Makepeace, 1972). The availability of herbicide treatments is therefore least at the very time when the crop most requires effective protection from weeds. Since adverse effects on first-year growth may persist for several years, there is an obvious need for more research and development work on safe herbicide treatments for young top fruit. Further investigations on the critical periods during first year growth when the crop is most vulnerable to interference by weeds would help to define the type and timing of herbicide treatments likely to be most effective.

From the information available on soft fruit it is clear that these crops are likely to be even more vulnerable than top fruit to competition from weeds in the year of planting. Their smaller size permits shading by weeds as well as potential competition for nutrients and water, and mortality of planting material may be high.

In the major soft fruit crops, with the exception of strawberries, the range of herbicides available for annual and perennial weed control in both newly-planted and established plantations is now extensive (Fryer & Makepeace, 1972) and suitable treatments are available for most weed problems. However the competitive importance of relatively light infestations of perennial weeds requires investigation so that "economic thresholds" of infestation may be determined and remedial treatment applied at these points rather than after the crop has already suffered considerable injury. More information is also needed on effects of annual weeds in newly-planted bush fruit.

For strawberries and the main flower bulb crops fewer herbicide treatments are available and more emphasis is needed on the development of suitable contact or translocated herbicides for use in late spring or early summer to control weeds which may be present during the critical phases of first year growth. Further studies on effects of annual weeds in established strawberries and in bulbs left in the ground for more than one year would be helpful in designing appropriate weed control programmes for these crops. In narcissus and tulip, it appears that the direct effects of weeds are not only on yield of bulbs but also on their size distribution. The effects carry over into future flower production and quality either in the field or in the forcing house. The indications are that weed levels considerably lower than those giving substantial reduction in bulb yields can have a marked influence on subsequent flower production. This aspect requires further investigation in these and in other flower bulb crops.

While information on effects of weeds on ornamental crops other than flower bulbs is desirable, the first priority in these crops must remain the search for safe herbicides and their integration into crop management systems.

To sum up, a better understanding of the crop/weed relationship is necessary if optimal weed control programmes with existing herbicides are to be developed for fruit and ornamental crops. By pin-pointing the requirements for improved weed control, this can also permit more effective screening of candidate herbicides. Since labour for hoeing or hand-weeding is expensive and often in short supply a better knowledge of the critical periods of weed/crop competition should permit more effective and timely use of this scarce resource. Factual information is also required on the effects and costs of weeds interfering with crop management and harvesting so that these factors may also be given due consideration when the economics of weed control are being assessed.

References

BRIGGS, J.B. (1970) Flower bulb production - Agriculture, London, 77, (8), 353-363.

BRIGGS, J.B. (1972) Effects of herbicides when applied to narcissus & tulip pre-and post-flowering. Proceedings 11th British Weed Control Conference, 601-607.

COX, R. (1972) Weed control in nursery stock production. Proceedings 11th British Weed Control Conference, 1096-1099.

CURTIS, O.F. (1965) Weeding apple orchards. Farm Research, 30,(4),12.

DAVISON, J.G. (1974) Report ARC Weed Research Organization, 1972-73, 56-62.

DERMINE, E. & DETROUX, L. (1966) Chemical weed control in fruit growing. Bulletin de Recherche Agronomique, Gembloux, 1, 246-273.

FISHER, V.J. (1965) The effect of weed control by isocil and bromacil on growth of young peach and apple trees. Proceedings of the American Society for Horticultural Science, 86, 148-151.

FREE, J.B. (1968) Dandelion as a competitor to fruit trees for bee visits. Journal of Applied Ecology, 5, (1), 169-178.

FRYER, J. & MAKEPEACE, R. (Eds.) (1972) Weed Control Handbook, 7th Edition, Volume II. Blackwell Scientific Publications, Oxford.

GODDRIE, P.D. (1969) Research on weed control in fruit crops. Jaarverslag. Proefstation voor de fruitteelt in de volle grond. Wilhelminadorp 1968, 109-122.

HANSCHKE, D. (1968) Weed competition and quantitative evaluation criteria. Forst-und Holzwirt Hanover, 23, (21), 434-439.

HUMPHRIES, D.J. & SHEARD, G.F. (1964) Report Glasshouse Crops Research Institute 1963, 122-130.

JEFF, A.E. (1960) Observation studies on the use of residual herbicides on anemones during 1958-59 and 1959-60. Proceedings 5th British Weed Control Conference, 419-424.

KELLY, J.C. (1970) Use of terbacil and other herbicides on some ornamental shrubs. Proceedings 11th British Weed Control Conference, 727-731.

KING, J.M. (1972) Objectives of weed control in vegetables. The effects of weeds and herbicides on the growth and yield of vegetable crops. Proceedings 11th British Weed Control Conference, 925-931.

LAWSON, H.M. (1971) Weed Competition in narcissus crops. Acta Horticulturae, 23, (1) 300-304.

LAWSON, H.M. & RUBENS, T.G. (1970) Experiments on the control of perennial weeds in established raspberry plantations. Proceedings 11th British Weed Control Conference, 760-767.

LAWSON, H.M. & WISEMAN, J.S. (1972a) Weed investigations. Annual Report Scottish Horticultural Research Institute 1971, 25-26.

LAWSON, H.M. & WISEMAN, J.S. (1972b) Experiments with pyrazone and chlorbufam in narcissus. Proceedings 11th British Weed Control Conference, 608-614.

LAWSON, H.M. & WISEMAN, J.S. (1973) Weed investigations. Annual Report Scottish Horticultural Research Institute 1972, 24-25.

LAWSON, H.M. & WISEMAN, J.S. (1974a) Effects of weeds and herbicides in young raspberry plantations. Proceedings 12th British Weed Control Conference, 683-690.

LAWSON, H.M. & WISEMAN, J.S. (1974b) Weed investigations. Annual Report Scottish Horticultural Research Institute 1973, 24.

MELLENTHIN, W.M., CRABTREE, G. & RAUCH, F.D. (1966) Effects of herbicides and weed competition on growth of orchard trees. Proceedings of the American Society for Horticultural Science, 88, 121-126.

MÜLLER, G. (1969) Costs of different soil management practices for road-side fruit growing. Obstbau, Berlin, 9, 5-6.

MYRAM, C. & FORREST, J.D. (1970) The development of terbacil and bromacil for the control of Agropyron repens and other weeds in some fruit crops. Proceedings 11th British Weed Control Conference, 752-759.

RAESE, J.T., WILLIAMS, M.W. & SCHOMER, H. (1974) Yield and vigour of 'd'Anjou' pears with early application of triazole and triazine herbicides. HortScience, 9, (1), 32-33.

RATH, N. & O'CALLAGHAN, T.F. (1972) Further experiments with herbicides for the control of perennial grass weeds in strawberries. Proceedings 11th British Weed Control Conference, 398-405.

ROBERTS, L. & HARRIS, D.C. (1972) Use of terbacil, atrazine and other herbicides in bush rose production. Proceedings 11th British Weed Control Conference, 632-634.

SPENCER-JONES, D.H. & WILSON, D. (1968) Trials to investigate the herbicidal efficacy of dichlobenil in bush fruit with special reference to the control of Agropyron repens. Proceedings 10th British Weed Control Conference, 907-915.

STALDER, L., POTTER, C.A. & BARBEN, E. (1969) Herbicide and vole problems in intensive fruit growing. Schweizerische Zeitschrift für Obst-und Weinbau, 105, 213-216.

STOTT, K.G. (1973) Report of the Agricultural and Horticultural Research Station, University of Bristol 1972, 146-147.

SUMPTER, D.W.F. (1970) The control of perennial and annual weeds in strawberries with N-(1,1-dimethylpropynyl)-3,5-dichlorobenzamide (RH 315). Proc.11th Br. Weed Control Conf, 818-820.

SUTHERLAND, J.P. & STEPHENS, R.J. (1960) Effects of some chemical weedkillers on a raspberry cane nursery. Proceedings 5th British Weed Control Conference, 381-386.

THOMAS, P.R. (1969) Crops and weed plants compared as hosts of viruliferous Longidorus elongatus (de Man). Plant Pathology, 18, 23-28.

TURQUAND, E.D. (1962) Trials of herbicides on narcissus and tulip. Proceedings 6th British Weed Control Conference, 661-664.

TURQUAND, E.D. (1964) Trials of herbicides on narcissus and tulip. Proceedings 7th British Weed Control Conference, 235-240.

TURQUAND, E.D. (1966) Linuron as a herbicide on narcissus and tulip. Proceedings 8th British Weed Control Conference, 110-116.

WHITE, G.C. & HOLLOWAY, R.I.C. (1967) The influence of simazine or a straw mulch on the establishment of apple trees in grassed down or cultivated soil. Journal of Horticultural Science, 42, 377-389.

WOOD, C.A., SUTHERLAND, J.P. & STEPHENS, R.J. (1960) Effects of the use of herbicides on the growth, cropping and weed flora of raspberry plantations. Proc. 5th Br. Weed Control Conf., 373-380.

WOOD, J. & HOWICK, S.J. (1958) Experiments with herbicides on beds of narcissus and tulip. Proc. 4th Br. Weed Control Conf., 112-115.

WOOD, J., HOWICK, S.J. & TURQUAND, E.D. (1960) Trials of herbicides on narcissus and tulip beds. Proc. 5th Br. Weed Control Conf., 425-431.

THE RESULTS OF RESEARCH INTO THE USE OF MINIMUM AND ZERO CULTIVATION TECHNIQUES IN APPLE ORCHARDS IN ROMANIA

D.Prica and N.Sarpe

The Academy of Agricultural and Sylvicultural Sciences, Bucharest, Romania.

Summary This report presents the results of research into the use in apple orchards of minimum and zero cultivation techniques based on the herbicides atrazine and paraquat. The experiments were carried out on soil containing 2.2% humus and 41% clay. The following weed species were present:- *Agropyron repens*, *Echinochloa crusgalli*, *Setaria spp.*, *Digitaria sanguinalis*, *Capsella bursa-pastoris*, *Veronica arvensis* and *Symphytum spp.*

The results obtained show that these techniques can be used successfully in apple orchards in Romania.

INTRODUCTION

Specialists in many countries have looked towards weed control with different herbicides as a means of reducing labour requirements. It is well known that in orchards the presence of perennial weeds as well as annual weeds creates a considerable nuisance, and therefore much research into methods of control of perennial weed species has been carried out. Schmitlin and Pigot (1969) obtained very good control of *Agropyron repens* with herbicides based on aminotriazole and paraquat. Satisfactory results against *Agropyron repens* were also obtained by Myram and Forrest (1970) using terbacil and bromacil. Broad-leaved perennial weed control with growth-regulator herbicides in orchards in England was reviewed by Davison (1973). Banwell (1972) showed that the use of herbicides in the management of modern orchards is absolutely necessary.

In Romania, research into the application of herbicides in orchards carried out by Coman (1967), Prica *et al* (1972), Sarpe and Prica (1973), was directed towards establishing which herbicides were the most effective under various conditions in Romania.

The main objective of the experiments described in this paper was to develop systems of weed control using herbicides which could replace traditional cultivation practices in Romanian apple orchards.

METHOD AND MATERIALS

The experiments were commenced in 1971 in apples cv. Golden Delicious grafted on to MM 104 stocks. The trees were 4 years old grown on the "palmette" system, planted at 4 x 5 m spacing. The work was carried out at the Experimental Station at Geoagiu, Romania on a clay-loam soil containing 2.2% humus and 41% clay and having a pH of 6.8.

The weed species present were:- Agropyron repens, Setaria spp., Echinochloa crus-galli, Digitaria sanguinalis, Capsella bursa pastoris, Veronica arvensis, Convolvulus arvensis and Symphytum spp. The experiment was laid out with a randomised block design with four replicates. The area of each plot was 225 m^2 planted with four trees.

Herbicide applications were carried out both pre-emergence in March and post-emergence in April, May and June. A spray volume of 500 l water/ha was used for all applications. The following herbicides were used:-

1) A-3587 w.p. containing 25% terbuthylazine + 25% terbumeton.

2) Atrazine w.p. (50% a.i.)

3) Simazine w.p. (50% a.i.)

4) Paraquat a.c. (20% a.i.)

Application rates of herbicides used and a description of the cultivation techniques are given in Tables 1 and 3. All herbicide rates are given in terms of the total amount of active ingredient applied.

The autumn ploughing was made to a depth of 20 - 22 cm and discing to a depth of 5 - 10 cm. Hand hoeing was carried out in the tree rows to a width of 1.5 m. Soil moisture readings were noted throughout the growing season. The soil moisture was determined using a gravimetric method, and was expressed in % water against the dry soil weight. The soil samples were taken at a depth of0-20;20-40;40-60;60-80 and 80-100 cm at a distance of 1.80 - 2.00 m from trees.

In the months of May - August the degree of weed control was recorded using the EWRC scale. In September weeds from each plot were collected and separated into three groups as follows: perennials (mono-and dicotyledonous): monocotyledonous annuals and dicotyledonous annuals. All three groups were weighed separately, after air drying.

RESULTS

The comparison between soil moisture content readings taken from conventionally cultivated and non-cultivated plots is presented in Table 2 (no moisture readings were taken from plots that received minimal cultivations).

On the basis of the readings taken, it was evident that there was no significant difference in soil moisture retention between the zero cultivated plots (where herbicides alone were used) and plots cultivated mechanically or by hand.

A comparison of the results for weed control and fruit production obtained by zero, minimum and conventional cultivation techniques is presented in Table 3.

During the first 2 years of treatment with triazine herbicides (atrazine, simazine and A 3587) very good control of annual monocotyledonous and dicotyledonous weeds was observed. Complete control of Agropyron repens, Convolvulus arvensis and Symphytum spp. was not obtained.

In 1973 as a result of the repeat application of triazine herbicides and paraquat more than 95% of all annual and perennial weeds, including Agropyron repens, were controlled on minimum cultivation plots and more than 98% control was achieved on zero cultivation plots.

Table 1

Details of cultivation and herbicide treatments used in the experiment

Time of treatment	Conventional cultivation	Minimum cultivation A	Minimum cultivation B	Zero cultivation A	Zero cultivation B	Zero cultivation C
Autumn	P*	P	P			
Spring	DH (1)	A3587 (5kg/ha)	A3587 (5kg/ha)	Atrazine (5kg/ha)	Simazine (5kg/ha)	A3587 (5kg/ha)
	DH (2)	H (1)	A3587 (5kg/ha)	A3587 (4kg/ha)	A3587 (4kg/ha)	A3587 (4kg/ha)
Summer	DH (3)	D				
	DH (4)	H (2) D	H (1) D	Paraquat (0.8kg/ha)	Paraquat (0.8kg/ha)	Paraquat (0.8kg/ha)
	D (5)					

*P - Ploughing; D - discing between rows; H - Hand hoeing of rows

Table 2

Soil moisture (as % dry wt.soil) in relationship to the method of cultivation

Date	Conventional method (cultivated) Depth 0-60 cm	Conventional method (cultivated) Depth 60-100 cm	Zero cultivation method Depth 0-60 cm	Zero cultivation method Depth 60-100 cm
		Year - 1973		
20.IV	28.8	30.2	28.6	30.1
15.V	32.2	31.0	31.9	30.7
10.VI	28.6	29.6	28.4	29.4
13.VIII	26.6	26.4	25.3	29.1
24.VIII	13.2	11.7	12.5	12.0
19.IX	22.4	21.2	20.4	22.7
4.X	13.7	16.9	12.4	16.7
		Year - 1974		
8.IV	30.9	31.4	31.5	31.5
29.IV	31.2	32.4	29.3	32.3
9.V	28.4	31.7	27.1	29.2
29.V	20.7	19.8	19.4	20.4
11.VI	30.6	30.8	29.5	30.6
27.VI	28.2	30.3	28.5	29.5
13.VII	28.6	29.4	27.7	29.4
29.VII	32.1	32.7	30.3	30.0

Table 3

Effect of cultivation and herbicides on weed growth and fruit yield, 1971 - 1973

Treatment		Weed growth (September) EWRC scale 1971 P^+	M	D	1972 P	M	D	Dry wt. weeds (quintals/ha) 1973 P	M	D	Total	%	Fruit yield (%cultivated) 1971	1972	1973	Total
Cultivations		4	3	2	3	2	2	1.0	0	0	1.0	0.5	100 (275)*	100 (161)	100 (308)	100 (248)
Minimum cultivation	A	4	3	2	3	3	2	1.3	0.3	0.7	2.3	1.3	114	132	119	120
"	B	7	4	4	4	3	2	9.4	0	0	9.4	5.1	110	97	103	104
Zera cultivation	A	4	2	1	2	2	1	1.0	0.5	0.5	2.0	1.1	116	132	114	118
"	B	4	2	1	2	2	1	0.2	0	0	0.2	0.1	113	128	119	119
"	C	4	2	1	3	2	1	0.2	0	0	0.2	0.1	110	117	110	112
No cultivation and no herbicide		9	9	9	9	9	9	105	38	42	185	100				

*P - perennial; M - monocot; D - dicotyledonous weeds. *actual yield (quintals/ha)

These results demonstrated that almost complete control of perennial and annual weeds could be achieved by the use of herbicides without cultivations, the choice and use of these herbicides being determined by the weed species present.

Over the three years period covered by the work reported in this paper fruit yield from minimum and zero cultivation plots was equal to, or more than, the yield obtained from conventionally cultivated plots.

No difference was noted between the yield obtained from plots subjected to the same cultivation techniques but different herbicide combinations.

DISCUSSION

On the clay loam soils of Geoagiu, Romania, soil moisture content on zero cultivated plots was equal to that of conventionally cultivated plots that had received six mechanical and manual cultivations. This suggests that the most important benefit of cultivation was obtained from the control of weed growth and not from the retention of soil moisture. The tendency for fruit yields on conventionally cultivated plots to be lower than on the minimum or zero cultivation plots may have resulted from the destruction of part of the root systems of the trees during the winter ploughing.

Annual and perennial weeds were almost completely controlled during the 3 year period by repeat applications of atrazine and simazine in conjunction with A 3587 and paraquat.

The conclusion may therefore be reached that these modern methods involving the use of herbicides to replace conventional cultivation can be used to aid orchard management in Romania.

References

BANWELL,M.G. (1972) The role of herbicides in modern fruit management. Proceedings 11th British Weed Control Conference, 1002-1012.

COMAN, St. (1967) Rezultate privind folosirea erbicidelor in livezile de mar pe rod. Recomandari pentru productie in hortiviticultura. Red. Rev.Agr. Bucuresti, 1-10.

DAVISON,J.G. (1973) The use of growth-regulator herbicides in orchards. ADAS Quarterly Review, 9, 40-47.

MYRAM,C. and FORREST,J.D. (1970) The development of terbacil and bromacil for the control of Agropyron repens and other weeds in some fruit crops. Proceedings 10th British Weed Control Conference, 752-759.

PRICA,D., SARPE,N. and DUMITRACHE,I. (1972) Resultats des experiments concernant certains aspects de la lutte contre les mauvaises herbes avec herbicides dans les pommeraies en Roumanie. Notiziario sulle Malattie delle Piante, 86, 203-216.

SARPE,N. and PRICA,D. (1973) Combaterea pirului (Agropyron repens) si altor specii de burieni cu diverse triazine in livezile de mar. Revista Ferma si intreprinderea Agricola de Stat, 7, 14-16.

SCHMITLIN,B. and PIGOT,J.P. (1969) Lutte contre chiendent (Agropyron repens) dans les vergers à l'aide de l'aminotriazole et de paraquat. 5e Conference du COLUMA, Versailes, 178-180.

TECHNICAL AND ECONOMIC ASPECTS OF THE SUPPLY AND DEMAND FOR AGRICULTURAL CHEMICALS

Introduction by A.P. Ball Session Organiser

This session presented the first opportunity at BCPC conferences for a commercially orientated session. It could have been planned solely to discuss the economic aspects of the title of the session. However, at the time of session planning, it was uncertain what level of significance would attach to supply problems in Agrochemicals by November 1974. Thus a buffer was built into the session which at the same time gave a rather more gradual break into a commercial session by ensuring a reasonable content of technical contribution and discussion, on a subject which, whilst of minority interest, did seem to highlight some grey areas in respect of herbicide development for minor crops.

The brief given to the speakers, and as printed in the initial programme circular was:

"The past two years have seen many problems related to an apparent shortfall in supply of agricultural chemicals. Little has yet been said of how well demand was met at such a time. In addition to this topical aspect of this subject, other issues also warrant consideration and discussion. How does the agrochemical industry gauge demand and what parameters, both economic and technical, govern the meeting of that demand? How do Industry's decisions affect the merchant trade, as well as the growers? The grower of high value, small acreage crops such as vegetables and herbage seed is not always able to find a suitable supply of chemicals for use in such crops. The expensive development of chemicals for use solely in limited markets may not be justified by Industry. Do other organisations have a part to play here? It is well known that vegetable growers have technical problems in the use of herbicides and herbicide mixtures and programmes. What help is given by Industry, Merchants, ADAS, etc.? And what more could be done? The Session will permit each of a panel of speakers to give a short paper followed by open discussion by the panel and from the floor."

This brief is covered in the 4 papers presented. Mr. Bevington's paper gave valuable background on the critical supply problems, with some comment on future trends. Mr. Lidstone followed this up with his own experience regarding shortages from the merchant trade. He then led into a broader introduction to the technical problems facing growers of 'smaller acreage' crops. Mr. Hobcraft highlighted the complexity of the programmed use of Agricultural Chemicals used in large scale intensive vegetable producing units, and the degree of co-operation offered in developing chemicals for use on minority crops. Finally, Mr. Whitwell gave some stimulus to all involved by his suggestions as to how 'minor-use development' could be approached. His paper included an example of a cost-benefit exercise, justifying his proposed approach to such problems.

Under the chairmanship of Mr. M. Barker, Agricultural Development and Advisory Service, all speakers fulfilled their brief. It was appreciated that the whole session could have been devoted to the purely economic problem of supply, and it was quite clear that this would have been appreciated by a number of delegates. Being the first time that such a commercial subject has featured in a BCPC conference, overall comments were very favourable. It is to be hoped that such a venture, albeit with even greater commercial content, may well be both pertinent and acceptable in future conference programmes.

Proceedings 12th British Weed Control Conference (1974)

TECHNICAL AND ECONOMIC ASPECTS OF THE SUPPLY AND DEMAND FOR AGRICULTURAL CHEMICALS

A Merchant's View

D. G. Lidstone

W. A. Lidstone Ltd., Grove Mills, Lake End Road, Taplow, Berkshire.

The title of this session belies the very much wider brief that is set out in the summary following it in the original programme and there are some aspects of the subject that I shall not attempt to cover, but will leave to one or more of the other members of the panel far more able than I to comment on them, and you have already heard a manufacturer's comments. Please bear with me if I sound a little parochial but my business in agrochemicals covers only a comparatively small area; however it does have in the area something well in excess of 5,000 acres of intensive market gardening with, I suppose, as wide a range of vegetable crops as you will find anywhere in the country. And, I would add, these crops are all for the 'fresh' market.

So far as problems of supply and demand are concerned I think that in the past season we have heard more talk of shortages than we have in fact suffered them. In my own area I think I can honestly say that no customer has been without the product he needed or a perfectly acceptable alternative by the time he needed to use it. Certainly there have been some 'touch and go' situations where this desirable state has but barely been achieved, and certainly there have been a few exceptions where a farmer or grower has been let down because of a merchants inability to supply; but they have been, in my opinion, minimal. I suppose that the only really difficult products this season (and here I must repeat I can only speak for my own area, but I believe this also applied nationally) were phenmedipham, TCA, ioxynil, mevinphos and dimethoate granules with paraquat being a little difficult at times.

Looking ahead for a moment to next season it would seem that, all things being equal, we shall not see lesser quantities of raw material, and hence finished product, being supplied to the trade by our major manufacturers but it is highly probable that there is less 'carry-over' stock in merchants stores than there was at this time last year; this could well mean less over-all being available to the farming community between now and the end of next spring. On the other hand, the position is yet further confused by the number of farmers who, last autumn, after a season of high cereal prices, shopped around and covered their 1974 requirements of pesticides well in advance of their normal buying pattern and then bought again in spring 1974; this latter purchase will then be on their farm for usage in 1975 when they may or may not buy again according to the state of their own exchequers. I think that in particular the shortage of paraquat was caused, or at least accentuated, by this factor.

There is little doubt that the true stock on farm and in store situation must be very difficult to assess. What is certain is that, by and large, our own U.K manufacturers do seem to have played fair with U.K agriculture and though in many cases product could have been sold at much higher prices abroad, they appear to have channelled approaching, if not up to, normal quantities onto the U.K market.

It remains to be seen whether their shorter term responsibilities to their shareholders will again this year be out-weighed by their consciences and their need to ensure the long term retention of their share of the U.K market.

I must point out that I prepared this paper some weeks ago and since then a few facts have come to light which would seem to indicate that if I were writing it now it would be with 'tongue in cheek'. However I still think that so far as cereal hormone weed-killers are concerned we shall get by, just as we did this last season. We may well however have greater difficulties in the realm of the more specialist products; methazole, or rather the complete absence of it, is a case in point.

If I may put in a plea to our manufacturers and suppliers on behalf of myself and my merchant friends it would be for you to pay more attention to keeping us - and hence the farmer - 'in the picture' so to speak as to availabilities of products; suppliers vary greatly in their approach to this problem, some are very good and some are appalling.

The mention of manufacturers profits brings me into the next section of this paper. We have the situation in this country whereby for any new product to be successful it virtually has to be listed under the Agricultural Chemicals Approval Scheme. The resulting amount of costly trials and toxic residue work means that it is quite likely that a new product looking promising for a wide market such as that of residual weed control in potatoes or of blackgrass control in cereals will only be developed for that very purpose with possible further uses on minor acreage vegetable and fruit crops left unexplored. And with the vicious escalation in research and development costs it would seem likely that this position must worsen; manufacturers will only be interested in developing products for the uses with very large potential.

We shall then have the situation whereby many vegetable crops will receive but scant attention by manufacturers for the simple reason that their potential is so small. Who is going to be really interested in developing products, or even developing the extension of existing products, for say, leeks, when a total of only 3,000 acres is grown in the country; or for parsley when there are only perhaps 250 acres grown. And yet we are talking here of high value crops where a high cost of chemical is perfectly acceptable to the grower.

Again, take the lettuce crop. It is estimated that nationally 19,000 acres are grown in open ground annually. With the labour situation as it is now, and looks like being in the future in the industry, growers of this crop would find a cost figure of £12 - £15 per acre perfectly acceptable for good crop-long weed control over a wide range of annual weeds and grasses.

If it is then accepted that manufacturers are not commercially interested in comparatively small acreage specialist crops simply because of the costly trials and clearance work involved, have we any alternative way of getting some of this work done. I think we have. I think that we have, amongst our vegetable growers, many highly professional growers who would be more than ready to be involved in some proper trials work and would be prepared to give ground and crop for this purpose. We then need a body that can be responsible for setting up the necessary trials and keeping all the relevant records and data. Surely here is an area in which our local ADAS organisations can be involved ? Surely this sort of work could be a logical extension of its existing work and responsibilities. They would need access to sophisticated laboratory facilities for residue analysis work and in this sphere surely manufacturers would be prepared to help ? New techniques of analysis often need to be developed specifically for new products and once a manufacturer has himself developed these for use on an existing chemical being marketed for wider use it would surely be comparatively easy for him to co-operate in this way.

I think that manufacturers themselves, the ADAS organisation, the Vegetable Research Stations, processors fieldsmen, and the chemical specialists working for companies such as mine, as well as growers themselves, all have a part to play in presenting information that would give guidance as to what products should be investigated for possible potential new uses on the smaller acreage crops. Co-operation from all sides is what is required.

Without some such scheme I think we shall see an increasing "experimental" use of pesticides by certain growers themselves as they become ever more ready to turn to anything that may help in the ever more difficult labour situation; and some of these uses could well unwittingly involve toxic residue situations ! If growers know that they could refer such uses to an organisation like this for official sanction it would go a long way to minimising possible irresponsible usage.

Developing this theme a little further is it perhaps possible to envisage a local committee operating in each major vegetable producing area. It should be small and would perhaps consist of one or two grower representatives from the local market garden community, a member of ADAS, and one or two merchant chemical specialists or processors fieldsmen. They would meet as often as necessary, perhaps four or five times a year, and discuss generally the pesticide situation inasmuch as specific deficiencies of existing products within their area were concerned. There would be suggestions, perhaps, as to how a particular existing product might be adapted to further uses. ADAS, if they considered it a practicable suggestion, would then contact the manufacturer and put the position to him and would be given (I would like to think) a large degree of co-operation by them, they releasing to ADAS details of any of their trials on the crops in question and any toxic residue data which they may already have. These discussions would probably resolve whether or not the suggested extension of use might be practicable.

If it was decided to go ahead, ADAS, with the co-operation of local chemical specialists, would be able to arrange for proper trials to be carried out over a range of conditions within the area and for the subsequent necessary assessment of residues by manufacturers. I would like to think that the results obtained may perhaps then be used as the basis of a "limited use" recommendation by the manufacturer, even relating possibly to only a specific area of the country.

There is in fact an example locally of the sort of co-operation I have envisaged above. Two years ago one of our growers appealed to ADAS for more help in controlling 'White Tip' in leeks. ADAS posed the problem to Wye College who, in conjunction with two local ADAS offices and our own chemical specialist, laid down a number of trials with local growers using Captafol. Excellent control was obtained; they approached the manufacturer for residue analysis which was readily undertaken and we now have a firm recommendation for the use of captafol in controlling 'White Tip'. As I remarked earlier there are only approximately 3,000 acres of leeks grown in the country; hardly sufficient incentive in the way of increased sales for a manufacturer to carry out costly trials work. Compared with sales for the potato crop the added potential for leeks would have been negligible.

Leaving now the question of the extension of use of existing products let me turn to another area in which growers receive little help from manufacturers or from ADAS; the former because they say "they don't know" and the latter, I suppose, because they daren't say ! This is in the use of herbicide mixtures - some would say 'cocktails' but I think this conjures up pictures in the mind of all sorts of witches brews ! I refer to tank mixes of two herbicides each designed to take care of a specific problem in the crop. There come to mind, in particular, the use of mixtures of propyzamide and sulphallate/CIPC mixtures on lettuce; chlorbromuron/metoxuron and prometryne/metoxuron mixtures on carrots. In these three instances we are considering products from different manufacturers and seldom it seems will one manufacturer give a firm recommendation for the use of one of his products in conjunction with one of another manufacturers'. One can appreciate the position which each finds itself in; sometimes each will be maintaining that it has the whole answer to the weed control situation in its own product anyway; or that such recommendations could involve a too free exchange of manufacturers specialist formulation "know-how". But where experience has shown a mixture to give better overall weed control under some or all situations is it not time that heads were taken out of the sand so to speak, and that information was exchanged, perhaps resulting in a joint label recommendation.

I hope I have adequately indicated my concern that the minor acreage (and indeed most vegetable) crops are likely to take less than second place in the queue for new developments in the herbicide field. A recent article in the grower press maintained at some length that this was not, and would not be, so. With the realities of commerce as they are today I fear I cannot subscribe to this view.

Proceedings 12th British Weed Control Conference (1974)

TECHNICAL AND ECONOMIC ASPECTS OF THE SUPPLY AND DEMAND FOR AGRICULTURAL CHEMICALS

A Farmer's View

R.L. Hobcraft
L.S. Sayer and Son Ltd, Thanet

In recent years there has been an undoubted acceleration in the development, diversification and distribution of available agricultural herbicides. This increase has been made in the light of a rapidly expanding demand over a wide range of crops. With the greater knowledge of specialist growing techniques ranging from the seed merchant to the machinery manufacturer, then the agrochemical industry is, of necessity, being called upon to play an ever increasing part in the picture. This inter-relationship within the allied agricultural industries is a chain within which the farmer is looked upon with varying degrees of sympathy. In this respect the so-called specialist grower can find himself less well equipped when it comes to the practical availability of the right 'tools' for the job. In our turn we are all specialists, although acreage demand will often dictate overall supply.

The vegetable grower is dealing with potentially high value cash return crops integrated into a relatively inflexible close cropping programme. In this system the emphasis has to be on timeliness of operation with close attention to a balanced herbicide programme allowing for little margins of error. For certain crops we have such alternatives available as herbicides for pre-drilling incorporation, post drilling pre-emergent residual and contact sprays.

Specialist crops develop within areas of specific soil and climatic type. Such factors invariably produce weeds unique to both area and, hence, crop. With costs continuing to rise for all items of production, whether it be seed, fertiliser, machinery or labour, then a greater degree of efficiency must be required from all factors, of which herbicides are not the least important.

Thus a demand is created for a high value specialist crop within a rotation with specific weed problems associated with that climate and soil type. It is then that we as growers look towards the agrochemical industry with its extensive powers of research and advice. For the full benefits to be found, then close co-operation must be forthcoming from all departments of the industry. We wish for unbiased advice in the selection of suitable materials. We must be made aware of the inter-relationship of two chemicals, whether being used in the same mixture or just within the same spray programme. Equally important is the overall effect under varying weather conditions on both crop and weed. We are frequently alarmed by the claims made for the length of residual chemical reaction by some manufacturers. The added bonus of extra weeks protection by higher concentrations of active chemical ingredient is often not required by those growers following a close double cropping programme. In fact it is not just a waste of material and, of course, money, but often has an inhibiting effect upon the germination of the second drilled crop.

We all farm in a delicately balanced ecological state, where a weed is a plant out of place. The correct choice of chemical can tip the scales in the direction of success or, alternatively, can bring into prominence weeds hitherto of little significance. Manufacturers must be well aware of these changing patterns and needs: research programmes must be kept flexible and intercommunication between growers and the agrochemical industry plays a vital part in the development of the needs of growers today. We have always found that to extend this co-operation to the level of providing facilities for experiments gives us ultimately the greatest benefit. It is in this way that we can assess the performance of seed varieties, sprays or machines within our own farming situation of climate, soil, weed type etc. Often we find ourselves judging the results of sprays on crops other than those for which it was initially developed. It is from this extension to the work that is basic to any experimental development study, that we can derive the most help in extending spray programmes ahead. Within the last twelve years we have found ourselves involved in the early development of sprays such as the residual herbicides on potatoes, different soil incorporation techniques, the inter-row contact spray machines and latterly the work with Paxilon on onions and related crops. As a result of such trials we look for rapid availability of successful products, and naturally find it frustrating when the agrochemical industry is not quick to meet our new found demands.

Despite the pioneering experimental work conducted at research station or farm level, which can 'throw-up' a potentially sound commercial chemical, we are informed that its subsequent development is impractical. Reasons given are that its likely market sale would be uneconomic for it to be manufactured, priority being given to the bread and butter chemicals with a guaranteed estimated sales potential. To a grower seeking to improve his husbandry techniques this is the ultimate in frustration, and the recent news that Methazole, or Paxilon as I know it, is unlikely to be manufactured for next year by the Velsicol Chemical Corporation puts us back several years in this line of onion herbicide research. Whilst realising that companies have to make marketing policy decisions based on economic principles, surely here is a case that must warrant some reconsideration.

In our own situation, in round figures we farm 750 acres consisting of 220 acres of early potatoes, 100 acres of bulb onions, 200 acres of winter greens and cabbages and 230 acres of grass seed. Throughout the year we spray 3,000 acres, divided almost equally between insecticides and herbicides. In this current year spray materials have cost about £15,000, or an average of four sprays per acre at £5 each. Interesting figures I believe, that reflect not only the increasing price, but also the increasing reliance over the years in the effectiveness of available materials, coupled with the accepted wide-spread use of the precision drill.

In our close cropping programme, this year's crop can be next year's weed problem. Potatoes in greens, and grass in onions can be problems unique to our situation. At the present time we are co-operating into the use of certain sprays on our herbage seeds for the control of other grass species. This aspect of our farming has been brought to prominence recently with the increase in returns for herbage seed production and the more rigid E.E.C. regulations governing the finished samples.

Session Organiser's Note

Mr. Hobcraft then illustrated the complex spraying programmes used in his own farming system. These slides highlighted some of the problems, particularly on onions and brassicas faced by the intensive vegetable grower.

Proceedings 12th British Weed Control Conference (1974)

TECHNICAL AND ECONOMIC ASPECTS OF THE SUPPLY AND DEMAND FOR AGRICULTURAL CHEMICALS

Problems of Herbicide Usage on Minor Crops

J. D. Whitwell

Agricultural Development and Advisory Service, Luddington Experimental Horticulture Station, Nr. Stratford-on-Avon, Warwickshire, CV37 9SJ

Summary The low commercial acreage of certain horticultural crops in the U.K. excludes the development and manufacture of herbicides for specific use on them, and this does create difficulties for a number of producers who rely on these crops for a livelihood. The problems which arise in obtaining PSPS clearance for extended use of herbicides on minor crops is discussed, and reference made to wasted effort in trialling discontinued chemicals, and discussing results from such trials at Weed Control Conferences, and a plea is made for the operation of a co-ordinated system to prevent this.

A cost benefit exercise balancing the cost of obtaining clearance for a very minor crop use against the benefit to the horticultural industry is discussed and cases quoted where good herbicides have been withdrawn, or discontinued for some reason or excluded from sale in the U.K. Such cases are rare, and the manufacturers and developing companies usually make a good job of sifting the herbicides suitable for horticulture crops from the large number produced for agricultural use each year. Nevertheless the author feels that these useful herbicides could be cleared more quickly for minor crop use by better co-ordination of the interested parties and a more organised approach to experimentation. The advent of herbicide combinations and mixtures and the need for more information on compatibility, possible synergistic effect, and phytotoxicity is also discussed.

INTRODUCTION

It has been suggested by sections of the horticultural industry that new crop pesticides suitable for horticultural crops are not coming forward as quickly as one might expect in view of the tremendous developments in the chemical industry, and that this unsatisfactory situation stems from the onus placed on manufacturers to collect and provide information for the authorities in order to obtain clearance and approval for these minor uses.

The problems are accentuated by the changes in manufacture, development and trading in agricultural chemicals which has resulted in fewer larger companies operating on a world-wide scale, with only indirect interest in small acreage horticultural crops when the profits necessary for commercial Research and Development are derived from cotton, cereals, rice, vines and others of major agricultural importance.

This means that growers of horticultural crops have to utilise herbicides developed for use in these major world crops and this places the horticulturist in a relatively weak position, because clearance under the Pesticides Safety Precautions Scheme may not have been sought or granted for the minor use proposed. Fortunately the flow of new chemicals does not escape the notice of the manufacturing and development companies who endeavour to extend their use to minor crops where possible. This search by the companies, together with the screening work conducted at the Weed Research Organisation and National Vegetable Research Station successfully sift out the herbicides that have some potential for horticultural use.

Nevertheless, there is always the fear that because the manufacturers aim at world markets, and application to staple crops, some of the spin-off for minor usage may be missed, or ignored, and preclude the use of some chemical on a specialist crop where weed control is limiting production. Fortunately such cases are rare, although a few exist.

In order to obtain PSPS clearance for a new herbicide on minor crops or extend the use of an existing herbicide it is necessary to coordinate trial and development effort at an early stage before trials commence, this becomes clear from study of the regulations scheme outlined in recent papers by Jones A G, and Makepeace R J.

Lone trials by individual officers may provide information, but are of little value if they don't contribute to the herbicide being cleared for commercial use. Manufacturers can help considerably by being as quick to inform interested people that they have ceased to develop a chemical, as they are to distribute it for trial purposes. There are four rules that should be observed when trialling new herbicides

1. Check that the herbicide has trials clearance for the crop in question and if not find out why.
2. If the trial is on new agricultural herbicides which require clearance for extended use make sure the manufacturers are made aware of your interest, and are willing to submit the chemical for clearance on the minor crop.
3. Plan and organise the experiments so that full information is available on phytotoxicity, and the correct range of dosages are included for crop residue tests.
4. Always consult the big three, viz, the manufacturer of the herbicide, those responsible for Agricultural Chemical regulations in the UK, and the statistician to make sure the trial will provide the information required.

Observance of these rules inviting proper consultation will eliminate time wasting effort on none-starters and provide the evidence necessary for clearance as quickly as possible.

In June 1974, the first report of the Horticulture Board of the Joint Consultative Organisation (JCO) for Research and Development in Agriculture and Food included a statement to the effect that one problem facing the agricultural chemical firms is the relatively small outlets for pesticides in horticulture and the high cost of clearance through the Pesticides Safety Precaution Scheme. They felt that there may need to be some method of giving assistance to firms in the development of new pesticides to ensure that growers continue to be provided with efficient means of pest, disease and weed control.

This recognition of the problem by the JCO is of interest and one hopes that due weight will be given to it by the three sponsors, MAFF, ARC and DAFS and the Chief Scientists Organisation when the reports from the various Boards of the JCO are considered for fund allocation. Meanwhile the Horticultural Industry must provide for itself and the screening tests for new agricultural herbicides for extended use goes on.

The cost benefit approach is one way of determining the value of clearance of a herbicide to the Industry and to the manufacturer, although it might be argued that cost benefit techniques have not yet been devised which would enable correct assessment of R and D priorities to the satisfaction of the JCO for Research and Development in Agriculture and Food.

Horticulturists are also interested in herbicide mixtures not only for weed control over a wider spectrum but also to determine possible synergistic effects at low dosage rates, which may offer advantages in cost and reduce the problems of residue and environmental pollution. Sweet D R et al 72 at Cornell University reported that this effect has been extensively proven in the United States.

Evaluation of herbicides for minor use

The need to use a herbicide on a minor crop is of most interest to Growers and those conducting herbicide trials on farms or Experimental Centres. Problems arise when the manufacturers cease to develop a new chemical included in the trial for technical or other reasons, or have very little enthusiasm for extending the use of an available substance in short supply. This intelligence may or may not be imparted to the enthusiasts conducting the trials and on occasions the results obtained from defunct chemicals are solemnly read out in Conference proceedings.

Clearly there is a need for early discussion outlined in the Introduction to this paper to prevent this happening and to establish that the chemical, if a new one, will be manufactured or that the manufacturers are interested in clearing an existing product for the minor use proposed.

In addition, the choice of trial sites, treatment rates, experimental design and laboratory techniques for residue testing should be agreed at this early planning stage.

If the herbicide is being tested for extended use the trials would start at year 3 (at least) on the 7 year, full commercial clearance cycle, and the early discussions would decide the mode of trialling to provide adequate data for clearance under PSPS and possibly approval under ACAS.

Some crops still require a satisfactory herbicide but it is readily conceded that manufacturers would find it uneconomic to develop one for such use or even extend usage of suitable existing ones. Examples of these crops are given in Table 1.

Minor use crops in which herbicides are unsatisfactory and there are weed control problems

UK Production

	output 1000 tonnes	area 1000 ha.	Value £000
Courgettes and marrows	4.6	0.1	230
Lettuce	131	7.9	12,937
Direct drilled leeks	26	1.1	1,934
Swedes & Turnips for human consumption	118	3.2	1,900
Runner beans (and French)	89	8.8	5,500
Spinach	5	0.15	500
Cauliflowers (post emergence)	292	16.1	15,047
Navy beans	0.9	0.48	150

A cost benefit approach to justify the use of a herbicide on a minor crop

Any attempt to determine the feasibility of extending clearance of a herbicide to a minor crop may prove disappointing but there are other criteria worthy of consideration such as

1. The crop may have potential for expansion or export.
2. The crop may be important to a particular locality in supplying a specialist outlet.
3. In the absence of an effective herbicide, weeds may carry diseases which seriously affect production, eg, cucumber mosaic virus on courgette marrows.
4. The knowledge that an available herbicide is suitable but cannot be used because no application was made for PSPS clearance encourages growers to take risks and use it anyway, eg, Cyanazine on Brassicae. To prevent this undesirable practise the chemical should either be cleared quickly for minor use, or reasons given why it is withdrawn.

Taking the case of courgette marrows, one is confronted with a very marginal case on cost benefit evidence.

(a) There are only 230 acres of crop grown in the UK (although this is still increasing).
(b) Methazole has shown promise at Luddington EHS for pre emergence weed control at the low rate of 0.5 lbs ai/acre of 75% product, or 0.7 lbs commercial product per acre.
(c) This is equivalent to a total usage of only 161 lbs of "Paxilon" or "Probe" valued at approx. £1,370, which clearly represents insufficient extra trade to interest the manufacturer.

Growers however might argue that the problem is a real one for them and merits some consideration. To them the following facts apply:-

(i)	230 acres of courgettes and marrows total gross output		£230,000.00
(ii)	Hand weeding costs £27.00 per acre		£6,200.00
(iii)	Methazole used on total acreage		
	chemical cost 230 acres x 0.7 lbs x £8.5		£1,370.00
	application cost 230 x £1.40		£320.00
	Total cost of herbicide application		£1,690.00
	This is equivalent to £7.30 per acre		
(iv)	The use of the herbicide would therefore save growers £20 an acre (hand weeding less chemical)	total	£4,600.00
(v)	10% loss in yield (equivalent to £100.00 per acre) due to weeds carrying mosaic virus		£23,000.00
	Total savings possible on present acreage		£27,600.00

(vi) Putting it another way the lack of suitable herbicides for marrows is costing the growers up to £27,600.00 per annum.

The loss of £27,600 by a few marrow growers must be balanced against the sale of an extra 161 lbs of a product already in short supply. Hardly sufficient incentive for anyone to seek extended clearance. However, there is a need to pursue this bearing in mind that the facilities for doing so already exist, and may even be improved in the future following the deliberations of the Joint Consultative Organisation for Research and Development in Agriculture and Food.

To make the case one should look at the cost of the R and D necessary, which in the marginal crop of marrows is as follows.

The cost of obtaining PSPS clearance for marrows

1. Cost of conducting a 1 acre trial

Materials cost to grow 1 acre experiment courgette marrows

Materials	Quantity per acre	Price	Cost
Seed	4 lbs	£8.00 per lb	£32.00
Fertilisers - base	8 cwts	£34.90 per ton	14.00
top	5 cwts	£28.00 per ton	7.00
Water (Irrigation)	44,000 galls		1.00
Tractor fuel oil	4 galls	25 p per gallon	1.00
Paraquat	3 pints	£10.64 per gallon	4.00
Methazole	1 lb	£8.50 per lb	8.50
		Total	£67.50

Labour requirements per acre

Operations	Regular labour man/hrs	Casual labour woman/hrs	Tractor hours
Ploughing	2		2
Cultivations and fertiliser application	2		2
Applications of paraquat	1		1
Sowing seed	1		1
Application of herbicide treatments - knapsack	8	8	
Weeding control plots by hand		9	
Top dressing by hand	8		
Irrigation 2"	6		
Marking out plots	4	4	
Harvesting		72	
Recording	10		
Miscellaneous	10		
Total	52	93	6

Labour costs:	52 @ £1.00	=	£52.00
	93 @ 50p	=	46.00
	6 @ £1.00	=	6.00
	Total	=	£104.00

Total Costs

Cost of materials	£67.00
Cost of labour	104.00
Rent	20.00
Cost of statistical analysis	50.00
Cost of residue analysis	100.00
Total costs	£341.00

The approx. cost of running 1 acre of trials is	£340.00
but since three sites are considered necessary this will be	£1,020.00

The outcome of this study shows that to solve the herbicide problem in marrows, it is necessary to spend £1,000+ to gain clearance for one pre-emergence residual herbicide which it is estimated will save the growers between £4,500 per annum and £27,000 per annum.

Problems of development and availability of new herbicides

It is desirable that new herbicides should be assiduously screened each year for horticultural use so that those showing selectivity can be put in trial at the first opportunity, but it is important that those which do go into such trials have more than an even chance of going through to the commercial stage for use by the industry. Experimenters are always inquisitive and keen to grasp new products as they become available, but this enthusiasm can be mis-spent on none-starters.

Good examples of these in the UK are PH 4021 which had trial clearance for peas and beans in 1969 and showed promise in trials throughout the country. The chemical was not manufactured. The Coded Chemical UC 22463 known as Sirmate had trials clearance for Sugar Beet and Dwarf Beans in 1967 and was eagerly picked up by those seeking herbicidal crumbs for horticulture. It has not been heard of again until this year when rumours suggest it may reappear. 2900H Prynachlor or Butisan had a good round at the 1972 Conference when it featured in a number of papers, but although it had trials clearance for Cabbage, Onions, Maize, Swedes and Rape it is still unavailable for commercial use in the UK and has not received commercial clearance. PP493 Holoxydine had trials clearance in 1970 for cereals and Brassicae and was included in trials reported at the last Weed Control Conference, but it has been withdrawn by the manufacturers. Delachlor or Butachlor received trials clearance in 1967 and 1970 but has been dropped subsequently for commercial reasons. However to restore confidence in the previous proceedings "Devrinol" or napropamide, a persistant soil incorporated herbicide has received provisional commercial clearance for Swedes and Rape and pre-drilling or transplanting on Brassicae, peas and potatoes.

Herbicides which are available in other countries but not in the UK

Occasionally useful herbicides are unobtainable in the UK.

"Lir-Onion" or difenoxuron at 5 kg/ha gives good weed control in onions post emergence when the crop is 5 cms high and although widely used in Holland and elsewhere in the EEC, it is not available in the UK.

"Lir-Onion" gave very good results at Kirton EHS in 1971 when applied to bulb onions at 5 kg/ha at the post crook stage when the weeds were very vulnerable. There are few post emergence herbicides available for onions which can be used post crook and there is no doubt that "Lir-Onion" would have helped growers in the UK, particularly if they missed pre-emergence herbicide application. Another example is Alachlor, Methachlor or "Lasso", widely used in Holland for pre-emergence use on Brassicae and now cleared for this purpose in the UK. However it is not freely available in the UK presumably because it has no advantages over Ramrod. This fact has never got over to Growers who read articles in the Trade Press written by visitors to Holland, and assume that they are being deprived of a herbicide available in other areas of the EEC. This brings focus on the problems of writing about chemicals in the Trade Press; and those that do so have a responsibility to state all the facts and not just those that interest them.

Examples of Herbicides cleared for use on major crops but where clearance is not actively sought for use on minor crops

Typical examples here are methazole for minor use on courgettes and marrows, methabenzthiazuron "Tribunil" on onions, "Bentazon" on onions, Cyanazine on brassicae (Cyanazine has PSPS clearance for use post emergence on onions on Fen soils only but is not cleared for use on Brassicae even though it is reported that growers in the SE region are using it for this purpose.)

Examples of New Herbicides showing promise for horticultural crops which have not yet received clearance for commercial use

Examples of these are Dacthal or chlorthal dimethyl on a wide range of crops. Difenzolium "Avenge" for use on onions, carrot, cabbage and lettuce for control of wild oat and a few major broad leaved weeds, benzoylprop ethyl "Suffix" for control of wild oat in onions, leeks, carrots and brassicae. Bidisin has received final clearance for use as a wild oat control in carrots. Oxadiazon "Ronstar" which has been suggested as having some value as a herbicide on carrots and celery has so far only been notified for outdoor grapes. It is reputed to give good control of bindweed.

Herbicide combinations, and herbicide mixtures

For a long time growers have mixed the pre-emergence contact herbicides paraquat and diquat with pre-emergence residual herbicides such as pyrazone + chlorbufam, even though this is not advised on grounds of chemical reaction between the two. Other mixtures have also been tried such as trifluralin + propachlor in brassicae, bentazon + pyrazone + chlorbufam on onions and a number on lettuce such as trifluralin + chlorpropham, propyzanamide + chlorpropham and propyzanamide + sulfallate. Azolomid + lenacil is suggested for red beet and trifluralin + chlorthal methyl (S1445) for marrows and there are a number of others.

More recently, Sweet D R, Duke W B, and Minotti P L at Cornell University have reported a synergistic effect which boosts the weed killing power of certain herbicide combinations. They state that the increased potency gained when herbicides are mixed is extensively proven and quote that as little as 4 ozs of Atrazine + 4 ozs alachlor per acre gave excellent weed control throughout the growing season on sweet corn. These small doses combined gave much better results than either of the single chemicals applied at the recommended dosage rates or a mixture of both chemicals at standard rates.

We require more information on possible combinations of herbicides that can be mixed in the tank for specific horticulture uses, herbicide compatibility particularly when the products come from different manufacturers, and the synergistic effects of herbicide mixtures or combinations.

One final problem that is consistantly reported by Advisers and Growers is the absence of small packs, which would assist growers to carry out spot treatments by knapsack sprayer. Small measured quantities in sachets would be helpful in these circumstances.

Acknowledgements

The Author wishes to thank especially A G Jones, R J Makepeace and H Roberts for time given to discussion on various aspects of the Paper, and also many ADAS colleagues who kindly volunteered information and in particular G C Williams who made valuable comments on the draft.

References

Jones, A.G. (1974) Report by ADAS Liaison Unit at ARC Weed Research Organization, Yarnton (unpublished).

Makepeace, R.J. (1972) Regulatory schemes of applicant countries to EEC. Proceedings 11th British Weed Control Conference, 1041-1050.

Sweet, R.D. et al (1972) Herbicide combinations. The American Vegetable Grower, March 1972.

Proceedings 12th British Weed Control Conference (1974)

TECHNICAL AND ECONOMIC ASPECTS OF THE SUPPLY AND DEMAND FOR AGROCHEMICALS

An Industry View

H.L.S. Bevington

Fisons Ltd., Agrochemical Division, Harston, Cambridge, CB2 5HU.

INTRODUCTION

The supply and demand of agricultural chemicals has never been discussed as part of any previous British Weed Control Conference. It has become an important and topical subject within the last two years and I am very glad that we have all been given this opportunity to discuss some aspects today in the Conference.

I am honoured by the invitation to give an industry view on the subject, but must stress that I can only give one view. I cannot do justice to the whole subject and will therefore pick those parts that I am personally best able to speak to. My intention is to look briefly at the overall supply and demand both historically and at the moment, and to point out the limitations which are affecting all manufacturers to a greater or lesser extent. I will then look forward in general terms to how we forecast demand and supply and how we determine development priorities and timescales, especially for smaller uses of new or existing chemicals.

GROWTH OF DEMAND

The first thing that needs to be said is that until last season the world demand has really been met without any major problems for at least a decade. This is worth remembering because during the period 1962 - 1972 sales for all agrochemicals worldwide multiplied three times - about 12% per year compound. Weedkillers have grown faster than this average - at nearly 20% per year in the United Kingdom for example. These rates are far above the industrial average. Inflation has not played a large role until very recently, as traditionally product prices declined almost annually - though this may already be hard to recall.

This rate of extended growth is a very high achievement reflecting credit on users, advisors, distributors and manufacturers alike. We are convinced that the results have given enormous benefits to agriculture, as well as transforming the manufacturing and distributing industries involved. This rate of growth however gives problems, especially as an individual product, or group of related products, may grow by far more than this in any one year. I need only point out the exceptional growth of the use of wild oat killers in cereals over the last two years. This would have been hard for us to predict with complete confidence say four years ago. It is therefore against this background of rapid growth over a long period that I would now like to look at the present position.

PRESENT POSITION

Everyone already realizes that the oil crisis triggered all the talk, and the occasional reality, of product shortages as well as accelerating the rate of inflation enormously. I would like to attempt to explain - in non chemical terms - how the oil crisis, and other factors, brought about such a rapid change in the balance between supply and demand after so long a period of coping with high growth. The main technical factors which influenced the position are:-

1) The highly seasonal nature of so much of agrochemical demand - the chemicals are all used in a short period and manufacturers and distributors have to build stocks well in advance to meet the high demand.

2) The agrochemical manufacturing plants are the end of the chain, or network, or intermediate chemical plants leading back (or "upstream" in chemical industry jargon) to the basic petrochemical plants and other major raw material sources. The primary intermediates (e.g. Phenol) are usually those used in many industries beside agrochemicals, while those second or third downstream are often nearly specific to agrochemicals (e.g. chlorcresol).

3) It takes some time for products to pass downstream through these plants to the final agrochemical plant and user - anything from about 6 - 18 months to the user.

When the price of oil was quadrupled and supplies reduced, allocations were essential, especially as the value of oil as a fuel exceeded its previous value as a chemical source. These upset the closely balanced operation of the petrochemical plants and then the primary intermediates. In the particular case of phenol, there was also a fire in a major European unit at the critical time last year which severely, but temporarily, reduced supplies affecting particularly the hormone weedkillers.

Thus from the physical supply side there were a number of disruptions, mostly quite shortlived, but a few of which are still with us. From the demand side, came a rapid and early pressure at least as great as any met in previous years.

A lot of this came from our "normal" increase in demand, especially as the North American crop acreage had been substantially increased, but some was undoubtedly due to the prospect of rapidly increasing prices and potential scarcity. It is worth pointing out that the sharp rise in world agricultural prices following the huge food shipments to Russia, India, Bangladesh and Ethiopia etc., also intensified agrochemical demand.

This early season then caught the downstream plants stretched to maximum operating capacity and led to delays in supplying some of the traditional Autumn purchases. The result is well known to most of us - allocations, nearly all based on previous purchases, which lasted all the season. My own estimate, and here I would value the opinion of others, is that last season's U.K. demand in general terms was very nearly met - say about 5-10% short, though deliveries were often closer to the use period than is desirable, and of course some individual products fared far worse than this. I have the impression that North America and parts of Europe fared worse than we did in the United Kingdom.

For this coming season there is certainly no reduction in world agrochemical demand as far as I can see, in spite of the increased costs of products. In this context, it is worth noting that in the U.K., weedkiller prices have trailed behind cereal crop prices over the last few years, and many other costs. The demand however is again early and there are generally lower starting stocks to meet it than last year - we all regret we have not seen the end of allocations and I personally believe that the tight supply position will remain with us for most products for the whole of this coming season across the world. Some individual products of course will be relatively freely available while others extremely short indeed. Beyond this season it is really impossible to forecast accurately - the future depends on the degree of recession in other industries affecting raw material supplies, and the support given to agriculture. This then leads me to the next point - how do we gauge demand?

DEMAND FORECASTING

I would like to highlight two aspects at opposite ends of the scale. The first is the type of forecast required for an investment decision for a major new plant, whether for a new product or an increase to existing capacity. The key is that it is a long term forecast - you are concerned with the period 3 - 15 years ahead. It therefore has to be something of a broad brush approach, though using past growth trends and present crop and competition economics. The technical prospects are seldom really clear, let alone the forward economics when such decisions are made - frankly all such forecasts, on which the eventual product supply hinges, are no more than well informed guesses, and no amount of market research, by individuals or governments, can assure you of a correct answer.

At the other end of the scale is how much chemical are we to make for next season or the one after that. This is very much open to market research, and the feedback we get from users and distributors is invaluable. To be short means dissatisfied customers and lost profits, to make too much ties up working capital which no-one can afford - particularly now. The interesting feature I would pick out in comparing these two extremes is the influence of field development -large in the first, perhaps neglible in the second. It is the key to my next point on smaller uses which other speakers will touch on.

SMALL MARKETS

I have already mentioned the 3 - 15 year timescale of the demand forecasts for a new product - this is similar to the timescale of total development for any significant new product. I do not want to labour the well known points of how long it takes to put any new product on the market with all the necessary and desirable approvals, but from any manufacturer's point of view it is absolutely essential that he begins to recover his development and investment expenditure as soon as possible. It is now reaching the stage where it is difficult to foresee a total cash outflow of less than £½ m in R & D and plant for even a very small new product before any returns are made. In the circumstances, it is hardly suprising that the manufacturer has to concentrate his initial efforts on what he believes are the products major markets. Note that I said his initial efforts, for this is where I believe some of the misunderstandings arise. Of course every company wishes to establish its products as widely as its technical and economic position properly permits, but it has to do so in some order of priority since no-one has unlimited resources. It is for this reason that manufacturers generally welcome the assistance of advisory and other specialists in firstly exploring, and later developing, specific uses of new products. The process of exploration and development overlap and it is really common sense to start looking at smaller use. before you decide a product's future, since they may turn out a great deal larger than you would first expect. This does then sometimes lead to the abandonment of a product because it cannot reach a threshold of viability overall, even though it appears ideal on individual small markets. The key to the co-operative effort here lies in good communications. It must be clearly understood by all parties whether or not a decision to introduce the product has been taken, and the timetable required to introduce each particular use must be established early on.

The only other point I would like to make on small uses relates to the labelling problems when additional provisionally approved uses are added to existing approved uses. This has been under recent discussion in this country and the new proposals to clarify the approval status of all recommendations would ap appear to give a greatly improved system which could well be copied elsewhere.

CONCLUSION

To finish I would summarize by saying that I regret that some supply and demand problems will be with us for this coming season, but probably no worse than last year's in overall terms. Inflation is now our main worry. Gauging demand will always remain difficult, but the flexibility of the industry will be able to overcome the main problems. Finally we welcome assistance on a planned basis for the development of products on smaller uses.

BRITISH CROP PROTECTION COUNCIL PUBLICATIONS

The following publications of the British Crop Protection Council can be obtained by post from Mr. A.W. Billitt, Clacks Farm, Boreley, Ombersley, Droitwich, WR9 0HX. The prices quoted are post paid.

Conference Proceedings

10th British Weed Control Conference, 1970
Vols. 1, 2 and 3 .. .. £ 7.50

11th British Weed Control Conference, 1972
Vols. 1, 2 and 3 .. .. £ 8.00

12th British Weed Control Conference, 1974
Vols. 1, 2 and 3 .. .. £10.00

4th British Insecticide and Fungicide Conference, 1967
Vols. 1 and 2 .. .. £ 4.50

5th British Insecticide and Fungicide Conference, 1969 .. Out-of-print

6th British Insecticide and Fungicide Conference, 1971
Vols. 1, 2 and 3 .. .. £ 7.50

7th British Insecticide and Fungicide Conference, 1973 .. Out-of-print

Monograph Series

No. 1 - 1st Annual Review of Insecticide and Fungicide Usage, 1970 .. .. 75p

No. 2 - Symposium on the Application of Pesticides, 1970 .. .. £ 1.50

No. 3 - 7th Annual Review of Herbicide Usage, 1970 .. .. Out-of-print

No. 4 - 8th Annual Review of Herbicide Usage, 1971 .. .. 75p

No. 5 - 2nd Review of Insecticide and Fungicide Usage (Cereals), 1972 .. .. 75p

No. 6 - 9th Annual Review of Herbicide Usage, 1972 .. .. 75p

No. 7 - 2nd Symposium on Herbicides in British Fruitgrowing, 1973 £ 1.50

No. 8 - 3rd Annual Review of Insecticide and Fungicide Usage, 1973 .. .. 75p

No. 9 - 10th Annual Review of Herbicide Usage, 1973 .. .. 75p

No. 10 - 1st Symposium Weed Control in the Northern Environment, 1974 .. .. £ 2.00

No. 11 - 1st Symposium on Pesticide Application by U.L.V. Methods, 1974 .. .. £ 5.00

No. 12 - 4th Annual Review of Insecticide and Fungicide Usage, 1974 .. .. 75p

No. 13 - 1st Symposium on Higher Education for Crop Protection in Europe, 1974 .. .. Price on application