SESSION 7A

CEREALS — ECONOMIC CONTROL PROGRAMMES

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INVITED PAPERS 7A-1 to 7A-7

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7A—1

TO SPRAY OR NOT TO SPRAY: THE THEORY BEHIND THE PRACTICE

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ABSTRACT

The aim of rationalisation of pesticide use, for whatever reason, requires a decision of whether or not to spray. Various ways of defining thresholds are discussed, along with the relative merits of each. Competition thresholds are considered as a mis-interpretation of statistics. Economic thresholds, at least for A. fatua and probably for other species, are dependent on yield effects rather than contamination or harvesting problems. The economic threshold is based on a single-year calculation; studies of population dynamics can be used to obtain longer-term economic optimum thresholds. Finally, a need is identified to predict the expected infestation from the population in the previous year, and to allow for unpredictable events and risk-aversion.

INTRODUCTION

It has become popular to talk of "rational" pesticide use. Although rarely defined, in essence this means relating pesticide use in some way to need. Needs themselves vary, for instance they may include the maximisation of yield, net profit, game-bird population or aesthetic value, minimisation of the risk of crop failure, or some combination of such factors. Spraying every year regardless of pest level will seldom be regarded as rational, except perhaps where the need is for maximum yield or minimum risk regardless of cost, since resources are likely to be wasted and an undue burden placed on the environment. Pest control by guess-work based on little understanding is likely to over-use pesticides in some years, under-use them in others, and result in the farmer constantly playing "catch-up" with his pests. Although a totally rational pesticide programme based on detailed understanding may only be completely attainable on paper, a system that approaches it will have the greatest chance of meeting the needs of the farmer in practice.

The establishment of such a programme must be founded on a firm theoretical structure. It is the aim of this paper to discuss some of the underlying theory upon which we may choose to base weed control programmes in cereals, within an overall need to maximise net profits. Herbicides often contribute a high proportion of the total variable costs in cereal-growing and increases in the efficiency of their use are potentially likely to have an important economic effect. As eradication is regarded as unattainable for most species in practice and is seldom cost-effective over a reasonable time-scale it has not been included in the subsequent discussion. The question to be posed is: how can we best manage our weed populations?

Competition Thresholds

It is often stated (e.g. Zimdahl 1980) that in general the relationship between yield loss and weed density is sigmoidal (Fig. 1a), with negligable losses at low weed density, or quasi-sigmoidal, with a competition threshold below which no loss occurs. It could be argued that we can aim to restrict weed populations to a level below the competition threshold such that no yield penalty is incurred. However, if the data from competition experiments which include a range of weed densities are plotted it is apparent that the relationship is not sigmoidal, but hyperbolic (Fig. 1b) (Cousens et al. 1984). Since this means that a competition threshold does not exist, then management below such a level is not a viable option. The sigmoidal relationship appears to have been proposed on the basis that low infestations of weeds cannot be shown to produce statistically significant differences in yield from controls. The limit below which yield loss is regarded as negligible is thus based on statistics and not on either biology or economics. Because of variation within experiments there is a statistical limit below which differences can seldom be detected as significant even if they exist. The competition threshold is likely to have arisen from an inadequate appreciation of statistics and insistence of the use of analysis of variance rather than response curve methods.

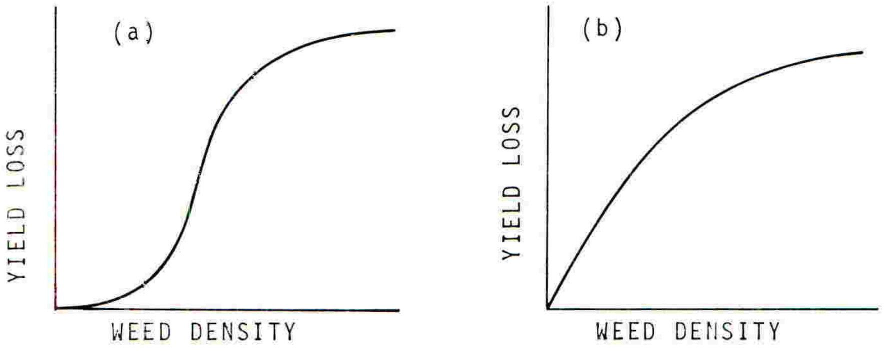

Fig. 1. Two models relating yield loss to weed density : (a) sigmoidal; (b) hyperbolic

Economic Thresholds

The economic threshold is defined as the weed density at which the cost of herbicide application would just equal the financial benefit which results in that year. On a single year basis it can be argued that it is only profitable to spray when the weed population exceeds this level. The presence of weeds in a crop can reduce profit in three principle ways.

a) Interference with harvesting operations. Weeds may affect harvesting by lodging the crop and making the yield difficult to retrieve. Lodging may keep the crop damp and may either restrict harvesting to certain weather conditions or may increase grain moisture levels and hence drying costs. Those species which are green at harvest may also affect grain moisture and timing of harvesting, as well as clogging up the combine, necessitating frequent maintenance. These effects are likely to be important in only certain weed species in certain crops, perhaps only at reasonable high weed density, and consideration need only then be given to harvesting problems. With the exception of Elliott (1980) little consideration has been given to the economic effects of weeds at harvest. He proposed that weeds may affect combine through-put by increasing matter other than grain (MOG). This will decrease the grain-to-MOG ratio and may decrease combine speed and the efficiency of grain separation. Even at very high seedling populations of weeds only slight increases in MOG/unit area were shown for Avena fatua (60-390/m^2), Alopecurus myosuroides (770/m^2) and Galium aparine (220/m^2); larger increases in MOG were shown for Elymus repens (over 60 shoots/m^2). These studies were conducted in a relatively dry season and in a wet season such as 1984/85 the problems of MOG may well be more pronounced. Although Elliott (1980) made some attempt to examine the economic consequences, this area has received little attention.

b) Contamination. The presence of certain weeds in the crop may result in contamination of the grain, reducing its value and perhaps necessitating cleaning. Few weed species will cause a total rejection of the grain and only a few, such as A. fatua, will cause serious contamination. Fig. 2 shows the effect of A. fatua seedling density in spring barley on combined grain contamination. Few data appear to have been published on contamination, or on its effect on grain price. If the crop is to be grown for seed the regulations are stringent and very few A. fatua panicles can be allowed to develop; at present, however, premiums for seed grain are relatively low and the costs of extra control to achieve purity may often exceed the increase in price obtained, even for comparatively low infestations. For feed a certain degree of contamination can be allowed; present EEC intervention limits are 3% total impurities (including weed seeds). Linear regression of the data in Fig. 2 estimates that intervention standards would be violated by 125 A. fatua seedlings per m^2 in spring barley. The model of Cousens et al. predicts 3% contamination by 201 seedlings per m^2 in winter wheat; data for winter barley are scarce, but the earlier harvest of this crop can lead to far greater contamination problems. In a single unpublished experiment we found that a seedling density of 200 A. fatua per m^2 in winter barley resulted in 17.5% contamination.

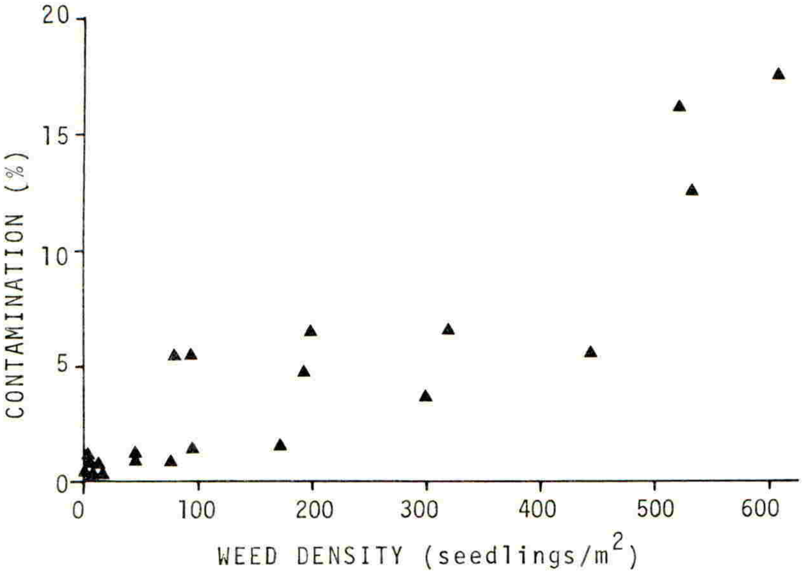

Fig. 2. Contamination of combine-harvested spring barley cv. Triumph by Avena fatua

The price paid by merchants is highly variable and depends very much on their reason for buying (Fig.3). If the assumption is made that intervention price is the same as that of the merchants' clean grain price, then a failure to meet intervention standards through *A. fatua* contamination alone would result in an average price reduction of 15% through having to accept a merchant's offer. Of course, intervention and merchants' clean grain prices are unlikely to be equal and actual penalties may be higher or lower. There is clearly scope for more study in this area, particularly since continuing over-production in the EEC may lead to more stringent contamination limits in the future.

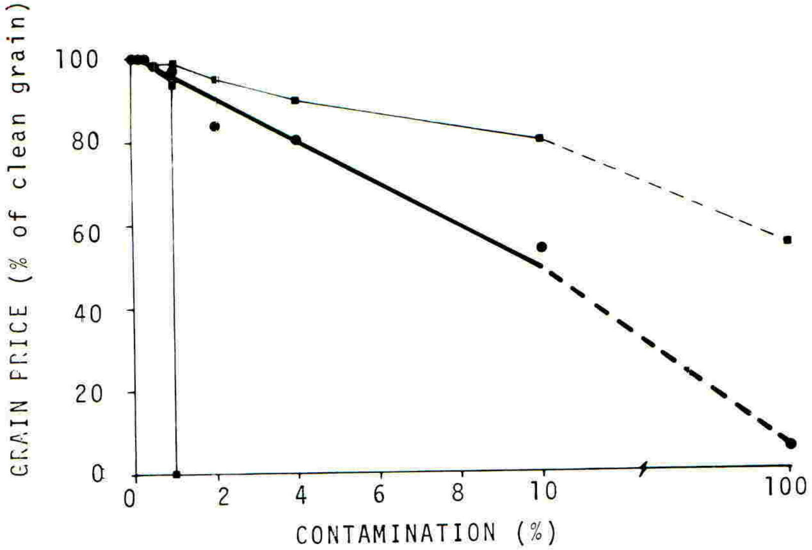

Fig. 3. Prices offered by 9 merchants for grain contaminated by *Avena fatua* in a non-random survey. Broad line - mean; narrow lines - extremes.

c) Yield reduction. By far the major reason for killing weeds is because they reduce yield through competition with the crop. For most species in most crops the economic threshold for reasons of contamination or harvesting problems alone is likely to be well above the economic threshold for yield reduction. At low weed density the relationship between yield loss and weed infestation is approximately linear. It is therefore common to see economic threshold defined as

$$d^* = (C_a + C_h)/(HLYP) \qquad (1)$$

where d^* is the economic threshold, C_a and C_h the costs of application and herbicide respectively, P the price per unit weight of grain, H the proportional reduction in weed population by the herbicide, L the proportional yield loss per unit weed density and Y the weed-free yield (e.g. Marra & Carlson 1983). Examples of economic thresholds for yield loss are 8-12/m^2 for *A. fatua* and 30-50/m^2 for *A. myosuroides* (Anon 1982; Tottman *et al*. 1982) without specific reference to the herbicide to be used. For cases where the economic threshold is likely to be outside of the initial approximately linear phase of the yield curve, the calculations must be more elaborate. Cousens (1985) has shown that yield loss is well described by the equation

$$YL = Id/(1 + Id/A) \qquad (2)$$

where d is weed density, Y_L the % yield loss, I the % yield loss per unit density for low infestations and A the upper limit to % yield loss. The economic threshold weed density can then be obtained by combining equations (1) and (2). Figure 4 shows the resulting relationship between economic threshold of A. fatua and herbicide cost. It can be seen that the economic threshold would be approximately $9/m^2$ for the full rate of the herbicide and $6/m^2$ for the half rate for the herbicide considered.

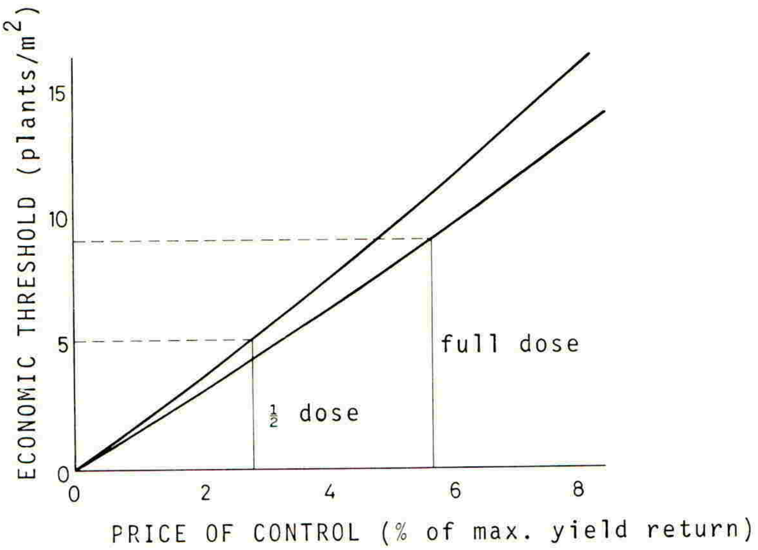

Fig. 4. Theoretical relationship between economic threshold weed density and relative price of control $(C_a+C_h)/PY$. The following assumptions were made:

Proportional reduction in weed population (H) = 0.91 for full dose
= 0.78 for half dose
Cost of herbicide (C_h) = £40/ha for full dose
= £20/ha for half dose
Cost of application (C_a) = £4.50/ha
Price of grain (P) = £120/t
Weed-free yield (Y) = 6.5 t/ha
Yield loss at low weed density (I) = 0.75% per unit density (plants/m^2)
Yield loss at high weed density (A) = 97%

Rather than follow this theoretical approach, there have been many studies which have attempted to derive economic thresholds from field trials designed to study herbicide performance. This type of approach can lead to erroneous conclusions since the design of the trials and the analytical techniques used are not suited to a study of weed thresholds because their objective is hypothesis testing and not estimation. The high variance usually obtained means that for some species and herbicides the economic threshold is often likely to be below the least significant difference obtained. Specific experimentation appropriate to the objective of threshold estimation should be carried out and the relevant optimisation or regression methods applied.

Economic Optimum Thresholds

The economic threshold is based upon a consideration of likely profits and losses in the current year only. Present management decisions will have repercussions in the future, through population changes and market trends. High weed populations, with large seed reserves, may well demand repeated herbicide treatments, perhaps more than once a year, regardless of exact population size. Similarly, very low populations are economically unlikely to warrant treatment for many years. However, once a population is within range of the economic threshold a decision to spray in one year may well affect whether or not the threshold is exceeded in the next year. It is clearly naive to manage according to the economics of only the present year. Doyle et al. (1985) and Cousens et al. (in preparation) have used models of the life-cycles of A. myosuroides and A. fatua respectively to simulate the effects of various management practices on the economics of control. They calculated the optimum threshold which, if applied over ten years, would maximise profits. For A. myosuroides this optimum was found to be 7.5 seedlings/m^2 for an early post-emergence application of chlortoluron in winter wheat, whereas for A. fatua the optimum was 2-3 seedlings/m^2 for difenzoquat. In both cases, for the particular herbicide considered, the ratio of this economic optimum to the single year economic threshold was about 1:4 for current prices. These results were found to be little affected by husbandry; although the frequency of spraying would be greater under minimum tillage, the optimum threshold at which to spray was relatively constant. The combination of population dynamic and economic models shows promise and gives far more meaningful practical advice than a single year economic calculation.

Uncertainty

The performance of most herbicides is, outside broad limits, unpredictable (Baldwin 1979); so too are the exact population increases, the competitiveness of the weeds and the future economics. If a population is being managed according to some threshold calculated in a deterministic way, the likelihood of deviations from the initial assumptions will influence the decisions taken. For example, if an economic threshold is calculated from average data, in extreme years yield losses may well exceed those anticipated; a decision not to spray may well result in a substantial financial loss. Similarly, a chemical may give very poor control, giving losses in the current year and problems in future years. Sudden changes in economics, such as market prices, interest rates and intervention standards are difficult to predict with certainty. For such reasons it is perhaps advisable to err on the cautious side and to reduce thresholds to allow for these chance effects. The degree to which they should be reduced to a safe threshold requires much study and at present allowance for risk can only be arbitrary. In future, however, safe thresholds should be determined analytically.

Predictive Thresholds

In insect population management it is common to refer to an action threshold, a level at which, if control measures are made, the future population will be prevented from exceeding the economic threshold (Walker 1983). Although not currently used in weed management, there is appreciation that one of the reasons for killing weeds is to prevent future build-up. Also, the use of pre-emergence herbicides demands a spray decision before the new seedling population can be assessed. Finally, it is far easier to monitor accurately weed infestations at flowering time in the previous crop. There is clearly a need for calculating predictive thresholds in order to determine future threshold populations from the previous year's infestation. This can be achieved by considering the potential rate of increase of the species in question. However, data on population dynamics are available only for a very few species, such as A. fatua and A. myosuroides. Predictive thresholds which take risk into account in an arbitrary way are currently being used to advise on spraying in the MAFF Boxworth project (Stanley & Hardy 1984).

CONCLUSIONS

There are clearly a number of ways in which weed infestations can be managed. In order to maximise profit the upper limit for a threshold is the economic threshold, but realistically some threshold below this will be chosen. Examples of possible thresholds for A. fatua and A. myosuroides are given in Table 1. As discussed previously, some of these will depend on the crop, the herbicide and the tolerances of the farmer. Husbandry will affect predictive thresholds, since this has a substantial affect on population dynamics (Wilson & Phipps 1985). It should be pointed out that most of the thresholds calculated are well above a level which would currently be visually acceptable by a self-respecting farmer. Most farmers do, at present, use their own arbitrary visual thresholds to determine whether or not to spray; it would be of interest to find out how these compare with calculated thresholds. Although some thresholds can be calculated for a few species from present data, little is known of the competitiveness and population dynamics of the majority of weeds. A further complication is that only a few species can be considered alone; weed populations are usually mixed and herbicides may kill many species. Decisions taken on one species will therefore affect decisions on another. Current work at Long Ashton Research Station is attempting to predict the effects of mixed populations of broad-leaved weeds on yield, and hence to calculate economic thresholds. Individual weed weight is being expressed relative to the weights of weed-free crop plants, as 'crop equivalents', at a series of dates. The assumption is made that there is little interspecific competition between weeds and these crop equivalents are summed across all species. This work is showing some encouraging signs, but is still far from completion.

TABLE 1

Example threshold weed densities (seedlings/m^2) for two grass weed species

	Avena fatua	Alopecurus myosuroides
Competition Threshold	0	0
Economic Threshold	8-12	30-50
Economic Optimum Threshold	2-3	7.5
Safe Threshold	1 (?)	5 (?)
Predictive Threshold*	Threshold/2	Threshold/2

* heads/panicles in previous crop. A. myosuroides value is for ploughing only.

At some point, however, we must put theory into practice. All thresholds demand assessments of population density, and monitoring costs money. In the calculations presented above no attempt has been made to include assessment costs. How detailed the monitoring should be, how much time it would take and the costs of analysis all need to be addressed. This clearly requires input from statisticians in developing sampling procedures. If weed density is estimated as a whole-field average, then thresholds applied to this should assume that the whole field is to be sprayed. However, since weed distribution tends to be patchy this would mean that the entire yield could be lost in certain parts of a field while others remain clean and the overall field threshold is not exceeded. There are great savings to be made by determining thresholds and then applying herbicides only in those individual areas where the weeds occur (Haggar *et al*. 1983). To determine thresholds on one infested part of the field and then apply herbicide to the whole field is clearly a waste of resources and is illogical unless this is allowed for within the calculation of the threshold.

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A MANAGEMENT INFORMATION SYSTEM FOR WEED CONTROL IN WINTER WHEAT

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ABSTRACT

Information about the harmfulness of the weed vegetation and about the costs and the benefits of weed control treatments can save money. At present however it is questionable whether the existing information is used sufficiently in making decisions because gathering and arranging the information takes up a lot of time. In this respect a computerized weed management system may be helpful. During the last three years a prototype of such a system for winter wheat was developed and proved in the Netherlands. The system is based upon knowledge about the detrimental effects of weeds to the wheat crop and to the next years crops. To calculate the potential damage of the weed vegetation Standard Weed Units, attributed to different weed species, are introduced. The system uses information on about forty herbicides, such as selectivity, critical crop stages and costs. This information is derived from a database. Field specific data, e.g. crop stage and weed vegetation, have to be entered by the user of the system. A sample method to record the composition and density of the weed vegetation has been developed. The system can give the farmer general information about weeds and weed control but also very field specific information like the expected harmfulness of the weed vegetation and the utility of the different herbicides. Now the system is thought to be ready for use in practice. Incorporation in a crop management system is considered.

INTRODUCTION

In the last few years computers have shown a substantial fall in price, have become less susceptible to technical problems and have become easier to operate. It is to be expected that in the near future the computer will be fully incorporated in agricultural life. Besides its use for process-control, like controlling the volume of liquid applied by a field sprayer, the computer can contribute to improved farm management (Reiner & Mangstl 1984).

Because crop protection is not only costly but also influences crop yield to a large extent, computerprogrammes on crop protection might be very useful. Many farmers regard decision making in crop protection as a very difficult part of their job and like to have a good support. In the Netherlands a computerbased system for supervised control of diseases and pests in winter wheat, called Epipré, has been in practical use for some years (Reinink 1984).

The good experiences with Epipré led to the decision to make also a system for the supervised weed control in winter wheat and to incorporate it, together with Epipré, in an overall crop management system.

AIM OF THE SYSTEM

Decisions in weed control have to be based on information about the harmfulness of the weed vegetation and about the effects and costs of weed control treatments. Information about the long term effects of weed control strategies, like changes in the composition of the weed vegetation, can also be important in this respect. At present however, it is questionable whether the available knowledge is used sufficiently in making decisions. The main problems seem to be the complexity and poor accessibility of the existing information and the rapid change of that information.

The main aim of the system is to contribute to the solution of the information problem by making relevant information available for the farmer at the right time. That means that the system has to inform the farmer in a fast way about the harmfulness of the weed vegetation and about the possibilities to control the vegetation. The system is not dictating the farmer what to do exactly but is only giving him the tools to decide.

DESCRIPTION OF THE SYSTEM

General description

The system is made to be used by the farmer himself. Therefore running the computer programme has to be easy. Moreover questions must be accompanied with background information or instructions for better understanding. A simplified design of the system is given in figure 1.

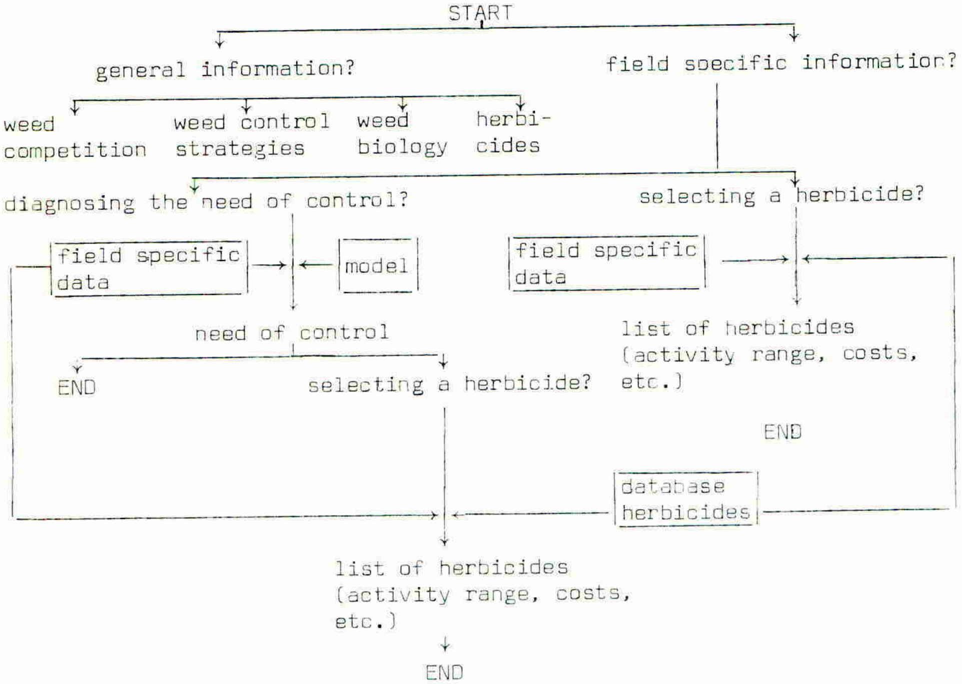


Fig. 1. General design of the information system for weed control in winter wheat.

On starting the programme the user is offered two options. The first option provides the user with general information, the second one with field specific information. To economise on space this paper deals only with the field specific part of the system.

When the farmer decides to ask for field specific information he has to make a choice between information useful to diagnose the need of control or information to select a herbicide. For diagnosing the need of control field specific data are needed, like the crop stage and the composition and density of the weed vegetation. These data are used in a model describing the relationship between weed vegetation and crop production, the population dynamics of some weed species and the possibilities to control weeds in the current or next stages of the crop and in the next years crops. A model can only be a simplification of reality. The strategy was to start with a rather simple model and to go more into details when it proved to answer expectations.

The model is composed of four submodels. The first one is used to generate information in autumn and early winter. A part of this model, the need to use pre-emergence herbicides, is given as an example in figure 2. In general post-emergence control is preferred. Therefore recommendation of the use of pre-emergent herbicides is restricted to situations in which post-emergence weed control is expected to be impossible or very risky. In the Netherlands, as in other countries (Sturny et al 1984) the use in the past of pre-emergence herbicides is regarded as one of the main factors responsible for the enormous expansion of _Galium aparine_.

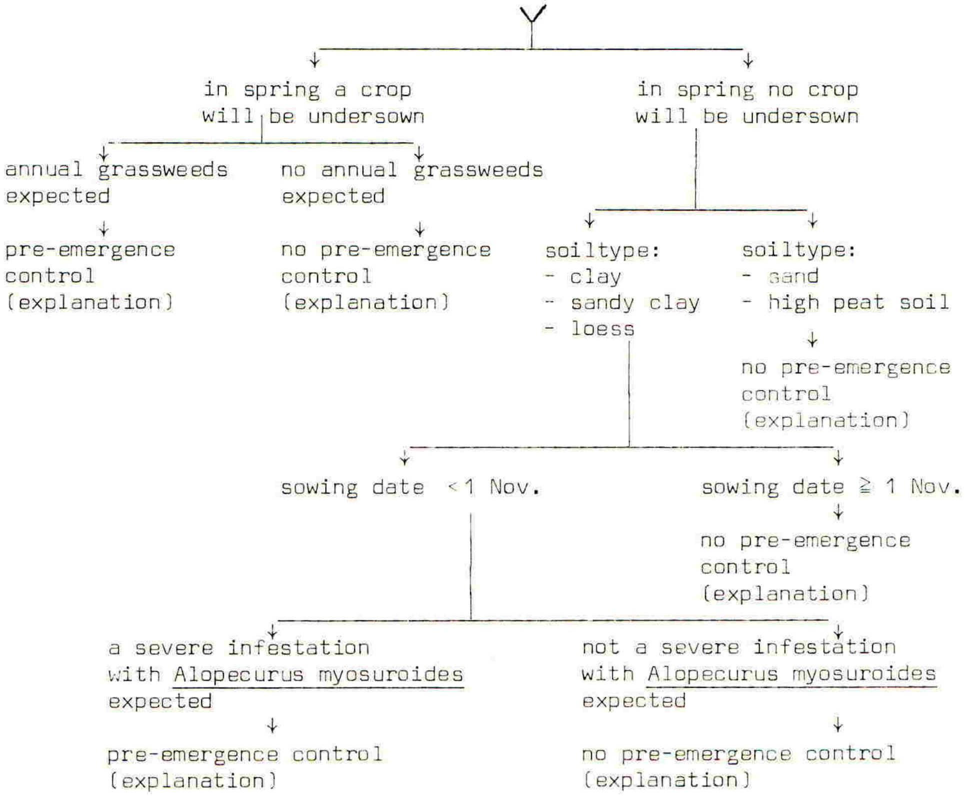


Fig. 2. A part of one of the submodels used by the system, the need for pre-emergence control (simplified).

The second submodel is used in the second part of the winter and in early spring when the crop is in the tillering stage. The third submodel is used in late spring and early summer. Especially the submodels used in spring make it possible to predict weed damage. The method is described later. The fourth model is used to give information about the need for preharvest control.

The outcome of this part of the system is information about the need for control. The information provided is thought to be sufficient for making the decision on whether or not to control the weeds. A next step can be the selection of a herbicide. In a database all the important characteristics of the available herbicides are stored. Using the field specific data already stored in the system, a selecting programme can create a table in which all relevant herbicides are listed together with the susceptibility of the different weed species the farmer wants to control. The herbicides that appear on the top of the list are expected to be the most active ones. The least effective herbicides are listed at the foot. However, other properties can also be important in choosing a herbicide. Therefore the farmer can be provided with additional information like costs, impact of weather conditions and toxicology. In general this information will be sufficient for making an optimum choice.

If a farmer has decided to use a herbicide but needs to select a herbicide he only has to provide some field specific data (e.g. crop stage, variety and the names of the weeds).

CALCULATION OF THE EXPECTED DAMAGE CAUSED BY THE WEED VEGETATION

Weeds can cause a reduction in the financial yield of the wheat crop. In West Germany recently a lot of research has been done to find threshold values for the control of weeds in winter wheat (Niemann 1981). As a result, farmers are advised to control only by the presence of more than 30 plants of Alopecurus myosuroides per m² or more than 20 plants of Apera spica-venti per m². Broadleaved weeds control is thought to be profitable when more than 40 plants per m² are present or when the ground cover of these weeds is 5 to 10%, dependent on the time of the year. Exceptions are made for the species Galium aparine (0,5 plant/m²), Polygonum convolvulus (2 plants/m²) and Vicia sp. (2 plants/m²) (Bartels et al 1984).

The results of the German research combined with the opinions of Dutch research workers, advisers and farmers made it possible to create a rather detailed threshold value list useful for Dutch circumstances (table 1).

Some weed species have both a threshold value for competition and for obstruction of weed control in next years crops. The second threshold value is much lower than the first. The reason for that is the rather small proportion of cereals in the common crop rotation in the Netherlands. The other crops are mainly root crops, like potatoes and sugarbeets, and vegetables. Especially in these crops the presence of Galium aparine or the perennial broadleaved weeds like Cirsium arvense, Sonchus arvensis and Tussilago farfara can lead to considerable problems in weed control. Therefore it is of great importance to avoid problems by controlling these weeds in the cereals, even when the density is rather low.

In most cases, a number of weed species is present in the weed vegetation. To calculate the expected damage caused by the weed vegetation Standard Weed Units are attributed to the various weed species by dividing 500 by the

Table 1

The maximum tolerable density of some weed species (spring time, only one weed species present).

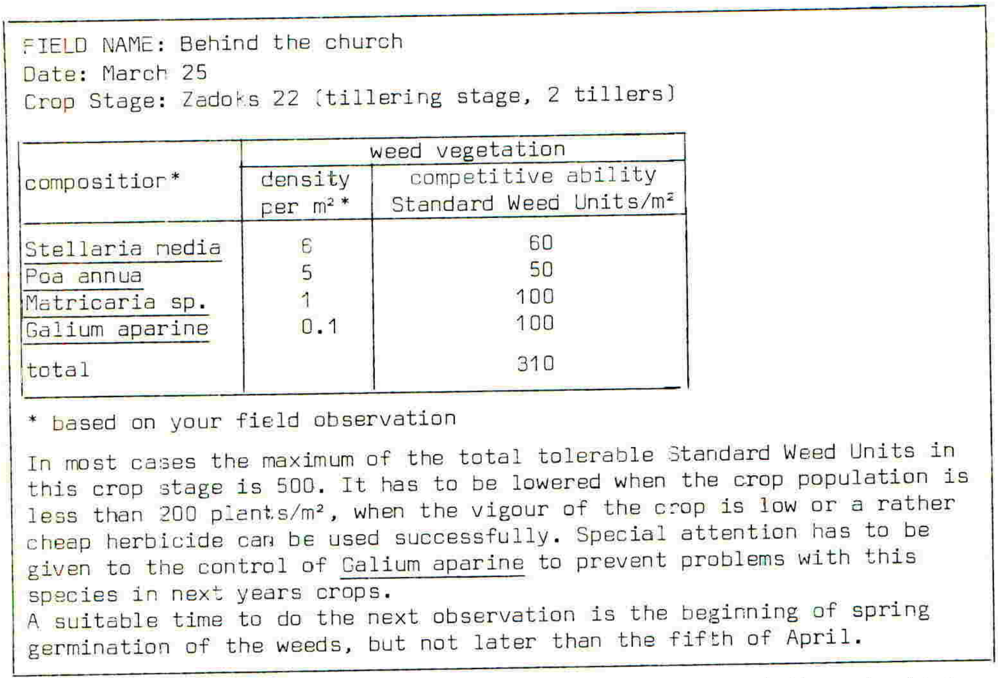
	maximum in view of			
	competition			obstruction weed control in next years crops
	number per m^2	ground cover		number per m^2
		early spring %	late spring %	
annual grasses				
Alopecurus myosuroides	25	5	10	
Apera spica venti	15	5	10	
Poa annua	50	5	10	
annual broadleaved weeds				
Matricaria sp.	5			2
Galium aparine	0.5			0.01
Stellaria media	50	5	10	
Veronica sp.	50	5	10	
Thlaspi arvense	30	5	10	
Lamium purpureum	40	5	10	
Polygonum aviculare	30	5	10	
Polygonum convolvulus	5			
perennial weeds				
Tussilago farfara	0.5			0.01
Cirsium arvense	0.5			0.01
Sonchus arvensis	0.5			0.01

maximum number of plants per m^2 that can be tolerated in spring. So a single plant of the least competitive species like Veronica sp., with a tolerable maximum of 50 plants per m^2, becomes 10 Standard Weed Units. The reason to take the number 500 was to obtain numbers that are "user friendly". In principle any number could be taken. The Standard Weed Units of the total weed vegetation can be calculated by multiplying the density of each species by its Standard Weed Units and by counting up the results. How the density of the weed species has to be assessed is described later on.

At the different crop stages, sometimes in combination with calendar dates, maxima of Standard Weed Units that can be tolerated are adjudged. These maxima are based on the average costs of control measures, and the expected financial damage of the weed vegetation. In the early spring the maximum is 500 Standard Weed Units per m^2. Later on it increases to 1000 per m^2 when the crop is jointing. The main reason for that is the increasing competitive ability of the crop (Spitters and Aerts 1983).

The calculated total potential damage of the weed vegetation and the contribution of each weed species in it is presented to the farmer together with the maximum Standard Weed Units that can be tolerated in view of crop competition (fig. 3).

In case of severe weed infestation, the above mentioned calculation overestimates the real potential damage, because at a high weed density a



FIELD NAME: Behind the church
Date: March 25
Crop Stage: Zadoks 22 (tillering stage, 2 tillers)

composition*	weed vegetation	
	density per m²*	competitive ability Standard Weed Units/m²
Stellaria media	6	60
Poa annua	5	50
Matricaria sp.	1	100
Galium aparine	0.1	100
total		310

* based on your field observation

In most cases the maximum of the total tolerable Standard Weed Units in this crop stage is 500. It has to be lowered when the crop population is less than 200 plants/m², when the vigour of the crop is low or a rather cheap herbicide can be used successfully. Special attention has to be given to the control of Galium aparine to prevent problems with this species in next years crops.
A suitable time to do the next observation is the beginning of spring germination of the weeds, but not later than the fifth of April.

Fig. 3. An example of a method to inform the farmer about the potential camage that can be caused by the weed vegetation.

mutual competition between weed plants restricts competitive effects of each individual plant to the crop. This deviation does not matter because at high densities control is always necessary.

REQUIRED FIELD DATA AND FIELD OBSERVATION METHOD

At the time of the first consultation the system has to be supplied with important invariable data, like variety, sowing date, soil type and the (expected) presence of an undersown crop. These data are stored in a database during the whole growing season. Every time the farmer wants field specific information he has to collect data concerning crop growth stage and weed vegetation.

To determine crop growth stage the Zadoks decimal code has to be used. To assess the weed vegetation farmers are expected to do a number of standarised observations. In observationspots of exactly 0.1 m² (100 cm x 10 cm) the number of individuals of each weed species has to be counted or, in case the ground cover percentage of one or more weed species is higher than the number of individuals, the ground cover percentage has to be estimated. Seedlings of the weeds must not be taken into account when the crop is in the jointing stage. For each ha the farmer is advised to observe five spots with a minimum of ten spots per field. In the Netherlands the average field size is about six ha so, on the average, a farmer has to make 30 observations. When observations are finished the accumulated data for each weed species are converted to populations/m² by the computer. If one or more of the perennial broadleaved weeds or Galium aparine were not present in the observationspot the farmer has to make an estimation of the number of individuals of these species per 100 m².

EXPERIENCES WITH THE SYSTEM

The examination of a management information system is rather difficult. The way the system will act depends strongly on unpredictable circumstances, like the weather conditions. Furthermore the system doesn't tell the farmer what to do but only gives him the information necessary to make a justified decision possible. Often a choice has to be made from more than one available option and of course the farmers personal interests will influence the choice.

Nevertheless the system was compared with some other systems. The examination was carried out on research farms in the most important arable regions of the Netherlands. The system was compared with the favourite control system of the managers of the research farms and also with some very common systems in practice. The common systems were partly derived from information supplied by Epipré participants. On about 35% of their fields pre-emergence herbicides are used. The use of soil acting post-emergence herbicides is almost zero and favourite post-emergence herbicides are MCPA and mecoprop. Other herbicides are (also) used on about 40% of the fields. In each trial a system without weed control was present to make an examination of the used threshold values possible.

Compared with the other systems the use of pre-emergence herbicides was strongly reduced by the information system. On the other hand the use of spring applied soil acting herbicides, combined with other herbicides, was slightly stimulated. Where control of the annual broad leaved weeds in spring was thought to be necessary to prevent strong competition the use of rather unknown products was promoted by the information system. Often these products were difficult to obtain.

In view of preventing loss of financial yield, in most cases threshold values were not reached at all or just slightly exceeded. The physical yield of the system without the use of herbicides was reduced by 0-5% compared with the yield of the best yielding system. That means that the threshold values seem to function quite well. Only when the expected yield is very high or the control measure is very cheap (for example DNOC) the threshold values can sometimes be too high.

To prevent weed problems in next years crops the information system suggested control of Galium aparine or the perennial broadleaved weeds in most trials. The managers of the research farms also regarded control of these species in those cases as necessary. In systems used in practice however, the control of these species was often insufficient.

The total technical and financial results of the information system were fairly comparable with the results of the system followed by the managers of the research farms and often better than the systems used in practice.

DISCUSSION

The first experiences indicate that the described information system can help to improve decisions and may save money. Nevertheless a lot of improvements are possible because the system is set up rather simply. The maximum of total tolerable Standard Weed Units at the different crop stages, for instance, can be made dependent on the variety, the crop density, the crop vigour, the expected yield and the price of the product. Some improvements can be made without much effort, others will cause confrontations with gaps in the existing knowledge and therefore will ask for detailed research.

An interesting issue is how the farmers will react to the possibility of having a private consultant and whether or not they are able to or want to carry out field observations properly. From Epipré participants we know that training in doing field observations and diagnosing pest and diseases in their wheat crops was very much appreciated.

Only a part of the financial return of the crop is influenced by weed control. Other important factors are pest and disease control, fertilization, variety choice and the use of growth regulators. Much effort will be done in the next years to create a crop management system and to incorporate the (sub)systems for the control of diseases, pests and weeds.

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A REVIEW OF YIELD RESPONSES TO WEED CONTROL IN ONE THOUSAND SPRING BARLEY EXPERIMENTS

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ABSTRACT

The possibility for the use of economic thresholds for weed control in spring barley is presented. Analysis of the connection between weeds/m^2 and yield increase for weed control shows that there is a great influence of soil type and weed species composition. The use of economic thresholds for weed control will be limited for clay soils while weedcontrol seems profitable on sandy soils and organic soils even at low weed levels. The influence of the weeds on the water content of the grain follows the same trends as those which affect yield.

INTRODUCTION

Weed control by thresholds is a concept which has been developed for some years in, for example, West Germany (Garburg 1974 and Beer 1979). The concept has emerged in acknowledgement of the fact that weed-free fields in themselves are not a goal, and partly because it is almost impossible to achieve. Because of this, there is a need to be able to advise on the profitability of controlling a given weed population.

The need for threshold values can be illustrated by some figures. In the spring barley trials carried out at the National Weed Research Institute, the number of weeds/m^2 in the untreated plots declined by ⅔ during the period 1945 - 1975 (Thorup 1980). During the same period the mean yield response for chemical weed control has declined from 0.31 to 0.12 t/ha. These figures are a result of more vigorous and competitive crops and of intensive chemical weed control measures.

The purpose of weed control is not restricted to effects on yield however. The benefits encompass such aspects as speed of combining, effects on drying and limitation of weed seed production. However, a lot of trials with very small or negative effects on yield must raise the question if it is possible to estimate the influence of a given weed flora on the crop so that spraying can be avoided in cases where it is not expected to be profitable.

MATERIALS AND METHODS

The presented results were obtained from field trials with chemical weed control in spring barley during 1974 - 1982. The trials were conducted by "Landskontoret for Planteavl" to test the efficiency of various herbicides. Because of that the counting of weeds has not been performed at spraying time, but about three weeks later when the effects of the herbicides can be evaluated. In order to use these trials for establishing damage thresholds it is, therefore, necessary to find the correlation between the number of weeds at spraying time when the decision of whether to spray or not has to be taken, and the number of weeds three weeks after spraying. This work is going on at the moment. Normally a little further germination of weeds can be expected between these dates. This will not, however, change the basic connections shown in this text.

In every trial there has been included a treatment with a standard herbicide. The data in this text come from this treatment.

The number of trials and their distribution of soil types and years is shown in Table 1. The sandy soils have a clay content of less than 10% while clay soils are characterised by having a clay content above 10%.

TABLE 1

Number of trials/years and soil types

	74	75	76	77	78	79	80	81	82
Sandy soils	116	66	75	52	49	48	50	31	31
Clay soils	73	73	61	60	53	29	23	8	15
Organic soils	14	8	16	5	13	8	8	10	6

RESULTS AND DISCUSSIONS

As a mean of all trials, irrespective of soil type, the herbicide treatment has resulted in a yield decrease in 27% of the trials. The yield decrease exceeded 0.15 t/ha in 11% of the trials. At the positive end of the scale, a yield increase greater than 0.15 t/ha was obtained in 49% of the trials. Table 2 shows the distribution of the yield responses to chemical weed control when the trials are divided into soil types. The figures are expressed in percentages and accumulated percentages. Generally great yield responses have been obtained for weed control on the organic soils. 90% of the trials on this soil type have, for instance, resulted in yield increases greater than 0.1 t/ha, and in 55% of the trials the yield increase exceeded 0.5 t/ha.

On the sandy soils the yield responses for weed control were considerably less than on the organic soils. In 24% of the trials on sandy soil the herbicide treatment resulted in a yield decrease while 59% of the treatments have given a yield increase greater than 0.1 t/ha.

TABLE 2

Distribution of yield increases, as percent and accumulated percent for soil types

		Sandy Soil		Clay Soil		Organic Soil	
		%	cum %	%	cum %	%	cum %
< 0	t/ha	24	24	38	38	5	5
0 - 0.1	t/ha	17	41	19	57	5	10
0.1 - 0.15	t/ha	8	49	8	65	2	12
0.15 - 0.2	t/ha	8	57	6	71	9	21
0.2 - 0.5	t/ha	27	84	21	92	24	45
< 0.5	t/ha	16	100	8	100	55	100

In the clay soil trials, generally little benefit has been obtained from the weed control measures. 38% of the trials gave a negative yield response, and only 43% of the trials gave yield increases greater than 0.1 t/ha.

Table 3 shows the mean yield increase for herbicide treatment in the trials divided into soil types and weed levels. Trials on organic soils have given high yield responses, even at low weed levels, but , as can be seen, the numbers of trials with less than 100 weeds/m^2 is very small compared to the other soil types. The most common weed level on clay soils is 20 - 80 weeds/m^2, and the mean yield increase obtained for controlling a weed population of this size has been very limited.

TABLE 3

Average yield increase for weed control within levels of weed, all trials (t/ha).

	Sandy Soil		Clay Soil		Organic Soil	
No. of weeds/m^2	No. of Trials	Yield Increase	No. of Trials	Yield Increase	No. of Trials	Yield Increase
0 - 20	28	0.06	28	-0.05	1	0.17
20 - 40	50	0.10	62	0.02	4	0.29
40 - 60	53	0.13	72	0.01	5	0.42
60 - 80	82	0.14	65	0.06	3	0.30
80 - 100	70	0.22	42	0.14	6	0.77
100 - 150	103	0.24	56	0.12	26	0.72
< 150	132	0.40	70	0.36	43	0.84

In Table 4 and 5 the trials have been divided according to occurrence of hemp nettle (Galeopsis sp.), which in Denmark is considered as the most troublesome weed in spring barley. In Table 5 is shown the mean yield increase within soil types and weed levels in trials without occurrence of hemp nettle, and in Table 4 corresponding figures for trials with occurrence of hemp nettle. Because of the high frequency of hemp nettle on organic soils of 85%, the trials without hemp nettle on organic soils has been omitted in Table 5. By comparing Table 4 with Table 5 it can be seen that trials with occurrence of hemp nettle have generally given greater yield increases for weed control than those without hemp nettle.

TABLE 4

Average yield increase for weed control within levels of weed in hemp nettle trials (t/ha).

	Sandy Soil		Clay Soil		Organic Soil	
No. of weeds/m^2	No. of Trials	Yield Increase	No. of Trials	Yield Increase	No. of Trials	Yield Increase
0 - 20	5	0.12	3	-0.04	1	0.17
20 - 40	20	0.10	10	0.09	2	0.70
40 - 60	20	0.15	11	0.30	5	0.42
60 - 80	30	0.20	16	0.12	3	0.30
80 - 100	32	0.33	9	0.26	5	0.55
100 - 150	44	0.36	16	0.21	23	0.73
< 150	71	0.56	23	0.55	36	0.89

TABLE 5

Average yield increase for weed control within levels of weed in trial with out hemp nettle (t/ha).

	Sandy Soil		Clay Soil		Organic Soil	
No. of weeds/m^2	No. of Trials	Average Yield Increase	No. of Trials	Yield Increase	No. of Trials	Average Yield Increase
0 - 20	23	0.04	25	-0.05	0	
20 - 40	30	0.11	52	0.01	2	-0.12
40 - 60	33	0.12	61	0.04	0	
60 - 80	52	0.11	49	-0.04	0	
80 - 100	38	0.13	33	0.11	1	1.87
100 - 150	59	0.15	40	0.08	3	0.64
< 150	61	0.21	47	0.27	7	0.58

Regression analysis of the trials shows that the relationship between weeds/m^2 and yield response for weed control is approximately linear within a broad weed-spectrum which is consistent with experiences from West Germany (Garburg 1974 and Beer 1979). In Figure 1 the linear relationship between weeds/m^2 and yield response for weed control is shown for the trials carried out on sandy soils and clay soils. The correlation between yield increase from spraying and number of weeds/m^2 is small. The regression is, however, statistically significant for both soil types. The weeds are generally more harmful to the crop on the sandy soils as can be seen from Figure 1. On clay soils where the crop is normally more vigorous and competitive the weeds are of less importance. The regression curves for the trials in Tables 4 and 5 are not included in this text. It can, however, be seen from the figures in the tables that the slope of regression will be greater in trials with hemp nettle and smaller in those without hemp nettle.

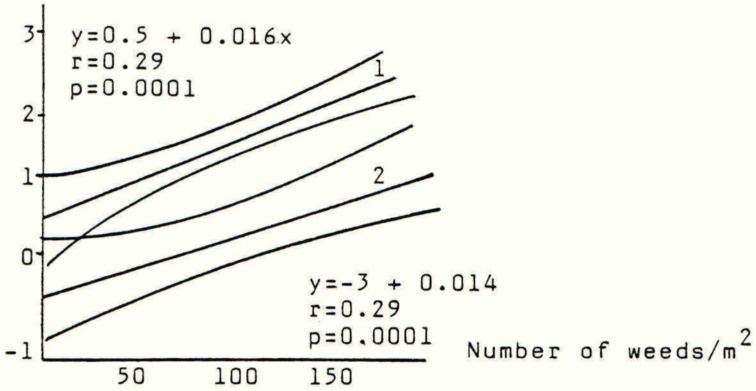

Fig 1. Regression between number of weeds/m^2 and yield increase on sandy soil 1. and clay soil 2. with a 95% confidence interval.

The yield response is, however, only one of the aspects that determines the final profitability of weed control. In Table 6, the influence of an omission of weed control on the water content of the grain is shown. The influence of weeds on the water content of the grain is greatest on the sandy soils and organic soils while the effects on clay soils is limited.

The other effects that determine the profitability of a weed control measure influence on harvesting process and weed seed production are not examined in these trials.

TABLE 6

Average difference in water content of grain between untreated and treated parcels (%).

	Sandy Soil		Clay Soil		Organic soil	
No. of weeds/m^2	No. of Trials	Average diff	No. of Trials	Average diff	No. of Trials	Average diff
0 - 20	32	0.3	29	0.1	1	0.5
20 - 40	49	0.3	65	0.3	4	0.8
40 - 60	54	0.5	74	0.2	5	1.1
60 - 80	78	0.7	57	0.4	3	0.1
80 - 100	66	1.0	40	0.7	8	0.7
100 - 150	106	0.7	51	0.7	24	1.4
< 150	127	1.4	68	0.7	45	1.6

It can be concluded that the use of damage thresholds for weed control seems to be a realistic possibility when the relationship between the number of weeds at normal spraying time and at the counting time in these trials has been established.

There is a statistical significance on soil type on the yield response that can be expected from weed control. This effect can be explained partly by the different potentialities and with that competitive ability of the crop on the different soil types and partly by the composition of weed species on the three soil types. It can be see that the possibilities for using damage thresholds is concentrated on the clay soils where the effects of weed control upon yield response and grain water content are small. On the sandy and organic soils, profitable benefits for weed control have been obtained even at very low weed levels.

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A LONG TERM EXPERIMENT ON TILLAGE, ROTATION AND HERBICIDE USE FOR THE CONTROL OF A. FATUA IN CEREALS

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ABSTRACT

The response of a population of A. fatua to cultivation, rotation and the use of herbicides was studied for six years. With no new seeding, three years of barley cut for silage exhausted the seed reserve while three years of grass allowed some to survive and produce seedlings in the following wheat crop. Where herbicides were used in winter wheat and spring barley the seed return from survivors maintained the population. The annual use of difenzoquat kept the population at a low level irrespective of cultivation. Barban allowed more seed return than difenzoquat; with tine cultivation the population increased steadily, whereas with ploughing the numbers of seedlings declined. This emphasises the need for an integrated approach to long-term control. It is concluded that as the input of herbicides is reduced, it becomes more important to follow the cultural system least favourable to the weed.

INTRODUCTION

Wild-oats (Avena spp) remain one of the most widespread weeds of cereals (Chancellor and Froud-Williams 1984), even though their seeds are relatively short lived in cultivated soils (Wilson 1985). It is likely that the continued presence of these weeds in arable fields is due mainly to inadequate control allowing new seeds to add to existing reserves, rather than to the persistence of seeds in the soil.

Seed survival is greatly influenced by husbandry factors such as cultivations and straw burning (Wilson and Cussans 1975). Cussans (1976) emphasised the need for a systematic long-term approach to control in which cropping, husbandry practices and herbicide use are integrated to keep the weed control at minimum cost. This paper describes an experiment in which two herbicides of differing cost and efficiency were applied annually for six years to Avena fatua in winter wheat or spring barley. The effects of annual arable silage and a grass ley on the persistence of A. fatua populations were also studied.

METHODS AND MATERIALS

The experiment was carried out on a silty loam soil in Parkers field at the Weed Research Organization, Oxford.

Establishment of Population 1976-78

In the spring of 1976 A. fatua seeds were sown by hand before sowing spring barley. Seeds, sown at a rate of $373/m^2$, were derived from natural infestations collected locally in previous years. The population was allowed to increase naturally in spring barley in 1977 and in winter barley in 1978. Crops were established after ploughing to encourage the build up of reserves of seeds throughout the cultivated soil profile. Further seeds ($214/m^2$) were added to the ploughed surface in autumn 1977. The A. fatua population was monitored each year for numbers of seedlings, panicles and seeds produced.

TABLE 1

Diary of Operations (Dates given as days.month)

Operation	1976	1977	1978	1979	1980	1981	1982	1983	1984
A. fatua sown	8.3	22.9							
Barley sown	11.3	30.3	-	17.4	4.3	6.4	26.3	19.3	19.3
A. fatua - seedling counts	7.5	16.5 25.10	-	17.4 15.5	15.4 22.4 14.5	6.2 14.5	5.4 20.4 6.5	28.3 21.4	16.4 26.4
Barban applied - wheat			18.12	12.12	-	5.1	7.1	11.1	6.1
- barley				15.5	22.4	15.5	7.5	29.4	3.5
Difenzoquat " - wheat				8.5	7.5	22.5	22.4	18.5	15.5
- barley				1.6	7.5	22.5	14.5	18.5	15.5
Arable silage cut				25.6	4.6	5.6	18.6	7.6	11.6
A. fatua panicle count (seed return)	13.7	21.7	2.7	17.7	8.7	14.7	8.7	27.7	11.7
Cereals harvested	6.8	13.9	25.8	20.8	27.8	22.8	27.8	3.8	10.8 3.9
Cultivation treatments	10.11	20.9	11-13.9	27.9-1.10	16-17.9	22-24.9	30.9	26-29.9	11-13.9
Grass sown			14.9						
Grass killed (glyphosate)									
after 3 years						10.8			
after 6 years									26.7
Wheat sown		3.10 (barley)	5.10	17.10	4.11	7.10	15.10	4.10	16.10

The Experiment 1978-85

The object of the experiment was to monitor the long-term effects of cultivation, rotation and herbicide use on a population of *A. fatua*. The following annual treatments were commenced in autumn 1978:

Cultivation		Rotation		Herbicide
Tine cultivation	x	Winter wheat	x	Barban
Ploughing		Spring barley		Difenzoquat

Additional rotational treatments were:

Spring barley (tine cultivated)) cut each year for
Spring barley (ploughed)) arable silage
Grass ley for 3 years
Grass ley for 6 years

The experiment was a randomised block with the 12 treatments (2 x 2 x 2 = 8 + 4 additional treatments as above) replicated 3 times. Plots of 20 m by 8 m were arranged in 3 rows, with the rows separated by 3 m grass paths.

Dates of the main operations relating to the experiment are shown in Table 1. Routine fertiliser, fungicides and broad-leaved weed herbicides were applied as appropriate to the normal husbandry of the crops.

Establishment of Crops

In the establishment phase barley varieties Julia, Aramir and Maris Otter were sown at 80-90 kg/ha, a low seedrate to encourage the build up of *Avena fatua*. In the experiment barley varieties Tyra, Goldmarker and Triumph were sown at 140-160 kg/ha. Wheat cv Flanders was used throughout at a sowing rate of 175 kg/ha. A standard perennial ryegrass + white clover mixture was sown on the grass plots and paths in September 1978.

Cultivations

The cereal plots were either mouldboard ploughed or tine cultivated. These primary cultivation treatments were done each year in September (Table 1). Ploughing was carried out to a depth of 20-25 cm, alternating each year the direction in which the furrows were turned in order to reduce the displacement of soil and seeds. Tine cultivation was done with a rigid tine cultivator, cultivating along and then across the plots to a depth of about 15 cm. Poor barley growth indicated the development of a pan after repeated tine cultivations. All cereal plots were deep tine (50 cm) subsoiled across the plots in September 1981 and August 1983.

Arable silage

The barley was cut in mid-June and all vegetation removed before *A. fatua* panicles had set seed. Regrowth of *A. fatua* was prevented by spraying the stubble with glyphosate.

One of the two arable silage treatments (the ploughed plots) was ended after three years, and then sown annually to wheat. No *A. fatua* herbicides were used, and the persistence of the original *A. fatua* population was shown by counting the *A. fatua* population in the first of these wheat crops.

Grass

Grass plots were maintained by cutting periodically with a rotary mower. They remained for either 3 or 6 years, after which glyphosate was applied to kill the sward, plots were ploughed and cropped to wheat. *A. fatua* panicles were counted in these wheat crops.

TABLE 2

Establishment of *A. fatua* population before treatments commenced in 1979

Future Treatment			1976 Panicles /m^2	1976 Seeds produced /m^2	1977 Panicles /m^2	1977 Seeds produced /m^2	1978 Panicles /m^2	1978 Seeds produced /m^2	Estimated reserve/m^2 before treatments
Wheat	Tine	Barban	19	785	12	599	16	1800	2139
		Difenzoquat	18	771	17	912	14	1540	2035
	Plough	Barban	15	617	15	813	15	1784	2221
		Difenzoquat	17	729	11	513	13	1430	1723
Barley	Tine	Barban	18	757	10	462	13	1279	1548
		Difenzoquat	18	757	14	634	15	1580	1934
	Plough	Barban	19	799	14	795	14	1668	2105
		Difenzoquat	17	715	14	632	14	1467	1818
Barley - Arable Silage									
		Tine	20	827	17	924	18	2612	3115
		Plough	18	757	17	921	21	3107	3605
Grass - 3 years then Wheat			17	729	14	666	17	2158	2527
6 " " "			17	729	14	802	21	3256	3693

Herbicides

Applications were made with a CO_2 pressurised sprayer with a 4 m boom carried by two operators. Barban and difenzoquat were applied with Spraying Systems Teejet 65015 and 8002 nozzles at 2.4 and 2.1 bar pressure at volume rates of 200 and 230 l/ha respectively. Barban was applied at 0.16 kg/ha a.i. when the early *A. fatua* had reached 2-3 leaves, in December or January for the wheat, and late April or early May for the barley. Difenzoquat was applied at 1.0 kg/ha a.i., to well-tillered *A. fatua*, usually 1-3 weeks after the barban application.

Assessments

A. fatua was counted annually as seedlings, panicles and seeds produced per panicle. Seedlings were counted in 30 quadrats of 0.1 m^2 on each plot, usually in April or May, sometimes earlier in the wheat; when several counts were done the last was timed to include the main spring flush of *A. fatua*. On the low density plots, panicles were counted in 2 swaths, each 1 m wide by 20 m (the length of the plot). On the high density plots panicles were counted in eight random 0.25 m^2 quadrats. Seeds were counted on a selection of 20 panicles from each plot. Grain yields were obtained by combining two swaths 2.1 m wide, from each plot with a small Claas plot combine.

RESULTS

During the establishment phase there was a gradual increase in the population, and in 1978 an average of 1893 seeds/m^2 were produced. It was estimated that over 2000 viable seeds/m^2 were present in the soil before treatments commenced in autumn 1978 (Table 2). This estimate was based on assumed seed losses in the soil of 50% in the first year after seed shedding and 90% per annum in the following years (Wilson *et al*. 1984). Seeds shed most recently (in 1978) made up over 80% of the total reserve.

In 1979 more seedlings emerged following tine cultivation than after ploughing (Table 3). Seedlings represented 10% and 4% of the estimated seed reserve respectively. Both herbicides allowed some seeds to be produced by survivors; barban gave poorer control than difenzoquat, many surviving plants having emerged late after the barban application. The seeds returned to the soil from survivors from barban averaged 446 and 210 seeds/m^2, and from difenzoquat 14 and 2 seeds/m^2 for tine and plough respectively. This differential seed return was reflected in the 1980 seedling populations, when 2-3 times more seedlings were recorded after barban than after difenzoquat; this ratio increased in subsequent years.

Cultivation had a major influence on seedling emergence; in 1980 and 1981 three times as many seedlings emerged after tine cultivation compared with ploughing; in 1982 this factor increased to 9, in 1983 to 33 and in 1984 to 90. This was due largely to the increasing population on the tined barban treatment, which after 5 years had almost increased to that at the start of the experiment. Difenzoquat gave good control, with little seed return and populations of *A. fatua* remained at low levels with both cultivation treatments.

Seed return was prevented with arable silage and with grass. After three years of arable silage no seedlings were recorded in the following wheat crop. After three years of grass an average of 2 seedlings/m^2 and after six years of grass an average of 22 seedling/m^2 were recorded in the following wheat crop.

Wheat yields remained fairly constant, (Table 4) averaging 5.5 t/ha.

TABLE 3

A. fatua populations during experiment. Seedlings/m^2 before spraying
(Panicles and Seeds/m^2 after spraying)

Treatment			1979	1980	1981	1982	1983	1984	1985
Wheat	Tine	Barban	217 (19,459)	26 (9,355)	9 (11,899)	27 (5,131)	53 (33,3185)	142 (48,2153)	
		Difenzoquat	206 (1,18)	12 (0,0)	1 (0,5)	1 (0,0)	1 (0,4)	1 (1,43)	
	Plough	Barban	97 (9,295)	9 (3,91)	10 (3,205)	8 (1,15)	3 (1,59)	3 (1,25)	
		Difenzoquat	75 (0,3)	3 (0,0)	3 (0,9)	1 (0,0)	1 (0,0)	0 (0,0)	
Barley	Tine	Barban	142 (13,434)	27 (8,259)	36 (10,553)	65 (72,4683)	142 (74,8044)	124 (115,11183)	
	Plough	Difenzoquat	201 (1,10)	9 (0,0)	8 (0,0)	1 (0,3)	2 (1,110)	4 (15,1603)	
	Plough	Barban	87 (3,124)	8 (1,11)	6 (0,14)	1 (2,55)	2 (1,40)	0 (1,58)	
		Difenzoquat	76 (0,0)	3 (0,0)	2 (0,0)	1 (0,1)	0 (1,30)	0 (1,62)	
Barley	Arable Silage								
	Tine		378	16	3	0	0	0	
	Plough (3 years) (then harvest)		143	11	2	0 (0,0)	0 (0,0)	0 (0,0)	
Grass	3 years then Wheat					2 (1,32)	1 (1,36)	1 (0,17)	
	6 years then Wheat								22 (35,3850)

Differences between wheat and barley yields were statistically significant ($p \leqslant 0.05$). Barley yields were more than halved with tine cultivations in the later years; an effect which became progressively more severe. Wheat yields in the first year after grass were more than 1 t/ha higher than those recorded with continuous cereals.

TABLE 4

Yields of Harvested Grain t/ha

			1979	1980	1981	1982	1983	1984	Mean
Wheat	Tine	Barban	5.59	5.25	5.77	5.63	5.24	6.02	5.58
		Difenzoquat	5.69	5.08	5.88	4.90	5.58	5.49	5.44
	Plough	Barban	6.21	5.06	5.76	5.76	5.61	5.81	5.69
		Difenzoquat	6.48	5.16	5.18	5.15	4.62	5.72	5.39
Barley	Tine	Barban	3.69	4.04	2.47	2.43	1.39	1.32	2.56
		Difenzoquat	3.84	4.56	2.70	2.33	1.40	1.88	2.78
	Plough	Barban	4.68	5.12	3.16	4.06	2.92	4.17	4.02
		Difenzoquat	4.29	5.12	2.98	3.83	2.83	3.66	3.78
Arable silage then wheat						6.00	5.61	6.08	5.90
Grass then wheat						7.00	6.71	6.43	6.71
		SE ±	0.250	0.362	0.440	0.808	0.484	0.522	0.422

DISCUSSION

The absence of seedlings after three years of arable silage confirms previous work showing that *A. fatua* seeds were not very persistent in cultivated soils (Wilson and Cussans 1975, Wilson 1985). The presence of seedlings in wheat after grass confirms previous work by Thurston (1966) where seeds declined rapidly in the first year of grass but thereafter persisted to give substantial seedling infestations after 5 years. The same author also showed that cultivation stimulated *A. fatua* germination (Thurston 1951). This suggests that the more rapid decline under arable silage was due to the associated cultivations which encouraged the germination and therefore death of seeds. This decline where the land was ploughed was similar to that predicted by a model of *A. fatua* population dynamics (Wilson *et al.* 1984) in which seedling populations decline to virtually zero in four years with complete control of seeding.

This study shows the significance of seed return on population trends of *A. fatua* in barley and wheat grown under two cultural systems. Two herbicides of contrasting efficiency and cost were used; barban, at a reduced dose, was chosen as a cheap, only moderately effective, treatment compared with difenzoquat. It was thus possible to study the influence of two differing levels of annual seed return on population trends. Difenzoquat gave very effective control leaving few survivors and few seeds shed, and populations were reduced to low levels over the five years. This supports the results of a long-term farm survey in which *A.fatua* populations have been reduced to low levels and there is a good prospect of saving on herbicides by relying on hand roguing alone (Wilson and Scott 1982). Barban was less effective, leaving more survivors and greater seed return. However, with ploughing, the cultivation system least favourable to the weed, populations remained low on plots treated with barban. Previous work has shown annual tine cultivation to favour A. fatua compared with ploughing (Wilson 1985). The A. fatua model (Wilson et al. 1984) predicts that an uncontrolled population will increase annually by a factor of 2.9 with tine cultivation and by 1.9 with ploughing. Here, with barban in continuous wheat, populations increased by 1.5 per annum with tine cultivation, and declined by an average factor of 0.8 with ploughing. The relative effect of tine cultivation compared with ploughing was similar to that predicted, although barban limited seed return and the rate of population increase.

Prediction by the model of the effect of cultivation on seedling emergence is confirmed here. In 1979, before the start of herbicide treatments, twice as many seedlings emerged after tine cultivation compared with ploughing. In barley the population increased more rapidly than in wheat due to poorly competitive barley crops from 1981 onwards. The barley with repeated tine cultivation appeared to have suffered from sub-surface compaction aggravated by the high silt content of the soil. The effects of compaction were made worse by the fact that this was a low lying site, prone to waterlogging in wet springs, and these effects were not adequately relieved by sub-soiling.

This work emphasises the need for an integrated approach to long-term control where both herbicides and husbandry practices need to be taken into account. This would apply to other weeds such as A. myosuroides where husbandry practices such as cultivation and straw burning have a strong controlling influence on population trends (Moss, 1980). It is particularly relevant at the present time when farmers are seeking ways to economise on inputs. If reduction in cost is synonymous with a poorer average performance by the herbicide, then it becomes more important to follow the cultural system which is least favourable to the weed.

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THE INFLUENCE OF CROP VARIETY AND SEED RATE ON *ALOPECURUS MYOSUROIDES* COMPETITION IN WINTER CEREALS

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ABSTRACT

In three experiments different winter wheat or barley varieties were grown in the presence or absence of *A. myosuroides*. The effect of cereal variety on weed and crop populations and yield were recorded. The winter wheat variety Maris Huntsman withstood weed competition better than Virtue. Also, the winter barley variety Hoppel was less affected by weed competition than Maris Otter. Differences in competitive ability were not simply related to either crop height or tillering capacity.

In another three experiments winter wheat was sown at three seed rates, again in the presence and absence of *A. myosuroides*. In the absence of weed competition, crop seed rate had little or no effect on crop yield. With high weed infestations, higher crop seed rates gave the crop a competitive advantage and this resulted in higher yields than at lower seed rates.

INTRODUCTION

Competition between crop and weeds is a two way process: the weed competes with the crop and the crop competes with the weed. The aim of most weed control measures is to promote conditions which favour the crop, at the expense of the weed. Many factors influence the competitive balance between crop and weed. Three such factors that may be important are the crop species, variety and population.

Five experiments were conducted in which different winter wheat and barley varieties or crop seed rates were used. The crops were grown alone or in competition with *A. myosuroides*. The varieties used were selected from those which appeared likely to differ in their competitive ability with weeds based on previous field observations. The seeds rates studied were selected as representative of the range normally used in cereal growing.

MATERIALS AND METHODS

Five field experiments were conducted at the AFRC Weed Research Organization, Oxford, on a sandy loam soil. Treatment details are summarised in Table 1 and non-experimental cultural practices were similar in all experiments. The results showing the effect of drilling date, which was one of the variables studied in two experiments (1 and 3), have been published elsewhere (Moss 1985). As there were no major interactions between drilling date and the other treatments, only pooled results showing the effect of variety and seed rate alone are presented here.

Each experiment comprised a randomised block design with four replicates. Plot size was either 16.5 x 2 m (Experiment 1), 13 x 2 m (Experiments 2, 3 and 4) or 10 x 3 m (Experiment 5). Within each plot of Experiments 1-4 were either three (Experiments 2, 3 and 4) or four (Experiment 1) randomised sub-plots, each 2 x 2 m, onto which

TABLE 1

Details of experimental treatments

Experiments 1-4: Main plot treatments = all combinations of drilling date, variety and crop seed rate; sub-plot treatments = *A. myosuroides* seed rate. Experiment 5: Main plot treatments = all combinations of crop seed rate and *A. myosuroides* seed rate

	Nos. of main-plot treatments	Drilling date	Cereal variety		Crop seeds/m^2	*A.myosuroides* seeds sown/m^2	
Expt. 1	8	25 Sept	Maris Huntsman	(WW)		0	
(1979-80)		24 Oct	Kinsman	(WW)	375	735	(L)
			Hoppel	(WB)		2206	(M)
			Maris Otter	(WB)		6618	(H)
Expt. 2	4	2 Oct	Maris Huntsman	(WW)		0	
(1980-81)			Virtue	(WW)	350	650	(L)
			Hoppel	(WB)		5200	(H)
			Maris Otter	(WB)			
Expt. 3	12	28 Sept	Maris Huntsman	(WW)	200 (L)	0	
(1981-82)		22 Oct	Virtue	(WW)	350 (M)	800	(L)
					500 (H)	6400	(H)
Expt. 4	3	2 Oct	Flanders	(WW)	190 (L)	0	
(1980-81)					333 (M)	650	(L)
					475 (H)	5200	(H)
Expt. 5	12	5 Oct	Flanders	(WW)	130 (L)	0	
(1983-84)					338 (M)	266	(L)
					557 (H)	1333	(H)

WW = winter wheat
WB = winter barley

L = Low rate
M = Medium rate
H = High rate

A. myosuroides seeds were broadcast at two or three different rates prior to drilling the crop. The remaining sub-plot within each plot was left weed-free. On Experiment 5 *A. myosuroides* seeds, at one of two rates, were broadcast over the entire area of each plot. There were also weed free plots for each crop seed rate.

All plots were ploughed prior to the start of each experiment and spring tine cultivated before drilling with either an Oyjord plot drill with 14 cm row spacing (Experiments 1, 2, 3 and 4), or a commercial farm drill with 12 cm row spacing (Experiment 5). A compound fertilizer supplying 0-23 kg N/ha, 50-60 kg P_2O_5/ha and 50-60 kg K_2O/ha was applied to each seedbed prior to drilling. N top dressing was applied twice in the spring - 42-52 kg N/ha in February/March and 84-110 kg N/ha in April each year. Broadleaved weeds were controlled by applying mecoprop and/or ioxynil + bromoxynil and fungicides were applied as necessary.

A. myosuroides and crop populations were assessed by counting the total number of plants in December and heads in June or July within fixed 1 m^2 quadrats within each sub-plot (Experiments 1, 2, 3 and 4) or within one fixed 0.25 m^2 quadrat within each plot (Experiment 5). Crop yields were obtained by sampling a 1 m^2 area within each sub-plot (Experiments 1, 2, 3 and 4) or two 0.25 m^2 areas within each plot (Experiment 5). Barley was harvested in late July and wheat in mid August on all experiments. Grain samples were obtained using a static plot thresher, sieved over 2.00 mm sieve, dried and weighed. Yields were corrected to 85% dry matter.

RESULTS

Influence of crop variety on *A. myosuroides* competition

Barley variety (Experiments 1 & 2; Tables 2 & 3)

The number of *A. myosuroides* plants that established was not affected significantly by the variety sown. However, there were significantly ($P < 0.05$) more *A. myosuroides* heads present in Maris Otter than in Hoppel at each weed infestation level in both experiments. The number of crop plants that established was similar for both varieties in Experiment 1 but slightly higher for Hoppel than Maris Otter in Experiment 2. Weed infestation had no effect on the numbers of crop plants in either experiment. Maris Otter tillered more than Hoppel and produced more crop heads on weed free sub-plots: Experiment 1 - Maris Otter 972 heads/m^2; Hoppel 529 heads/m^2. Experiment 2 - Maris Otter 622 heads/m^2; Hoppel 421 heads/m^2. Mean crop heights in Experiment 2 were: Hoppel - 95-110 cm; Maris Otter - 95-105 cm.

In the absence of *A. myosuroides* Hoppel outyielded Maris Otter by 1.5 t/ha in Experiment 1 and by over 2.5 t/ha in Experiment 2. The presence of *A. myosuroides* reduced the yield of Maris Otter more than Hoppel. At the highest weed infestation, Hoppel outyielded Maris Otter by over 3.5 t/ha in both experiments.

TABLE 2

Experiment 1. *A. myosuroides* and crop populations/m^2 and yield (t/ha)

Barley variety	Hoppel				Maris Otter				
Sown weed density	Nil	L	M	H	Nil	L	M	H	S.E.±
Weed plants	0	55	160	470	0	57	192	496	14.2
Weed heads	0	229	541	763	0	581	1073	1407	73.7
Crop plants	261	271	268	253	287	278	286	268	9.0
Crop yield	8.31	7.74	6.85	5.72	6.79	4.77	3.54	2.04	0.28
Wheat variety	**Maris Huntsman**				**Kinsman**				
Sown weed density	Nil	L	M	H	Nil	L	M	H	S.E.±
Weed plants	0	55	164	520	0	52	177	505	14.2
Weed heads	0	428	691	1050	0	515	914	1353	73.7
Crop plants	231	222	212	203	245	230	224	195	9.0
Crop yield	7.76	7.16	6.03	4.21	7.65	6.66	5.47	4.19	0.28

Sown weed density key: L = Low; M = Medium; H = High

TABLE 3

Experiment 2 *A. myosuroides* and crop populations/m^2 and yield (t/ha)

Barley variety	Hoppel			Maris Otter			
Sown weed density	Nil	Low	High	Nil	Low	High	S.E.±
Weed plants	0	93	629	0	80	645	20.9
Weed heads	0	97	312	0	230	578	27.6
Crop plants	311	292	323	275	267	283	10.0
Crop yield	7.13	6.20	6.89	4.52	3.74	3.17	0.27
Wheat variety	**Maris Huntsman**			**Virtue**			
Sown weed density	Nil	Low	High	Nil	Low	High	S.E.±
Weed plants	0	81	682	0	82	669	20.9
Weed heads	0	220	539	0	434	688	27.6
Crop plants	235	238	238	246	262	252	10.0
Crop yield	7.11	6.54	3.85	8.27	6.50	2.94	0.27

TABLE 4

Experiment 3 *A. myosuroides* and crop populations/m^2 and yield (t/ha)
(Data pooled to show effect of variety alone)

Wheat variety	Maris Huntsman			Virtue			
Sown weed density	Nil	Low	High	Nil	Low	High	S.E.±
Weed plants	0	82	500	0	96	505	17.0
Weed heads	0	205	483	0	269	589	16.5
Crop plants	227	225	205	214	207	184	6.1
Crop yield	7.13	6.65	5.43	7.73	7.05	5.16	0.14

Wheat variety (Experiments 1, 2 & 3; Tables 2,3 & 4)

As there were no major interactions between variety and seed rate in Experiment 3, only pooled results showing the effect of variety alone are presented in Table 4.

Variety had no effect on the numbers of *A. myosuroides* plants that established. However, there were significantly ($P<0.05$) more weed heads present in Virtue than in Huntsman in Experiments 2 & 3 and more heads in Kinsman than in Huntsman at the two higher weed infestation levels in Experiment 1. Variety had no effect on the number of crop plants that established in any experiment, although plant numbers declined slightly with increasing weed density in Experiments 1 & 3. The tillering capacity of Maris Huntsman and Virtue was similar but Virtue produced slightly more heads on weed free sub-plots: Experiment 2 - Maris Huntsman 510 heads/m^2; Virtue 577 heads/m^2. Experiment 3 - Maris Huntsman 343 heads/m^2; Virtue 385 heads/m^2. In Experiment 1, Maris Huntsman tillered slightly more than Kinsman and produced slightly more heads on weed free sub-plots: Maris Huntsman 495 heads/m^2; Kinsman 456 heads/m^2.

TABLE 5

Experiment 3. *A. myosuroides* and crop populations/m^2 and yield (t/ha)
(Data pooled to show effect of seed rate alone)

Crop seed rate	Low			Medium			High			
Sown weed density	Nil	L	H	Nil	L	H	Nil	L	H	S.E.±
Weed plants	0	90	504	0	87	499	0	90	506	20.8
Weed heads	0	286	614	0	232	531	0	194	464	20.3
Crop plants	143	133	128	216	226	202	302	287	253	7.4
Crop yield	7.14	6.28	4.68	7.47	6.94	5.42	7.68	7.34	5.78	0.17

Sown weed density key: L = Low; H = High

TABLE 6

Experiment 4. *A. myosuroides* and crop populations/m^2 and yield (t/ha)

Crop seed rate	Low			Medium			High			
Sown weed density	Nil	L	H	Nil	L	H	Nil	L	H	S.E.±
Weed plants	0	73	537	0	71	490	0	67	462	23.3
Weed heads	0	344	667	0	251	613	0	209	481	36.7
Crop plants	189	163	174	283	292	258	386	398	374	14.3
Crop yield	6.15	4.90	2.58	6.33	5.50	3.39	5.89	5.59	3.62	0.30

Sown weed density key: L = Low; H = High

TABLE 7

Experiment 5. *A. myosuroides* and crop population/m^2 and yield (t/ha)

Crop seed rate	Low			Medium			High			
Sown weed density	Nil	L	H	Nil	L	H	Nil	L	H	S.E.±
Weed plants	0	64	410	0	98	538	0	84	543	71.2
Weed heads	0	707	2605	0	520	1020	0	366	1195	248.5
Crop plants	102	95	120	314	321	316	494	523	508	13.5
Crop yield	9.57	5.49	4.36	9.64	8.05	5.42	9.67	8.02	6.13	0.32

Sown weed density key: L = Low; H = High

Mean crop heights were: Experiment 2 - Maris Huntsman 105-110 cm; Virtue 80 cm. Experiment 3 - Maris Huntsman 90-100 cm; Virtue 65 cm.

In the absence of A. myosuroides, Virtue outyielded Maris Huntsman by over 1 t/ha in Experiment 2 and over 0.5 t/ha in Experiment 3. The presence of weed competition, reduced the yield of Virtue more than Maris Huntsman. At the highest weed infestation, Maris Huntsman outyielded Virtue by almost 1 t/ha in Experiment 2 and by about 0.3 t/ha in Experiment 3. The yields of the two varieties used in Experiment 1 did not differ significantly in their response to increasing densities of A. myosuroides.

Influence of crop seed rate on A. myosuroides competition (Experiments 3, 4 & 5; Tables 5, 6 & 7)

As there were no major interactions between wheat variety and seed rate in Experiment 3, only pooled results showing the effect of seed rate alone are presented in Table 5.

In all three experiments differences in crop seed rate had little effect on the numbers of A. myosuroides plants that established and the number of crop plants was little affected by the level of A. myosuroides infestation. However, A. myosuroides head numbers increased as crop density decreased in all experiments. In the absence of A. myosuroides, differences in crop seed rate had no effect on yield in Experiments 4 & 5. In contrast, in Experiment 3, increasing crop seed rate resulted in significant ($P<0.05$) increases in crop yield. At the highest weed density in Experiment 4 crop yields were significantly ($P<0.05$) higher at the highest than at the lowest crop seed rate. In Experiment 5, yields were higher at the medium and high than at the low crop seed rate at both weed infestation levels.

DISCUSSION

Effect of cereal variety on competition with A. myosuroides

The results show that different wheat and barley varieties can differ substantially in their ability to compete with A. myosuroides. Varietal differences had little effect on the numbers of A. myosuroides plants established by December each year, but a much larger effect on the numbers of heads present. In some cases there was over a two-fold difference in weed head density between varieties grown at the same original weed infestation level. Crop yields were also influenced by the differential competitive abilities. The yield of Maris Otter, a two row barley variety, was reduced more than Hoppel, a six row variety, by weed competition. Other work has shown also that Maris Otter is particularly susceptible to weed competition (Kolbe 1980). In two experiments, the wheat variety, Virtue, outyielded Maris Huntsman in the absence of weed competition, whereas the order was reversed when subjected to severe weed competition. This shows that for a variety such as Virtue, good weed control is essential if its full yield potential is to be achieved.

The experiments do not show the manner in which competition differed between varieties. It is tempting to ascribe the differences in competitive ability of Maris Huntsman and Virtue simply to differences in crop height. These were respectively the tallest and shortest strawed winter wheat varieties on the NIAB recommended list at that time (National Institute of Agricultural Botany 1980). Appleby et al. (1976) also found that two short wheat varieties were more susceptible to Lolium multiflorum competition than were two taller varieties. In contrast, Reeves and Brooke (1977) found little evidence that semi-dwarf wheat varieties were more affected by Lolium rigidum competition than were "traditional" (taller) varieties. However, as competition between L. rigidum and wheat is mainly restricted to the pre-tillering period (Reeves 1976) it was not surprising that differences in mature crop height were not correlated with differing competitive abilities. A. myosuroides does compete with winter cereals during later growth stages (S.R. Moss, unpublished data), so mature crop height may be important. Other factors, such as rooting habit, are also likely to be involved.

Differences between Maris Huntsman and Virtue, in terms of tillering and crop head production, were small and not clearly related to competitive ability. However, it has been stated that 35 years ago, the variety Jubileegem was valued in west Cambridgeshire because it tillered very profusely and had a useful suppressing effect on A. myosuroides (Jarvis 1981).

In the first experiment, Kinsman was chosen as it was thought to be a poor competitor due to its limited tillering capacity. However, in that experiment, no significant difference in yield response between the two varieties tested was found, although there were more weed heads present in Kinsman than in Maris Huntsman. This suggests that there was a small difference in competitive ability which was not reflected in yield differences.

The differences in competitive ability of the two barley varieties was unlikely to be due simply to crop height, as there was little difference in the height of the two varieties in these experiments. Other work has shown also that the competitive abilities of different winter barley varieties is not simply related to mature height (Kolbe, 1980). Tillering capacity also seemed unimportant as Hoppel tillered less, and produced fewer heads/m^2 than Maris Otter, and yet was more competitive.

It is sometimes stated that winter barley is more competitive than winter wheat. The results of these experiments show that this is an oversimplification and that varieties, rather than species, need to be compared.

Although varieties differed in their ability to withstand weed competition, yields of even the most competitive varieties were reduced by the presence of A. myosuroides. Also the effects of competition varied between experiments. For example, the % yield loss of Maris Otter due to the highest weed infestation was 70% in Experiment 1, and 30% in Experiment 2 despite a slightly higher weed infestation in the second experiment. This demonstrates that it is difficult to predict the effects of competition and that choice of a competitive variety can be only one part of an integrated control strategy for A. myosuroides (Moss 1980).

Effect of crop seed rate on competition with A. myosuroides

Cereal seed rate is usually considered to have relatively little influence on final crop yield. This view was supported by the results of Experiments 4 & 5. In those two experiments, there were no significant differences in crop yield between the three crop seed rates used in the absence of weed competition. In contrast, in the presence of A. myosuroides yields were significantly higher at the higher crop seed rates. Also the number of A. myosuroides heads declined as crop seed rate increased, presumably due to greater crop competition.

In Experiment 5 there were approximately half as many weed heads in the crop sown at the highest seed rate as in that sown at the lowest rate. Similar responses to different seed rates have been found with other weeds in cereal crops (Cussans & Wilson 1975; Appleby *et al*. 1976; Hakansson 1984).

The differences in yield between crops sown at the medium and high seed rates and subjected to weed competition were generally small in all three experiments. The crops sown at the lowest seed rate was more vulnerable to weed competition. In consequence, it appears that there is relatively little advantage in terms of enhancing crop competition, in sowing higher than normal seed rates of winter wheat. However, there may be a distinct disadvantage in sowing at low seed rates, unless weeds can be controlled effectively.

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EFFECT OF WHEAT SEEDRATE ON AVENA LUDOVICIANA COMPETITION

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ABSTRACT

The competitive ability of two wheat cultivars in a naturally-infested field with Avena ludoviciana were studied in relation to five seedrates with and without wild oat control. The herbicide used was l-flamprop-isopropyl which had no effect upon the crop. The two year results showed that an increase in wheat seedrate increased grain yield and reduced the total wild oat weight; the effect was on the weight rather than on the number of weed plants. The effectiveness of the herbicide was less with the lower seedrates in the year of favourable conditions for weed regrowth. The yield increase obtained through the herbicide application was higher with lower seedrates than with higher. The two cultivars did not respond similarly for all seedrates and wild oat competition.

INTRODUCTION

Despite current advances in the practice of wild oat control very often there are cases where control is unsatisfactory. Since crop competition against weeds is needed for the effectiveness of the most commonly used herbicides, management of crop density may become increasingly important when the growers are planning a control strategy.

It is well known that when wheat is seeded at lower rates more tillers per plant are produced than when it is seeded at higher rates. However, in fields infested with Avena ludoviciana, that emerges at the same time as wheat in Greece, the competition between wheat and wild oats starts before the wheat plants produce tillers - both produce tillers at the same time. Therefore the crop density provided by higher seedrates will be essential in establishing enough competition against the weeds.

Many workers noted considerable reduction in the growth, seed production, and survival at harvest of wild oat where the seedrates of wheat and barley had been increased. Also the increase of the seedrate reduced the wild oat population and increased crop yield (MacNamara 1972, Cussans and Wilson 1975, Radford et al 1980, Thurston 1962). However, much of the experimental work on how seedrate can interact to affect the competition offerred by the crop against wild oat was done with Avena fatua either with spring cereals or with a rapidly growing Austalian winter cereal crop. There is a need to extend this work with A. ludoviciana and autumn sown wheat semidwarf cultivars.

The autumn sown wheat in Greece and most Mediterranean countries presents a different and difficult set of problems. The growing period is longer with maturity around 250 to 300 days after sowing. The growing season is also very variable; in some seasons crops may have two to three leaves before the end of November but in others not until the end of February. Weed development is protracted and is variable too.

The effects of wheat seedrate on the competition of wild oat with or without chemical control were studied at Thessaloniki, Greece in 1981-83.

MATERIALS AND METHODS

Two similar experiments were curried out on alluvial soil-typical of the wheat growing area-during 1981-1982 and 1982-1983. The field was naturally infested with a high population of Avena ludoviciana. The two wheat cultivars (Triticum aestivum) used, Generoso and Vergina, represent commercially available cultivars for the area. Each year the grains were planted in a split-split-plot arragement of a randomized complete block with four replications per treatment. Cultivars were the main plots, seedrates and wild oat control treatments were the sub-plots. Each sub-sub-plot consisted of 10 rows, 8.2 m long with 20 cm spacing. The wheat seedrates used were 120, 150, 180, 210, and 240 kg/ha. Seeding was done by hand in furrows opened by a small tractor. All wild oat or other weed plants were destroyed before seeding. Nitrogen (N) and phosphorus (P_2O_5) were applied at rates of 100 and 40 kg/ha, respectively, before seeding and 60 kg/ha of nitrogen was applied as top dressing at tillering. On the day of seeding the plots were rototilled and the fertilizer was broadcasted and incorporated.

1-Flampprop-isopropyl was used at the recommended rate 800 g/ha and at the two to three leaf stage to control wild oat. Half of each seedrate plot was treated with the hercicide and the remaining plot was left for the natural infestation by the wild oat. Barriers constructed by plastic sheets were inserted at the sides of sprayed plots to prevent spray drift. All experimental plots were sprayed with 2,4-D in March for the control of broadleaved weeds. A propane-pressurized sprayer with a 2 m boom was used to apply the herbicides.

Seedling counts.

Wheat seedlings were counted in two random quadrats each 0.5 m^2, placed at random in each replicate. The wild oat seedlings emerged during winter and early spring were counted with the same manner. Shortly before the wheat harvest wild oat plants were collected from two random quadrats each 0.5 m^2. Wild oat plants were hand pulled out, dried, and weighted. Both experiments were relatively free of broadleaved and grass weeds, with only very few plants of Lolium rigidum being present.

Grain yield.

When the wheat plants were matured, yields were obtained by cutting a single swath of 1.25 m width from the center of each plot with a small plot combine harvester. The grain from each plot was weighed and yields were adjusted to 12% moisture. The 1,000-kernel and hectoliter weight, sedimentation test (Zeleny 1960), and protein content were determined to find the effect of seedrate and wild oat competition on the quality of grains. Data were analyzed by analysis of variance for each year.

RESULTS

Crop density

Wheat was established well in each year and at the five seedrates. The average densities of the seedling populations are presented in Table 1.

TABLE 1

Number of wheat and wild oat seedlings/m^2 (1982-1983)

Seedrate kg/ha	Wheat seedlings/m^2		Wild oat seedlings/m^2	
	Generoso	Vergina	Generoso	Vergina
120	340j*	336j	43.25a	46.00a
150	402ef	376f	21.75bc	23.75bc
180	464d	412e	23.25bc	27.75b
210	522bc	512c	27.50b	26.00bc
240	580a	552ab	23.25bc	22.75bc

*Figures with a common letter do not differ significantly at $p < 0.05$.

Wild oat density

The infestation of wild oat was natural and the populations at both years were relatively dense. Seedlings emerged over a 2-month period but the majority of them emerged in autumn with the wheat. More seedlings emerged at the lowest seedrates of both wheat cultivars while at the other seedrates the mumber of wild oat seedlings was approximately the same (Table 1).

TABLE 2

Effect of seedrate on total dry weight of wild oat (g/m^2)

		1981-1982*					1982-1983**				
		Seedrate (kg/ha)					Seedrate (kg/ha)				
Cultivar	Treatment	120	150	180	210	240	120	150	180	210	240
Generoso	Unsprayed	406	365	355	360	216	422	441	362	292	203
	Sprayed	235	149	35	50	37	66	78	74	60	32
Vergina	Unsprayed	546	518	408	365	286	375	344	278	249	230
	Sprayed	250	180	80	75	63	68	71	80	54	64

* LSD 0.05, Seedrate 76, Treatment 24, T x SR 54, and T x SR x CV 75.
** LSD 0.05, Seedrate 55, Treatment 36, T x SR 80, and T x SR x CV 113.

1-Flamprop-isopropyl had no effect upon the wheat. This has been verified also in wild oat-free trials with these cultivars. The herbicide application gave satisfactory control of wild oat at the three higher seedrates but relatively poor control was obtained at the two lower seedrates in the 1981-1982 experiment. In this year it reduced wild oat dry matter weight by 42 to 54% at the seedrate of 120 kg/ha, 59 to 65% at 150 kg/ha, and 78 to 90% at the higher seedrates. In the second year of the experiment the herbicide treatment reduced wild oat weight approximately by the same percent in all seedrates tested and for both cultivars (72 to 84%, Table 2). By increasing the seedrate, wild oat dry weight was decreased progressively from the lowest seedrate to the highest with the exception of cv Generoso in the first year of the experiment. At the highest seedrate the weight of wild oat was about 50% less than that of the lowest seedrate for both cultivars in two year experiments.

Grain yield

Yield varied between the two years depending upon the environmental conditions. The highest yield in plots with wild oat control was 2918 kg/ha in the first year and 2229 kg/ha in the second, while the highest yield of the wild oat infested plots was 1863 and 1874 kg/ha, respectively (Table 3).

TABLE 3

Effect of seedrate on grain yield (kg/ha)

		Seedrate (kg/ha)				
Cultivar	Treatment	120	150	180	210	240
				1981-1982		
Generoso	Unsprayed	1160	1798	1828	1863	1780
	Sprayed	2450	2665	2688	2600	2820
Vergina	Unsprayed	1263	1353	1588	1700	1653
	Spayed	2510	2540	2643	2918	2608
LSD 0.05, Seedrate 202, Treatment 130, T x SR 291, and T x SR x CV 412.						
				1982-1983		
Generoso	Unsprayed	837	1029	1096	1173	1230
	Sprayed	1385	1526	1534	1613	2076
Vergina	Unspayed	1083	1221	1349	1848	1874
	Sprayed	2020	2078	1944	2229	2070

LSD 0.05, Seedrate 179, Treatment 92, T x SR 205, and T x SR x CV 290.

Wild oat control resulted in yield increases in the first year from 39 to 111% with cv Generoso and from 58 to 98% with cv Vergina and in the second year from 37 to 65% and 10 to 86%, respectively. The smaller increases were associated with the higher seedrates. This was reflected to the lower densities of wild oat populations in higher seedrates. Standard errors for differences between different seedrates were relatively high so that these differences did not often reach statistical signifficance.

After the control of wild oat the two cultivars showed little difference in grain yield between the seedrates except for the fifth seedrate of cv Generoso and the fourth of cv Vergina. However, a yield reduction was present for both cultivars of the lowest seedrates. The two cultivars under oat infestation had the lowest grain yield in both years at the 120 kg/ha seedrate, which was generally associated with an increase in wild oat infestation at this seedrate. By increasing the seedrates grain yields have been increased progressively up to 73%, except for cv Generoso in the first year in which the yield increase from 150 to 240 kg/ha seedrate was about the same (53 to 61%). Grain yield loss was proportional

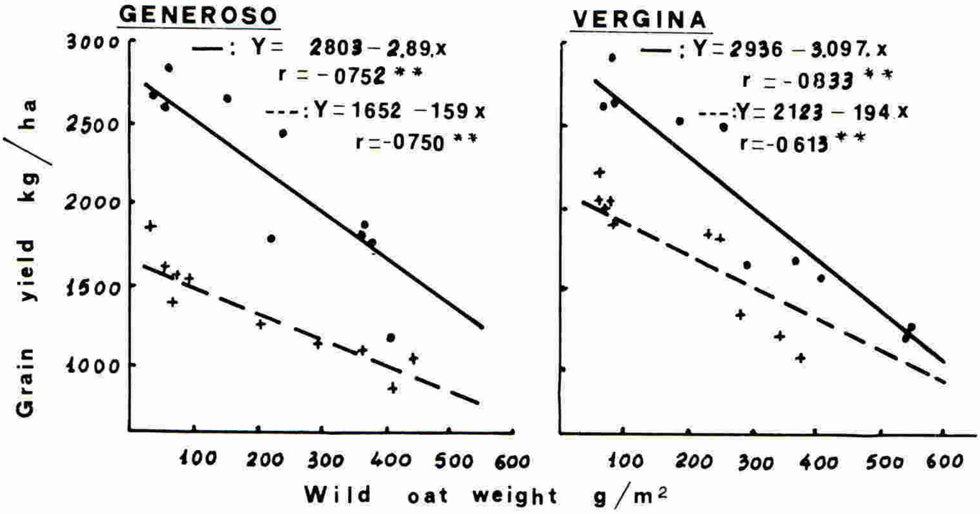

Fig. 1. Relationship between wild oat weight and wheat grain yield in 1981-82 ——. and 1982-83 ----+.

to the wild oat dry weight. This suggests a high degree of competition from the weed (Figure 1).

Increased seedrates had no effects on the baking quality of the grain for both cultivars with or without oat competition.

DISCUSSION

The seedrates studied in these experiments were selected as representative of the range normally encountered in wheat growing areas of Greece. Increasing wheat seedrate from 120 to 240 kg/ha leads to a marked reduction in wild oat weight but not to the level to prevent high grain yield reduction. Thurston (1962) has stated that Avena fatua is best controlled by a dense autumn crop and the density being more important than the crop grown. However, most of Avena fatua emerges in the spring when wheat has been already established and can suppress the weed (Thurston 1963). This is not true for Avena ludoviciana which emerges at the same time with wheat and is most competitive with the crop than Avena fatua. The decrease of wild oat was on yield of weight rather than on the number of weed plants. This is in accordance with earlier studies which showed that dense stand of wheat crop was effective in reducing wild oat dry wheight (Skorda 1974) because the wheat plant is not able to produce more tillers per plant when seeded at lower rates.

Although wild oat made more growth at the lower wheat seedrate than at the higher, its reaction to the herbicide treatment differed in the two years of the experiment. Treatment with l-flamprop-isopropyl, in the first year, gave only 42 to 65% control of wild oat at the two lower seedrates and for both cultivars while in the others the control was 78 to 90%. In the next year, for all seedrates the control of wild oat was high (72 to 84%). In the first year the precipitation was high after the herbicide application and wild oat was regrown in the thin, less competitive lower seedrate. In the next dry year no regrowth of wild oat was observed after the herbicide application. Jeffcoat and Harries (1974) have stated that for this herbicide, competition is essential for effectiveness as for most wild oat herbicides. More activity is seen during the time when the crop is offering most competition. Therefore, in order to reduce wild oat competition it is recommended that great attention be given to cultivar-specific seedrate so as to obtain optimum stand, especially in intensive crop management.

With the higher wheat populations, the wild oat densities were relatively low, the wheat crop largely suppressed the growth of the weed and was itself relatively less affected by competition. With the lower wheat populations, wild oat made more growth. The wild oat dry weight at the lowest seedrate was twice that at the highest.

The increase of seedrate from the lower to others resulted in most cases in higher grain yields under wild oat infestation but not under wild oat chemical control. This indicated that the effects of crop competition and the herbicide appeared to be separate and additive.

When the data were averaged over the two years indicated that the lowest seedrate yielded less than the others for both treatments and cultivars while the yield was progressively increased as the seedrate was increased. Again the seedrate 210 kg/ha of cv Vergina yielded more than the others and for cv Generoso the rate was 240 kg/ha.

These results show the importance of high seedrates to give a vigorous crop for maximum yield and some more effective control by those herbicides against wild oat, which need crop competition for their effectiveness and there are favourable conditions for wild oat regrowth. High seedrates suppressed wild oat but not to the level needed to prevent high grain losses.

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THE CONTROL OF ANNUAL BROAD-LEAVED WEEDS IN WINTER CEREALS: AUTUMN, SPRING OR AUTUMN AND SPRING APPLICATIONS COMPARED

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ABSTRACT

A review of forty two trials shows that two applications of foliar applied herbicides for annual broad-leaved weeds gave more reliable control than the same total rate applied at one timing. However, choice of herbicides and their rate of use was important. The first application in the autumn had to give reasonably effective control of the small weeds present, particularly those less susceptible to the herbicides. Unless this occurred, survivors were sometimes not controlled by the second application in the spring. The implications of the results are discussed.

INTRODUCTION

Trials conducted by the Agricultural Development and Advisory Service (ADAS) between 1978 and 1982 were reviewed by Bradford and Smith (1982). It was concluded that single applications of foliar applied herbicides were unsatisfactory for season long control of annual broad-leaved weeds. On average, single applications in the spring to winter wheat gave higher levels of weed control, when assessed in early summer, than autumn applications. The opposite applied in winter barley, presumably due to the more vigorous early growth of this crop. Weeds may be less able to recover from an autumn application and spring germination is less likely under a dense crop canopy. In addition, penetration of sprays to weeds under a winter barley crop canopy in the spring may be more difficult than in a more open winter wheat crop.

It was also clear from the same review that the conclusions were not generally applicable and that in individual trials the opposite result to the average occurred. It was suggested, from limited data, that two applications of bromoxynil with ioxynil and mecoprop made in the autumn and spring gave more reliable control than the same total rate of herbicide applied either in the autumn or spring. Such an approach was first suggested by the ARC Weed Research Organisation (Wilson 1980).

This approach has other potential attractions. The first application may give season-long control. If this were so, the second application would not be necessary, giving the farmer the opportunity to economise. Secondly, many farmers are reluctant to use foliar applied herbicides in the autumn/winter due to the fear of predisposing the crop to frost damage. According to experience and trials data, this fear is unfounded, except in specific circumstances (Orson 1983), but a lower rate of herbicide may persuade these farmers to reconsider. Finally, the need to apply other crop protection chemicals in the autumn means that the initial application can often be carried out in mixture with little inconvenience and the potentially lower rates should ease any tank-mixing problems. However, it should be emphasised that two applications may be involved and farmers considering such an approach must be equipped to carry out such a discipline.

In the harvest year 1983, ADAS started a trials series to investigate further the reliability of season-long weed control by foliar applied herbicides. This involved applying the same total rate of herbicide as two sprays rather than one. FBC Ltd started a similar series of trials in 1984. This paper reviews the results achieved in the harvest years 1983 to 1985.

MATERIALS AND METHODS

Field trials were carried out in commercial crops of winter wheat and winter barley. In the harvest year 1983, ten trials were carried out by ADAS. The following year, eleven trials were completed by ADAS and nine trials by FBC Ltd. In 1985, the numbers were seven and five trials respectively. Treatments and timings are given in Tables 1 to 5, and are based on 'splitting' the commercial recommended rate for large weeds in the spring in winter cereals between autumn and spring applications. Other rates were also tested, along with a 'three way' split in the ADAS trials in 1984 and 1985. The products used were:

Deloxil - 380 g/litre bromoxynil with ioxynil as esters
Starane 2 - 200 g/litre fluroxypyr as an ester
Ceridor - 187.5 g/litre bifenox with 462.5 g/litre mecoprop as salts
Ally - 20% wt/wt metsulfuron-methyl
Asset - 125 g/litre bromoxynil with 62.5 g/litre ioxynil and 50 g/litre benazolin as esters
Iso-cornox (FBC Ltd trials) - 620 g/litre mecoprop as a salt
various products (ADAS trials) - 570 g/litre mecoprop as a salt

The trials were of complete randomised block design with three or four replicates. Plot size was a minimum of 20 m^2 but where trials were taken to yield a minimum plot size of 30 m^2 was adopted. Herbicides were applied through fan nozzles by knapsack sprayer at a pressure of 200 Pa in ADAS trials and 280-300 Pa in FBC trials. Volumes equivalent to 200 litres/ha were used unless stated otherwise in Tables 1 and 2.

The ADAS trials were assessed prior to the final spray timing as weed plants per m^2 and in early summer as a visual assessment of weed growth. The final FBC assessment date at ear emerging of the crop is used in the results. Again this is based on a visual assessment of weed growth. The trials received commercial applications of fungicides and insecticides.

RESULTS

The results are given in Table 1 to 5. Owing to a shortage of space only the control of the more important and common weeds is included. The results are presented as the average percentage reduction on sites showing a common trend with mecoprop tank-mixed with bromoxynil and ioxynil with or without benazolin. Variation in the number of sites between assessments of the same weed in Tables 1, 2 and 5 are explained by the host farmer overspraying the site in the spring, results that are too variable for inclusion or where intra-weed competition has distorted the results. The variation in the number of sites per weed has resulted in the statistical information not being provided. The ADAS trials only contain assessments of weed reduction from sites where the number of weeds per species exceeded ten per m^2 in the unsprayed controls.

In 1983 (Table 1), the sequence involving a total of 570 gram a.e./ha bromoxynil with ioxynil as esters tank mixed with 2052 gram a.e./ha mecoprop salt generally gave more reliable weed control than a single application either in the autumn/winter or in the spring. The exception was Viola arvensis control in winter wheat; in winter barley the sequence was still more reliable. Higher total rates in sequence gave higher levels of control of this weed.

In 1984 (Tables 2 and 3), the sequences in both trial series gave more reliable results. There were some exceptions. Again V. arvensis was not so reliably controlled by the bromoxynil with ioxynil and mecoprop sequences in the ADAS trials in winter wheat and in a winter barley crop severely affected by Barley Yellow Dwarf Virus; a result shared with sequences involving bromoxynil with ioxynil and fluroxypyr in winter wheat and in one additional winter barley trial. The sequence of bifenox with mecoprop gave poorer control of Matricaria spp. than a single autumn application. In two trials, the sequences involving bromoxynil with ioxynil and mecoprop or fluroxypyr gave slightly inferior control of Stellaria media to the best single timing. In one of these two trials, the sequence of bromoxynil with ioxynil and fluroxypyr gave inferior control of Veronica persica to a single spring application. The autumn/winter applications in these latter two trials were made in cold conditions. In one trial, a sequence totalling 475 gram/ha a.e. of bromoxynil with ioxynil and benazolin esters and 1860 gram a.e./ha mecoprop salt gave inferior control of V. arvensis to the same total rate in one spring application. There appeared to be no overall advantage in a 'three way' split or in splitting the two applications one third:two thirds rather than half:half.

The 1985 results (Tables 4 and 5) were similar to the previous two years. There were one or two instances where the sequences were inferior. One related to bromoxynil with ioxynil and mecoprop or fluroxypyr on V. persica in winter wheat. Sequences involving metsulfuron-methyl with mecoprop gave less reliable control of Galium aparine and V. arvensis than the best single timings. Again there was no overall advantage from a one third:two thirds rather than a half:half split of bromoxynil with ioxynil and mecoprop and no overall advantage from a three way rather than a two way split of these herbicides.

DISCUSSION

The results show that with the herbicides investigated, a split application of the spring recommended rate for large weeds gives more reliable weed control than a single application. However, it is important that the autumn application is effective on weeds, especially those that are not very susceptible to the herbicides used. An example of this was V. arvensis where recovery and new germination meant that an insufficient control in winter wheat in the autumn with bromoxynil with ioxynil and mecoprop was often not compensated for by a lower than recommended rate in the spring. A similar situation occurred with bifenox with mecoprop on *Matricaria* spp. in 1984, and metsulfuron-methyl with mecoprop on *G. aparine* in 1985. However, the sequence totalling 570 gram a.e./ha of bromoxynil with ioxynil tank mixed with 2052 gram a.e./ha of mecoprop salt gave superior control of *V. arvensis* than single applications in healthy winter barley crops. This shows that crop competition is an important factor. Also, in some cases, reasonable growing conditions at the time of the first application are important for the success of the sequences.

Yields from the ADAS trials are not presented but they reflected the level of weed control obtained. FBC visual assessments four weeks after application suggest that the sequences showed improved crop safety over single treatments in the trials where some slight effects were seen.

These trials show that with careful choice of type and rates of herbicides, reasonably effective control of small weeds in the autumn can be 'topped up' in the spring to control survivors and spring germinating weeds in order to provide season long control. This second application would be at a lower rate than usually recommended in the spring. This is because spring recommended rates are usually determined in trials where no previous herbicide has been applied. FBC trials show that often the second spray is not needed. An autumn application of 237 gram a.e./ha of bromoxynil with ioxynil and benazolin as esters with 930 gram a.e./ha mecoprop salt (half the spring rate for large weeds) gave over 95 per cent control of weed growth at ear emergence of the crop in four out of nine trials in 1984, over 90 per cent control in five trials and over 85 per cent control in all trials. The sequence of two applications averaged 97 per cent control over all sites.

Annual broad-leaved weed control in winter cereals based on sequences of foliar applied herbicides can be both cost-effective and flexible. However, a good understanding of herbicide activity on the weeds present is required along with the ability to apply the herbicides at the correct time.

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TABLE 1
Herbicides, rates, timing and per cent weed control - ADAS trials, 1983

Treatment	Rate/application g/ha	Timing	S. media		V. pers.		G. apar.		V. arv.		Mat. spp.	
			A	B	A	B	A	B	A	B	A	B
Total volume of application 100 l/ha												
brom/iox	142	a + c	45	62	85	73	41	39	43 (32)	60 (15)	62	100
brom/iox + mec	142 + 1026	a + c	68	99	85	72	51	84	58 (7)	70 (2)	83	100
brom/iox + mec	142 + 2052	a + c	79	99	83	78	64	93	59 (21)	71 (48)	91	100
Total volume of application 200 l/ha												
brom/iox	142	a + c	38	54	68	80	30	26	50 (0)	52 (36)	58	100
brom/iox + mec	142 + 1026	a + c	65	93	91	93	50	75	50 (0)	62 (32)	76	100
brom/iox + mec	142 + 2052	a + c	85	100	87	94	51	88	63 (5)	63 (43)	78	100
brom/iox	285	a + c	55	77	96	94	54	54	59 (0)	67 (0)	70	100
brom/iox + mec	285 + 1026	a + c	82	99	92	97	71	91	100 (25)	92 (35)	83	100
brom/iox + mec	285 + 2052	a + c	84	100	97	96	75	98	100 (26)	92 (58)	89	100
brom/iox	570	a + c	71	90	100	100	45	67	100 (8)	92 (38)	91	100
brom/iox + mec	570 + 1026	a + c	88	100	96	99	64	97	92 (12)	95 (73)	92	100
brom/iox + mec	570 + 2052	a	88	99	99	94	83	79	100 (45)	89 (67)	83	94
brom/iox + mec	570 + 2052	c	-	85	-	69	-	70	- (-)	58 (25)	-	100
mecoprop	1026	a + c	58	96	34	51	56	58	58 (0)	64 (4)	27	69
mecoprop	2052	a + c	73	97	52	69	52	76	80 (8)	72 (21)	53	85
No. of trials			4	4	6	3	3	3	2 (1)	3 (1)	3	3

A - assessment prior to timing c   B - final assessment
a - weeds 2-6 true leaves
c - as crop canopy closed or just prior to crop first node detectable (which ever occurred first)
( ) trial(s) in which two applications gave inferior control to single applications of the same total rate

TABLE 2
Herbicides, rates, timing and per cent weed control - ADAS trials, 1984

Treatment	Rate/application g/ha	Timing	S. media		V. pers.		G. apar.		V. arv.		Mat. spp.	
			A	B	A	B	A	B	A	B	A	B
Total volume of application 100 l/ha												
brom/iox + mec	142 + 1026	a + c	85 (34)	98 (82)	81	96	37	85	34 (18)	53 (39)	89	96
brom/iox + mec	142 + 2052	a + c	89 (65)	100 (92)	87	92	59	87	68 (59)	86 (57)	91	99
brom/iox + mec	285 + 1026	a + c	99 (50)	100 (77)	94	99	63	93	71 (49)	71 (62)	98	99
brom/iox + mec	285 + 2052	a + c	98 (87)	100 (92)	93	99	55	95	79 (65)	91 (78)	74	98
brom/iox + mec	570 + 1026	a + c	98 (66)	99 (91)	98	100	72	94	85 (81)	91 (70)	93	97
brom/iox + mec	190 + 1026 380 + 1026	a + c	93 (54)	99 (87)	89	97	66	96	54 (49)	73 (57)	94	94
brom/iox + mec	142 + 1026	a + b + c	99 (67)	100 (86)	97	97	85	97	81 (63)	76 (63)	91	100
Total volume of application 200 l/ha												
brom/iox + mec	142 + 1026	a + c	96 (58)	100 (82)	77	94	53	83	67 (43)	76 (30)	58	91
brom/iox + mec	285 + 1026	a + c	99 (61)	100 (77)	95	100	61	93	80 (56)	89 (53)	93	100
brom/iox + mec	570 + 2052	a	100 (82)	100 (84)	99	96	62	80	95 (87)	89 (64)	97	85
brom/iox + mec	570 + 2052	c	- (-)	99 (75)	-	86	-	93	- (-)	50 (35)	-	94
bifenox/mecoprop	860 1740	a + c	63 (44)	94 (65)	98	99	33	89	98 (77)	96 (78)	46	46
bifenox/mecoprop	1950	a	95 (70)	82 (62)	100	99	68	65	98 (88)	92 (77)	95	83
bifenox/mecoprop	2600	c	(-) (-)	79 (79)	-	97	-	85	- (-)	39 (61)	-	0
brom/iox + flur	190 + 70 380 + 130	a + c	94 (57)	100 (88)	90	97	46	98	71 (24)	52 (37)	86	93
brom/iox + flur	570 + 200	a	100 (91)	98 (93)	98	91	87	71	86 (85)	74 (58)	94	77
brom/iox + flur	570 + 200	c	- (-)	99 (98)	-	91	-	92	- (-)	51 (40)	-	90
No. of trials			3 (2)	3 (2)	7	6	3	4	2 (3)	2 (3)	1	1

A - assessment prior to timing c　B - final assessment
a - weeds 2-6 true leaves　b - 4-5 weeks after a
c - as crop canopy closed or just prior to crop first node detectable (which ever occurred first)
( ) trial(s) in which two applications of bromoxynil/ioxynil + mecoprop gave inferior results to a single application of the same total rate

TABLE 3
Herbicides, rates, timing and per cent weed control - FBC trials, 1984

Treatment	Rate/application g/ha	Timing	S. media	V. persica	G. aparine	V. arvensis	Veronica hederifolia	Matricaria perforata	Lamium purpureum
brom/iox/benazolin	475	a	96	99	91	73 (68)	100	99	66
brom/iox/ben + mec	237 + 930	a	99	98	94	80 (83)	99	94	92
brom/iox/ben + mec	475 + 930	a	99	99	97	87 (74)	99	96	98
brom/iox/ben + mec	475 + 1860	a	99	99	97	89 (84)	99	97	93
brom/iox/benazolin	475	a + c	98	99	95	81 (84)	100	100	90
brom/iox/ben + mec	237 + 930	a + c	99	99	99	90 (86)	100	99	96
brom/iox/ben + mec	475 + 930	a + c	100	100	99	97 (92)	100	100	99
brom/iox/ben + mec	475 + 1860	c	95	86	97	60 (90)	99	100	65
No. of trials			9	6	2	4 (1)	3	3	3

( ) trial(s) in which two applications gave inferior control to one application of the same total rate

TABLE 4
Herbicide, rates, timing and per cent weed control - FBC trials, 1985

Treatment	Rate/application g/ha	Timing	S. media	V. persica	G. aparine	V. arvensis	L. purpureum
brom/iox/benazolin	475	a	97	99	86	95	100
brom/iox/ben + mec	356 + 930	a	99	100	89	98	100
brom/iox/benazolin	475	a + c	99	100	99	97	100
brom/iox/ben + mec	356 + 930	a + c	100	100	99	99	100
brom/iox/ben + mec	475 + 1860	c	99	99	98	86	97
No. of trials			4	1	4	1	1

a - weeds up to 5 cm high or across
c - as crop canopy closed or at or just prior to first node detectable (which ever occurred first)

TABLE 5
Herbicides, rates, timing and per cent weed control - ADAS trials, 1985

Treatment	Rate/application g/ha	Timing	S. media		V. pers.		G. apar.		V. arv.		Mat. spp.	
			A	B	A	B	A	B	A	B	A	B
brom/iox + mec	142 + 1026	a + c	93	100	96 (92)	100 (88)	76	98	37	55	85	100
brom/iox + mec	142 + 2052	a + c	93	100	100 (96)	100 (86)	86	100	63	68	54	100
brom/iox + mec	285 + 1026	a + c	89	100	100 (100)	100 (88)	95	100	69	75	86	100
brom/iox + mec	285 + 2052	a + c	96	99	99 (100)	100 (95)	92	100	87	90	69	100
brom/iox + mec	570 + 2052	a	94	98	99 (100)	98 (98)	96	96	94	77	81	82
brom/iox + mec	570 + 2052	c	-	85	- (-)	100 (87)	-	97	-	68	-	100
brom/iox + mec	190 + 1026	a +	90	97	99 (81)	100 (99)	87	100	48	90	41	100
	380 + 1026	c										
brom/iox + mec	142 + 1026	a + b + c	99	100	99 (96)	100 (93)	97	100	71	71	96	100
bifenox/mec	975	a + c	73	97	100 (100)	100 (99)	68	100	95	90	70	100
bifenox/mec	1950	a	86	99	100 (100)	100 (94)	89	90	98	90	81	90
bifenox/mec	1950	c	-	74	- (-)	100 (94)	-	81	-	64	-	100
brom/iox + flur	190 + 70	a +	96	100	100 (100)	100 (90)	85	97	41	81	77	100
	380 + 130	c										
brom/iox + flur	570 + 200	a	99	98	100 (100)	100 (94)	97	100	84	77	71	81
brom/iox + flur	570 + 200	c	-	81	- (-)	80 (90)	-	96	-	83	-	100
metsulfuron + mec	3 + 1026	a + c	85	100	94 (53)	99 (63)	33	59	21	51	85	100
metsulfuron + mec	6 + 2052	a	92	100	99 (65)	95 (56)	64	81	54	62	90	100
metsulfuron + mec	6 + 2052	c	-	100	- (-)	88 (37)	-	84	-	90	-	100
No. of trials			6	3	2 (1)	1 (1)	2	2	3	1	1	1

A - assessment prior to timing c   B - final assessment

a - weeds 2-6 true leaves   b - 4-5 weeks after a

c - as crop canopy closed or just prior to crop first node detectable (which ever occurred first)

( ) trial in which two applications of bromoxynil/ioxynil + mecoprop gave inferior control to single applications of the same total rate