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Organic and Low Input Systems in the United Kingdom

Chairman: MR J. NORTH

CROP PROTECTION IN LOWER INPUT SYSTEMS OF AGRICULTURE

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ABSTRACT

Crops need to be protected from pest and disease attack and from competition from weeds. The methods available vary from laborious destruction by hand to the application of long-lasting chemical biocides. Public concern about the latter, in terms of food safety, safety of operators and effects on the environment are exacerbated by the use of chemicals as an insurance even when the need may not be clear.

There is therefore considerable interest in low or lower input systems that reduce risks and costs without proportional reduction in output. There are real difficulties, however, in policing such systems and thus in guaranteeing that products have been produced in these ways.

Organic farmers and growers believe that it is wrong to rely on such inputs and worse to operate systems that depend upon them. Some consumers also take the view that the only way to eliminate the perceived risks is by using systems in which no "chemicals" are employed.

It is important therefore to explore a range of alternative ways of producing food and to provide the consumer with a credible choice of the products.

BACKGROUND

This paper is an introductory one and does not, therefore, attempt to go into detail on any of the many aspects that have to be covered in a subject as wide as this one.

The starting point has to be the proposition that crops need protection. Agriculture is always to an extent unnatural and thus operates in a hostile environment. It is carried out for specific purposes and normally involves a concentration on a very limited number of species, animal and crop, in order to produce what is required. Natural forces resist this concentration and agricultural crops usually need protection from the unwanted species. Not that the wanted species are confined to those directly producing agricultural products; but there is a whole range of species that compete with the agricultural ones, for resources and, indeed, for life itself.

In primitive agriculture, and still in many of the developing countries, protection is needed from large animal species that would otherwise consume or damage crops. Fencing often has to be high and strong to keep out such animals, most notably with, for example, elephants.

In developed countries, most of these large competitors have been eliminated or confined to non-agricultural areas and fences are primarily to keep domesticated animals in.

But pests, weeds and diseases cannot be physically excluded in most agricultural systems, and they result, worldwide, in losses on an enormous scale, during production, in storage and during transport.

These losses are extremely serious and it may often be the case that, where production is inadequate for people's needs, the priority should be to reduce losses rather than to try and produce more. The question remains as to how this is to be done and clearly, there is no general answer that will apply to all crops and all environments.

However, the arguments tend to rest on different general approaches or philosophies, broadly related to the use of inputs.

Some take the view that inputs should be minimised, or at least restricted to "natural" (as opposed to "artificial") elements, substances and species. Others see no reason to place restrictions on the use of inputs other than those imposed by legislation or "good practice".

Curiously both extremes are most strongly represented in affluent countries where, on the one hand, inputs can be afforded and, on the other hand, the higher priced food generally associated with minimum inputs can also be afforded.

In developing countries, there is generally a great need to increase productivity and a lack of money to pay for inputs: at the same time, low input systems are associated with extremely low outputs. It is worth dwelling on this link and asking whether it is inevitable.

LOW INPUT/LOW OUTPUT SYSTEMS

In any production system there is a direct relationship between <u>essential</u> inputs and outputs up to a certain point, beyond which the inputs are no longer essential. Obviously, if excessive inputs are provided, they can be reduced without affecting output. Equally, if inputs are very much lower than what is needed, output will rise if they are applied. This is true for providing nutrients for crops and for feeding animals.

However, the inputs have to be <u>balanced</u>, in the sense of the desired proportions between one element and another, and it is now seen clearly that they have also to be related to external effects, i.e. outside the system, in terms of pollution and other undesirable consequences.

But there is another argument concerning the effects of inputs on the system itself when viewed holistically.

The application of agrochemicals is an important example. The use of heavy applications can result in systems that depend upon them, because they result in reduced "immunity" or "resistance" to pest organisms.

When inputs are reduced in such "dependent" systems, output falls, but this does not show that "independent" systems cannot exist. Skilled management may be able to encourage predators and parasites of pest organisms to the point where no agrochemicals are needed and where their use only interferes with the system created. However, as may be seen in both developing and developed countries, this may not always be possible and may rarely be easy.

The links between inputs and outputs are, of course, different for nutrient inputs (feed and fertiliser) and for crop protection chemicals.

In the first case, nutrients are needed but the supply may come from another (biological) source - as with clover nitrogen.

In the second case, the chemicals may not be needed but an alternative method of pest control may be. This will not be so where it is possible to achieve systems in such biological balance that no species ever constitutes a pest. We may not know much about this yet but the possibility exists. Where it does, it is possible to aim at the "zero option" of using no chemicals at all.

THE "ZERO OPTION"

There is no need to make assumptions about the ultimate productivity of this option, or whether it could ever feed the world, or what price its products would have to be. In any case, all these issues may be greatly affected by other factors.

It is an option worth considering because it can make contributions to environmental control, consumer confidence, cost reduction and our understanding of agricultural biology.

To be in favour of exploring such an option need imply nothing derogatory about other options or those who operate them and need not imply that it would be the desirable option in all circumstances.

But it is legitimate to ask why one should aim at "zero" use of non-biological or artificial substances, having regard to the ways in which we run the rest of our lives. Toothpaste can hardly be said to be natural and fleas most certainly are, but we choose the less natural repeatedly.

Farming is itself "unnatural" except as an activity of man. The rabbit also is not interested in theoretical notions of ecological balance (and getting eaten) but, like us, does have an interest in sustainability. Wild species, however, have to tolerate population peaks and crashes, and the suffering that goes with them that may be natural but would not appeal to us.

The main arguments for the "zero option" then have to relate to principle or practicality: either that there is some powerful - perhaps moral - reason for using none at all of the substances in question or that only "zero" can be policed, guaranteed or relied upon to be low enough - in the absence of hard data on acceptable levels of all the substances involved.

These practical issues can be of very great importance in attaching a meaning to any low input system, simply because of the difficulties of establishing credibility for the products so produced.

Organic Standards

All the foregoing considerations played their part in determining that the National Standards for organically-produced foods were set by UKROFS (the U.K. Register of Organic Food Standards) at the very low levels of inputs that are recommended.

Only those chemically-extracted or synthesized substances are allowed that are either part of a legal requirement, are the only means of curing or preventing animal suffering or can be demonstrated to be essential in some fashion. Currently, no "artificial" fertilisers or synthetic pesticides or herbicides are included in these categories.

The Standards relate to production, including processing, and thus relate to the materials used, the way products are produced, treated, transported, packaged and sold. No claims are made about the products except that they have been produced according to these (policeable) standards.

The UKROFS Board is both independent and neutral. There is a market for organically-produced food and it is essential that producers and consumers alike can be sure that the label on it carries a credible guarantee. Furthermore, the Standards are published so that anyone can find out, in detail, what they are.

The problem for low or lower input systems of production cannot be so simply resolved.

LOWER INPUT SYSTEMS

Curiously enough, neither those who favour organic farming, nor those who argue that no unnecessary restrictions should be imposed are usually in favour of intermedite levels of inputs. The first fear confusion in the mind of the purchaser and the fact that false claims could easily be made. The second see no reason to restrict the producer from using any substance that, in the amounts used, is neither dangerous nor damaging to the environment. There are also concerns that ill-founded worries might prevent the use of substances that may increase productivity, profit and food safety.

Theoretically, the very characteristics of complex ecosystems render them capable of absorbing shocks and inputs: if the disturbance is too great for adaptation, a new ecosystem emerges that is adapted. This occurs even after volcanic eruptions, for example.

However, the fact that there are obviously natural disasters, poisons and suffering should not be used to attack the concept of "what is natural" where "appropriateness" is really implied.

It is often argued that "organic" management is much more difficult than "conventional" but it could be that the intermediate lower input systems actually require even more knowledge and skill in order to integrate inputs and the harnessing of biological organisms successfully.

It would be possible to set Standards for these intermediate levels of inputs, although they might have to include different levels for different crops, but policing would present major problems.

It can certainly be argued that lower input systems would increase safety margins, increase public confidence, decrease risks, and might even increase profits. It can also be argued that, for environmental reasons, conventional agriculture should move in this direction and that such a change would affect much greater volumes of food and areas of land than would be involved in organic farming.

THE FUTURE NEED

Since the nature of the demand for food may change in unpredictable ways and the population is not homogeneous in its wants, needs or desires, there is a powerful argument for allowing - indeed encouraging - a range of food production systems, so that the consumer is presented with a wide choice.

For this choice to be effective, there has to be public confidence in credible and informative labelling, backed by inspection and enforceable Standards.

The consequences of different production methods need to be monitored, both from the consumers' point of view and that of the environment, and "public good" R&D needs to be supported in order to increase our knowledge of what is happening in such systems.

There needs to be less confrontation between those who favour one method or another; there is little to be gained by impugning the honesty or intentions of others.

The debate needs much greater clarity in the use of terms and in the quality of the argument: there is also a need for much greater understanding of the issues and of the positions of those involved. Just take one example: the role of the scientist.

It is no use one side behaving as though scientists can pronounce with certainty on all the questions involved or the other side ignoring the scientific evidence that is available.

We have to recognise that a scientist can only operate on the evidence that is available and apply tests of its validity. This means that science cannot deal with questions where there is no evidence (or the evidence is inadequate) and that scientific views and advice (a) only relate to the evidence and to the areas to which it applies and (b) will change as soon as the evidence does.

Lack of evidence may be due to:

(a) the fact that it has not been sought
(b) the long-term nature of effects

(c) inability to measure low values
(d) inability to experiment on people or
(e) the fact that it is withheld or
(f) too costly to obtain.

High quality R&D is vital in this whole area.

Finally, since no confrontation at all is both unrealistic and perhaps unsafe, the greatest need is for independent, authoritative assessments of the issues. Only the latter will generate trust, not only in such answers as are available but also that the right questions are being asked and that someone is taking peoples' concerns seriously and is trying to understand them.

APPROACHES TO THE DEVELOPMENT OF LOW INPUT FARMING SYSTEMS

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ABSTRACT

Two new and broadly similar UK research projects are described; LIFE (Low Input Farming and Environment) and TALISMAN (Towards A Lower Input System Minimising Agrochemicals and Nitrogen). These are studies on integrated farming systems which aim to reduce the cost and increase the environmental safety of arable farming in the UK, and to provide options to enable UK agriculture to have a flexible approach in the face of an unknown future. This involves a shift of emphasis away from maximum production, based on chemically oriented technology and high inputs, towards improved production efficiency, through the substitution where possible of expensive and potentially polluting inputs by more environmentally acceptable alternatives. LIFE is a long term fully phased experiment occupying 19 ha on one site, with all five courses of the rotation represented each year. TALISMAN occupies 17 ha, spread over four sites, with only two courses of a six-course rotation represented each year. The experiments are all run as systems comparisons, and are supported at all sites by programmes of detailed experimentation on responses to individual system components.

INTRODUCTION

Agriculture is changing drastically but there are varying views about direction; there is no social consensus, no obvious national policy, and it is often regarded as the "sick man of Europe" with much diversity of opinion regarding possible therapy. Amongst the basic aims of the initial EEC agricultual policy were self sufficiency and cost acceptable food production, acceptable incomes for producers, and maintenance of employment in the agricultural sector. Subsidies were used to bring this about, but they were also the cause of increasing production surpluses and of growing disparity between aims. Set alongside these undesirable consequences are new social concerns: pollution of soil and water with fertilisers and pesticides, pesticide residues in food, fewer natural enemies of pests, harm to flora and fauna, overproduction of some crops, decreasing employment due to increased mechanisation, increased mistrust of the products of intensive agriculture, and increased inputs of fossil fuels and other non-renewable resources.

Whilst the use of agrochemicals is necessary to maintain food production, the public generally consider their intensive use to be socially and environmentally unacceptable. Organic farming, whilst apparently meeting the aims of environmentalists, raises questions about the adequacy and reliability of its methods for sustaining the required level of food production, and about increased contamination of foodstuffs with toxic chemicals produced by fungi and by infected plant tissues. Without going to the full extent of organic farming to UKROFS or Soil Association standards, there is clearly scope to reduce agrochemical use on many arable farms without a major impact on output. This can be achieved by paying closer attention to the need for, and cost-effectiveness of, individual agrochemical applications, and by adopting a range of husbandry practices designed to reduce the risk of problems arising that justify treatment with pesticide. It is this middle ground which our work aims to explore, in order to establish the costs and benefits associated with a more environmentally acceptable approach to pesticide use.

Long Ashton has recently been given special responsibility to research in depth aspects of low input farming (LIFE) within the Institute of Arable Crops Research, and ADAS are developing follow-up projects to the Boxworth Project (TALISMAN, SCARAB). Both organisations work in close collaboration and together with researchers in other European States, aiming to develop a compromise between "conventional-intensive" and organic farming, and to develop new agronomically, economically and ecologically acceptable agricultural systems.

Within the UK, research on farming systems has not so far been done in ways which enable comparisons to be made with projects in other parts of Europe. Most projects concerned with integrated farming systems have been relatively short-term and have aimed at specific objectives within crop production or crop protection. Examples are the MAFF Boxworth Project, concerned principally with the environmental effects of pesticides in whole fields within a cereal monoculture, the Cereals and Gamebirds project of the Game Conservancy which explores opportunities to increase gamebird survival by reducing pesticide use on crop margins, and research on the development of specific new techniques for pest, disease and weed control by the AFRC, ADAS and other organisations in the UK.

Research into the development of integrated farming systems, with the basic aim of reducing pesticide inputs and environmental concern is well advanced in some European countries, particularly in the Federal Republic of Germany (El Titi, 1986; 1989) and in the Netherlands (Vereijken, 1989; Wijnands & Vereijken, 1988; Wijnands, 1990 - this Symposium). The input of pesticides has been reduced by 30% (Germany) and even by 60-90% (Netherlands), as active ingredients, apparently without loss of income to farmers. Moreover, considerable savings in fertilisers have been achieved and bio-indicators for the health of crops and soils suggest there have been improvments.

LONG ASHTON LOW INPUT FARMING AND ENVIRONMENTAL RESEARCH (LIFE)

The overall objective of the LIFE project is to reduce agrochemical, nutrient and energy inputs and costs by 50%, whilst sustaining yield at 80% or more of that attainable from "intensively-grown" crops and maintaining or improving gross margins. Also, for specific crops to develop integrated control strategies which are compatible with environmental protection.

Cropping Sequences

The "farm scale" experiment began in autumn 1989 and occupies a 19 hectare area 3.6 km west of Long Ashton. It comprises five large fields, each divided into four sub-units: conventional rotation or integrated rotation, each with standard farm practice or low input husbandry options. Each sub-unit is 48m wide and at least 100m long.

Two cropping sequences are being compared, each rotationally phased and designed in such a way that the performance of specific crops can be compared within years and from year to year. A conventional 4-course rotation, based on the results of a survey done within the membership of the Long Ashton Members' Association, is being compared with an integrated rotation designed to: (a) provide greater opportunities for pesticide reduction by growing only first wheats to decrease disease carry-over, (b) optimise the use of profitable break crops to conserve N in the system for the potential benefit to yield of subsequent first wheats, (c) devise a system that contains cereal, oil and protein crops thus reducing the small-grain component in crop production.

Conventional Rotation

Winter Wheat / Winter Wheat / Winter Barley / Winter Oilseed Rape

Integrated Rotation

Winter Oilseed Rape / Winter Wheat / Winter Oats / Winter Beans / Winter Wheat

To each crop the following "standard farm practice" inputs or "low" inputs will be made annually.

Standard farm practice

All areas are being conventionally ploughed. Cultivars have been selected for their high yield potential and have been sown in mid-September. Fertiliser has been applied at optimal rates to achieve target yield. Chemicals for crop protection will be applied as the experimenters judge they might be used by a prudent and technically competent practitioner who is following managed pest, disease and weed control programmes, or else targetted at specific risks. A plant growth regulator has been applied routinely to winter cereals at GS 31, and will be again later if considered necessary. Attempts have been made to keep the overall frequency of pesticide application well within the UK survey average use figures (Sly, 1982).

Low input husbandry options

The following husbandry methods are preferred options in the development of the low input system at Long Ashton, and may be modified annually according to data acquisition. Soil cultivation will be done predominantly by non-inversion tillage techniques. Cultivars have been selected for disease resistance and sown in mid-October. Fertiliser requirement has been based initially on soil and crop chemistry. Crop protection sprays will be used only if considered essential, and will be chosen to be as benign as possible to the environment and non-target organisms.

Cultivation

Tillage systems have various effects on pests, diseases and weeds and also interact with other components. Complete inversion of crop residues by conventional ploughing has a considerable influence on the mineralisation of plant nutrients, and on the survival of pests, diseases and weeds. However, ploughing leaves bare soil which increases nitrogen volatilisation to the atmosphere and is therefore considered environmentally undesirable. Non-inversion tillage systems incorporate crop residues in the top soil layers and increase soil organic matter, earthworm biomass, and soil surface fauna - particularly predators of pests. These systems also conserve nitrogen and decrease soil erosion through improvements in soil structure (El Titi, 1989). The consequent concentration of crop residues near the surface is considered to increase the risks from trash-borne diseases, but data from field experiments that compared non-inversion tillage and direct drilling with conventional ploughing, have shown no significant changes in the incidence of major wheat diseases such as eyespot, sharp eyespot, *Fusarium*, powdery mildew and *Septoria* spp. However, in consecutive winter barley crops, the incidences of net blotch and *Rhynchosporium* were increased in non-inversion tillage and direct drilled systems (Jordan, unpublished). Weed problems may also be increased in systems that leave weed seeds near the soil surface. On balance, non-inversion tillage is considered the preferred option for exploiting natural regulatory mechanisms.

We are making non-inversion tillage a two machine-pass operation, thereby permitting weed and volunteer germination after the first cultivation and mechanical control with the combined second cultivation/drilling operation, using a Dutzi tillage/drilling system. Thus, the proposed establishment of crops and residue disposal in the 5-year low input system will be:

"first" wheat	-	sown with the Dutzi, straw baled after harvest.
oilseed rape	-	direct drilled for energy conservation, post-harvest residues incorporated.
"first" wheat	-	sown with the Dutzi, post-harvest residues incorporated.
winter oats	-	sown with the Dutzi, straw baled and sold.
winter beans	-	sown broadcast/ploughed, post-harvest residues incorporated.

Cultivar selection

The main factor in cultivar selection for the low input system is resistance to pests and diseases rather than yield potential. There are relatively few examples of cultivar resistance to pests, such as winter oats resistant to cereal cyst and stem nematode, but many wheat and barley cultivars possess a reasonable degree of genetic resistance to specific diseases. Thus, risks of serious disease attacks can be minimised by growing cultivars with genetic resistance to pathogens that prevail in the areas where they are to be grown. Cultivar trials, done in many areas throughout UK by the National Institute of Agricultural Botany (NIAB), and updated annually, provide information on comparative yield performance. They also publish disease resistance ratings on a 0 - 9 scale, which are good guidelines for cultivar selection, especially where the choice is between cultivars of similar potential yield. Thus, cultivars with desirable quality characteristics and disease resistance (e.g., winter wheat cv. Rendevous - eyespot resistance) will be included in the system.

Epidemics are most likely to occur if a single cultivar is grown on a large area in successive years; conversely, disease spread is likely to be hindered if neighbouring fields are sown with cultivars possessing different specific resistances. Hence, use will be made of the NIAB diversification groupings in choosing a range of cultivars for adjacent fields. Additionally, appropriate mixtures of varieties with different genes for disease resistance can limit considerably the spread of disease in a crop stand. This is particularly applicable to many diseases that are spread by airborne spores, and some splash-dispersed diseases may also be resticted in this way (Wolfe, 1985).

Sowing date

Manipulation of sowing date is a valuable means of influencing the incidence of pests, diseases and weeds. Delayed sowing is a time-honoured method of controlling annual weeds, particularly black-grass in winter wheat on heavy land, but is much dependent on weather conditions for weed germination and mechanical control. Similarly, crops sown in mid-late October are less prone to foliar and stem-based diseases, and to Barley Yellow Dwarf Virus which is spread by aphid vectors which invade crops in early autumn. However, it is usually considered unwise to delay drilling beyond the end of October, not only because of possible yield depression but also because soil conditions thereafter may limit or prevent autumn drilling opportunities. Thus, the target date for sowing autumn crops at Long Ashton, will be mid-October.

Nutrition

Nitrogen is probably the most expensive input into arable crop production and there is generally a high response to its use. Numerous nitrogen dose-response experiments have been done annually by many researchers, with much variation in yield optima. In general, increasing amounts of nitrogen increase plant growth and vigour as well as the likelihood of crop lodging, and also the risk of foliar diseases becoming severe. Additionally, the total production of protein in a crop is physiologically limited by nitrogen supply; thus, on average, more nitrogen fertiliser is applied to wheat crops grown for bread-making. However, data from a current series of experiments funded by the Home-Grown Cereals Authority on nitrogen fungicide interactions in breadmaking wheat, at Aberdeen, Cirencester, Long Ashton, Morley, Newcastle, and Bridgets, Boxworth and Drayton EHF's suggest that in first wheats, 120-150 kgN ha^{-1} is sufficient to provide optimum yields and meet the quality parameters required for breadmaking. It is important in the lower input context to ensure that nitrogen levels are not above the optimum. Considerable savings in applied nitrogen use can be made when soil mineral N levels are known to be high, although in soils with high organic matter levels prediction is difficult. At lower levels of soil nitrogen residue it should be possible to predict the N optimum for any crop. We intend to judge nitrogen fertiliser requirement for each crop using soil and plant N residue data compared against target yield. Thus, in 1990, 160 kgN ha^{-1} was the amount determined for "standard farm practice" to achieve a 10 t ha^{-1} crop, whereas in the low input system, 110 kgN ha^{-1} was indicated for a yield target of 8 t ha^{-1} .

Crop protection

Crop protection sprays are being used only if considered essential to prevent substantial yield losses from pests, diseases or weeds, and materials will be chosen to be as benign as possible to non-target organisms and the environment. Thus, it may well be that thresholds for spray decisions need to be revised upwards, or even re-defined. Insecticides are only applied according to forecast criteria, herbicide applications will be based on weed thresholds, and a single fungicide application will be made between GS 39 and GS 59, if considered essential. Plant growth regulators will not be used in the low input system.

Superimposed in each large field unit, in designated analysis areas, are small-plot experiments designed by the multidisciplinary research team, to examine the response variability of select system components, thus provide additional information for the database and the computer - integrated results system.

TOWARDS A LOWER INPUT SYSTEM MINIMISING AGROCHEMICALS AND NITROGEN (TALISMAN)

Within the overall objectives of the joint ADAS/IACR collaborative programme on reduced input cropping systems, the TALISMAN series and the LIFE experiments complement each other. TALISMAN and its sister trial series SCARAB were developed as natural successors to the Boxworth project, but whereas SCARAB concentrates on the environmental impact of reduced pesticide use, TALISMAN is primarily concerned with practical agronomic and economic issues.

TALISMAN occupies sites of about 3 - 6 hectares on each of Boxworth, Drayton, Gleadthorpe and High Mowthorpe EHFs, and will therefore be done on a range of soil types and in various farming conditions. A conventional replicated plot layout is being used, with a minimum plot size of 24m x 24m. Limitations of space and previous cropping do not allow a fully phased design to be used so only 2 courses of the 6-course rotations will be represented each year at each farm.

Crop Sequence

The rotations vary between farms, but they are based on a 6-course sequence of break crop / 2 cereals / break crop / 2 cereals. As in LIFE, the conventional rotation appears twice, that is at either the standard farm practice (SFP) or the lower level of agrochemical use. The integrated rotations in TALISMAN will be run only at the lower input level (LI). This will allow more than one integrated rotation to be included at Drayton and High Mowthorpe.

The relationships between the approaches are shown below:-

LIFE		TALISMAN	
Rotation	Inputs	Rotation	Inputs
Conventional	SFP	Conventional	SFP
Conventional	LI	Conventional	LI
Integrated	SFP	Integrated 1	LI
Integrated	LI	Integrated 2	LI

The conventional cropping sequences at each farm have been chosen to reflect current practice among technically skilled, committed farmers on similar soil types. They are:

Conventional Rotations

Boxworth - Winter Beans / Winter Wheat / Winter Wheat / Winter Oilseed Rape / Winter Wheat / Winter Wheat.

Drayton - Winter Beans / Winter Wheat / Winter Wheat / Italian Ryegrass / Winter Wheat / Winter Wheat.

Gleadthorpe - Sugar Beet / Spring Wheat / Winter Barley / Potatoes / Winter Wheat / Winter Barley.

H. Mowthorpe - Winter Beans / Winter Wheat / Winter Barley / Winter Oilseed Rape / Winter Wheat / Winter Wheat.

As at Long Ashton, the integrated sequences have been chosen to increase the opportunities for pesticide reduction. This has been achieved by increasing the proportions of spring sown crops, break crops and Take-all resistant cereals. They are:

Integrated Rotations

Boxworth – Spring Beans / Spring Wheat* / Spring Wheat / Peas / Spring Wheat* / Spring Wheat.

Drayton – Spring Beans / Spring Wheat / Spring Wheat / Spring Oats / Spring Wheat / Spring Wheat.

Gleadthorpe – Spring Beans / Spring Wheat / Spring Barley / Peas / Spring Wheat / Spring Barley.

H. Mowthorpe – Linseed / Spring Wheat / Spring Barley / Winter Beans / Spring Wheat / Spring Barley.

* autumn-sown.

Alternative Integrated Rotations

Drayton – Winter Beans / Triticale / Triticale / Ley / Ley / Triticale.

H. Mowthorpe – Linseed / Peas / Winter Wheat / Spring Oats / Winter Beans / Spring Barley.

The additional integrated treatments at Drayton and High Mowthorpe allow scope for an alternative lower input approach. At Drayton, this takes into account that on heavy land, restrictions on agrochemical use prompt consideration of a ley/arable system with the emphasis on feed grain production. At High Mowthorpe, the emphasis remains on arable cropping but diversity is increased by including three non-cereal crops plus spring oats, which can itself be regarded as a break crop. It is also intended to use this rotation in an extra treatment which will act as a negative control, receiving neither pesticide nor nitrogen applications.

Standard Farm Practice and Low Input Options

Standard Farm Practice will be on the same basis as in LIFE. The low input treatment will be very similar to that at Long Ashton, combining a target of halving agrochemical use with husbandry options selected to minimise the impact of reduced pesticide and nitrogen inputs. The choice of resistant cultivars and date of sowing will be as described previously: options for cultivation system and straw disposal will vary between sites according to local conditions. Consideration will also be given to the use of green manure catch crops to reduce nitrate leaching losses during winter.

Nitrogen

In the TALISMAN series the intention was to limit nitrogen use in the lower input treatments to no more than 50% of that in the Standard Farm Practice treatment, both to individual crops and over the rotation as a whole. This decision is currently being re-examined with a view to reconciling or justifying the difference in approach *vis a vis* LIFE.

Crop Protection

Crop protection sprays will only be used in the lower input treatments if they are essential to prevent substantial losses in yield. Even though the general validity of a managed approach to crop protection based on thresholds is well established, it is common experience that, for various reasons, many individual crop protection applications yield little or no direct benefit. In seeking to define lower input strategies for use in these experiments, various approaches were considered. It is possible to reduce the frequency with which crops are treated by raising the thresholds, whether for weeds, pests or diseases, which trigger a decision to spray. Alternatively, with thresholds maintained at their established levels, an overall reduction in agrochemical use can be achieved by applying only some fraction of the recommended rate of the chosen material. A third option that is increasingly adopted by farmers, particularly with fungicides, is to reduce or abandon thresholds altogether and adopt a policy of applying a low rate fungicide mixture at the very first sign of disease presence. For the low input system in TALISMAN, we have opted for an approach in which problems are not anticipated, so that fewer sprays will be used than on the conventional system, with reduced rates being used where they are likely to be effective and are needed to help meet the 50% target reduction. It is also planned to have a parallel series of experiments in winter wheat, winter barley and possibly other crops, looking in more detail at the outcome of some of the alternative strategies outlined above.

CONCLUSION

Between them, these ADAS anad AFRC experiments have potential to make substantial progress in resolving some of the most important questions facing arable farming in the UK at present; they have received support from policy makers, advisers and farmers, to all of whom the results will be of considerable relevance. They are designed as systems comparisons in which the treatments chosen represent a synthesis of the best available knowledge about the likely outcome of consistently reducing inputs to various crop sequences over a period of years. Inevitably factors are confounded in the design, so that precise "reasons why" may not be evident for all the responses obtained. However, shortcomings in this respect are offset by the ability to establish the consistency of response over a range of systems, sites and seasons. It makes maximum use of the opportunity of linking the Long Ashton experiment to those in four other important arable areas of the UK. In each case the systems approach will be underpinned by detailed conventional experimentation on components of the system, to ensure that there is a sound scientific basis for interpretation of the system outcomes.

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ORGANIC AGRICULTURE IN THE UNITED KINGDOM

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ABSTRACT

Organic farming is a coherent, ecological approach to the management and design of agricultural systems, emphasising reliance on ecological interactions and biological processes over direct intervention whether mechanical, biological or chemical. The potential environmental and food quality benefits have been recognised by consumers, resulting in a rapidly expanding premium market. Lower yields are compensated for by lower input costs and higher prices to produce overall incomes which are comparable to conventional systems, but the conversion period can present financial problems.

INTRODUCTION

Organic farming took on a new lease of life during the 1980s, not just in Britain but around the world. Overproduction, food quality and environmental issues in the industrialised countries, and underproduction in developing countries have concentrated minds and brought about a dramatic reassessment of the achievements of the post 1945 era. The effect can be seen not only in the range of policies which give greater weight to environmental considerations, but also in the growth of the organic movement and the market for organically produced food.

WHAT IS ORGANIC FARMING?

There are several problems which arise when presenting an explanation or definition of organic farming. Firstly, there are a number of misconceptions surrounding the topic which tend to a prejudicial view and divert attention from the main issues. Secondly, the nomenclature varies in different parts of the world, causing understandable confusion to the uninitiated observer. Thirdly, many existing practitioners believe that successful organic farming involves conceptual understanding as well as the employment of specific practical techniques.

These problems prevent the framing of a short, sharp, clear definition of organic farming. It has, therefore, become commonplace to define what it is by stating what it is not. Definitions and descriptions are frequently framed around negatives. What organic farmers do not do or use is

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summarised in the phrase that "organic farming is farming without chemicals". While such a definition has the advantage of being concise and clear, it is unfortunately untrue and misses [illegible] several characteristics which are of fundamental importance.

This notion about the non-use of chemicals is one of four misconceptions referred to above as problematic. In that all material, living or dead, is composed of chemical compounds, then organic farming utilises chemicals. Chemicals, albeit naturally derived, are also directly used in fertilising, plant protection and livestock husbandry. However, organic farming is a system which seeks to avoid the direct and/or routine use of readily soluble chemicals and all biocides whether naturally occurring, nature identical, or not. Where it is necessary to use such materials or substances, then the least environmentally disruptive at both micro and macro levels are used.

The second misconception is that organic farming merely involves substituting "organic" inputs for so-called "agro-chemical" ones. A straight substitution of NPK as mineral fertiliser by NPK as organic manure is likely to have the same - probably adverse - effect on plant quality, disease susceptibility and environmental pollution. Contrary to the dearly held ideas of "organic traditionalists", there is nothing magical about muck even if it is pushed in a heap and called "compost". The misuse of organic materials, either by excess, by inappropriate timing, or by a mixture of both, will effectively short circuit or curtail the development and working of natural or biological cycles. This approach has rightly been called "neo-conventional" and is rooted in the assumption that the farmer should seek to dominate rather than work with nature and natural cycles.

Another mistaken idea about organic agriculture is that it is a return to farming as it was pre-1939. While there is a shared focus on what has been described as "good, sound husbandry", involving balanced rotations, mixed farms and mechanical methods of weed control, modern organic farming seeks to develop upon increased understanding of such things as mycorrhizal associations, rhizobia and the rhizosphere, the turnover of organic matter and other areas of soil life, crop and animal husbandry that modern science has revealed. Organic farmers cannot be Luddites, setting aside the developments of the last fifty years. Indeed, it is more the case that modern agri-science has constrained itself by concentrating far too much on agro-chemical inputs and not enough on understanding and developing the inherent qualities to be found within biological science. The fact is that, whilst organic farming in Britain today generally has the same ley or mixed farming base that could be found forty years ago, many of its techniques and practices are modern developments. Crucially, the approach and attitude of its most successful practitioners is profoundly different.

The fourth misconception is that organic farming requires a change of lifestyle on the part of the farmer. While it is true that organic agriculture has been passionately supported by people with radical views on other issues and by those holding minority opinions about such things as nutrition, it has never been the case that organic farmers are either part of the love and magic, beard and sandals brigade, or that they are excessively puritan. Such cheap jibes have been the stock in trade of agricultural commentators unable to face up to the real issues generated by the growth of interest in organic food and organic farming. They ceased to be funny a long time ago, are now merely tiresome and just will not do as a substitute for genuine discussion and debate.

Turning to the problem of nomenclature, it has been estimated that there are about 16 different names used throughout the world for what we call organic farming, including biological, ecological and bio-dynamic (Merrill, 1983). The principles and practices that lie behind these different names are essentially similar. They have been concisely expressed in the standards document of the International Federation of Organic Agriculture Movements (IFOAM, 1989) as:-

* to produce food of high nutritional quality in sufficient quantity;

* to work with natural systems rather than seeking to dominate them;

* to encourage and enhance biological cycles within the farming system, involving micro-organisms, soil flora and fauna, plants and animals;

* to maintain and increase the long-term fertility of soils;

* to use as far as possible renewable resources in locally organised agricultural systems;

* to work as much as possible within a closed system with regard to organic matter and nutrient elements;

* to give all livestock conditions of life that allow them to perform all aspects of their innate behaviour;

* to avoid all forms of pollution that may result from agricultural techniques;

* to maintain the genetic diversity of the agricultural system and its surroundings, including the protection of plant and wildlife habitats;

* to allow agricultural producers an adequate return and satisfaction from their work including a safe working environment;

* to consider the wider social and ecological impact of the farming system.

For organic farmers worldwide, these principles provide the basis for day-to-day farming practice. They directly give rise to the techniques of organic agriculture, such as composting; the use of wide rotations which utilise leys and green manures; the avoidance of soluble fertilisers; the prohibition of intensive livestock operations; the avoidance of antibiotic and hormone stimulants; the use of mechanical and thermal methods of weed control; the emphasis towards on-farm processing and direct sales to the consumer; and the use of extra labour when not strictly necessary, as a positive contribution to the farm and rural community.

The United States Department of Agriculture (USDA, 1980) has framed a handy definition of organic farming which, although it misses out some important aspects, provides a description of the key practices:-

> "Organic farming is a production system which avoids or largely excludes the use of synthetically compounded fertilisers, pesticides, growth regulators and livestock feed additives. To the maximum extent feasible, organic farming systems rely on crop rotations, crop residues, animal manures, legumes, green manures,

off-farm organic wastes, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weeds and other pests.
"The concept of the soil as a living system........ (that develops)........ the activities of beneficial organisms .... is central to this definition."

This definition can be divided into three parts:

- what organic farmers do not do;
- what positive things they do instead;
- an indication of the underlying view of the soil as a living system that the farmer, in harmony with nature, should seek to develop.

This idea of the soil as a living system is part of a concept which maintains that there is an essential link between soil, plant, animal and man. Many people involved with organic agriculture believe that an understanding of this is the prerequisite for sustaining a successful organic farming system. This concept has been described as "wholistic", but it can be discussed in a less pretentious way.

Simplified, and put into a practical context, it is the recognition that - within agriculture, as within nature - everything affects everything else. One component cannot be changed or taken out of the farming or the natural system without positively or adversely affecting other things. For example, on an organic farm there is not one method of weed control or of supplying nitrogen. The ley, green manures and appropriate cultivations do both of these things, as well as their more obvious other functions.

Here indeed is the key to understanding what organic agriculture is about. It concentrates primarily on adjustments within the farm and farming system, in particular rotations and appropriate manure management and cultivations, to achieve an acceptable level of output. External inputs are generally adjuncts or supplements to this management of internal features.

Organic standards in Britain

The environmental and food quality benefits of organically produced food (evidence of which is reviewed in Lampkin, 1990) are not often immediately identifiable in the end product. If the consumer is to support environmentally sound production through purchasing decisions, then some other form of identification is necessary. The *bona fide* producer also needs protection, so that premium prices may help compensate the producer for the adoption of less profitable but more environmentally acceptable practices.

One way in which both consumer and producer interests can be protected is through production standards laid down by independent, competent bodies without direct commercial interests. In Britain, there are three main sets of standards currently in operation. Of these, the Soil Association's Symbol scheme (Soil Association, 1989) is the most widely adopted.

The Bio-Dynamic Agricultural Association operates the Demeter and Biodyn standards for produce from biodynamic systems, the Biodyn symbol being used for produce during the conversion period. These standards are in some respects more rigorous than those of the Soil Association, but few commercial producers in Britain adhere to them, although both biodynamic symbols are widely used in mainland Europe.

Finally, the Organic Farmers and Growers Ltd marketing co-operative operates its own standards including one for produce during the conversion or transition phase.

There are, however, a plethora of other standards which are sometimes used. These include standards operated by commercial interests such as Farm Verified Organic and which apply primarily to imported produce, as well as 'halfway house' standards such as Conservation Grade operated by the Guild of Conservation Food Producers which have little, if anything, to do with organically produced food.

In 1987, the Government established the United Kingdom Register of Organic Food Standards (UKROFS) under the auspices of Food From Britain, partly as a response to a forthcoming European Community Regulation on organic food standards and partly as a further attempt to unify standards in Britain and to overcome continuing disagreements between the Soil Association and Organic Farmers and Growers Ltd. The UKROFS standards were published in May 1989 and efforts are now concentrating on implementing the UKROFS scheme.

Organic standards internationally

IFOAM Standards

The International Federation of Organic Agriculture Movements (IFOAM) has member organisations in over 50 countries. The IFOAM Technical Committee is responsible for a standards document which is used as a basis for national standards operated by member organisations throughout the world. The Soil Association's standards are based on this document, the most recent and wide-ranging revision of which was approved at the IFOAM General Assembly in Burkina Faso in January 1989.

Individual producers cannot use IFOAM Standards, because IFOAM does not operate an inspection or regulatory procedure. They must use the standards operated by a national organisation in the country in which they farm. For similar reasons, produce should not be traded as 'conforming to IFOAM standards' as there is no inspection procedure to ensure that this is the case.

Recognising the increasing international trade in organically produced food, IFOAM has implemented an international evaluation survey of organic standards, policing both procedures and the status of the controlling organisations in member countries. Initially, only the major exporting countries are being assessed. Evaluation of the UK standards took place in May 1987. A directory of their findings is made available to the member organisations which have been evaluated. This enables organisations like the Soil Association to determine whether imported produce meets domestic standards.

The European Community

The European Commission is planning to introduce a regulation which will eventually apply to the production and sale of all organically grown produce in member states. When the regulation becomes law in 1990/91 it will become illegal to sell produce as organically grown unless it carries a quality mark authorised by a member state government. Draft standards were published in January 1990 which attracted widespread criticism, but these have since been modified to accommodate most of the concerns expressed during discussions between the Commission, member state governments and representatives from the organic movement in member states.

Crop protection in organic farming

Organic standards such as those of the Soil Association emphasise the role of husbandry practices such as rotation design, manure management, crop nutrition, varietal selection, seed rates, use of green manures and undersowing, sowing or planting dates and cultivations over the use of direct intervention for crop protection.

Direct intervention, whether manual, mechanical, thermal, biological or chemical, should be minimised to avoid undesirable effects on the farm system and environment. In many cases, good husbandry is sufficient to meet crop protection requirements without the need for direct intervention in any form.

For weed control, no chemical intervention is permitted. Pre- and post-emergence mechanical operations including stale seedbeds, harrowing, hoeing and flame weeding are permitted, as are plastic mulches although there is some debate about the latter.

For pest and disease control certain chemicals are permitted such as sodium silicate, sodium bicarbonate and soft soap. The so-called 'natural' pesticides, such as pyrethrum, rotenone and quassia, are only allowed on a restricted basis (i.e. permission is required from the Soil Association) because of their wide-spectrum activity (nicotine is completely prohibited), and other compounds such as copper sulphate are restricted due to their potential for environmental damage. Certain slug control chemicals may also be used on a restricted basis.

DEVELOPMENT OF THE ORGANIC SECTOR

The number of organic producers and the area of land managed organically has grown relatively rapidly over the last decade. In 1980, there were fewer than 100 organic producers certified by the Soil Association. Now there are some 450 producers managing 12,000 SA certified hectares. In terms of land area, there has been an increase of more than 30% in the last 12 months. Data from other organisations is less certain, but it is estimated that there are 150-200 producers working to Organic Farmers and Growers Ltd standards and a further 15-20 working to Demeter (bio-dynamic standards. The total number of organic farms is therefore probably between 600 and 700 (allowing for some farms not registered with any scheme) on a total area of 15,000-18,000 hectares.

The market for organically produced food was estimated by Elm Farm Research Centre to have a retail value of £36 million in 1987 (EFRC, 1988). In 1989, this was estimated to have grown to £50 million and may be £80-100 million in 1990. Demand continues to expand faster than supply, with imports playing a major role, accounting for more than 60% of produce sold in the UK. The involvement of all the major multiples in the full range of organic products, including meat, milk and wine, has been an important factor in this expansion.

There has been a parallel, if delayed, growth in support services. Advisory services are now provided by the Organic Advisory Service at Elm Farm Research Centre, as well as ADAS and the Scottish Agricultural Colleges. Research is being undertaken at a number of institutions including Elm Farm Research Centre, the Centre for Organic Husbandry at Aberystywth, the Henry Doubleday Research Association at Coventry and the Edinburgh Organic Farming Centre. Training opportunities are expanding rapidly, with courses now available from the Agricultural Training Board and more than a dozen agricultural and horticultural colleges, including Carmarthenshire, Derbyshire, Lackham, Otley, Pershore, Worcestershire, Greenmount (NI) and the Scottish and Welsh Agricultural Colleges. However, when compared with West Germany, with more than 20 full-time organic advisers, four University Chairs of organic or alternative agriculture and an annual research budget of more than £1 million, the United Kingdom is still a long way behind.

ECONOMIC PERFORMANCE OF ORGANIC FARMING

Detailed studies of the economics of organic farming are scarce; the last major study in Britain is that of Vine and Bateman (1981). A new study has been commissioned by the Ministry of Agriculture, Fisheries and Food and is being conducted by the Universities of Cambridge, Edinburgh and Aberystwyth. The results from this study, which will look in detail at 300 organic farms throughout Britain, are due to be published in 1991.

Recent evidence tends therefore to be taken from case studies on individual farms or groups of farms, as well as anecdotal reports. However, the results, which are reviewed comprehensively in Lampkin (1990), are consistent with studies from other countries so that it is possible to draw some general conclusions.

Yields

Most studies, including those conducted in Britain, suggest that cereal yields will on average be between 10 and 30% lower on organic farms. This figure hides considerable variations between different organic farms as it does between conventional farms, and estimates for horticultural crops are notoriously variable. Typical yields for organic cereals in the UK are between 4 and 6 t/ha, with some organic producers reporting yields over 7 t/ha. A survey of 200 farms in Baden-Württemberg, not a major cereal growing region of West Germany, also provides a good indication of yield variability and potential (Table 1).

TABLE 1: Yields in t/ha from survey of 200 organic and bio-dynamic farms in Baden-Württemberg, 1983

	organic	*(range,no.)*	*conv*
Winter wheat	3.3	(1.0-5.3, 145)	4.7
Spring wheat	2.8	(1.0-4.6, 52)	3.9
Winter barley	3.5	(1.0-5.0, 28)	4.8
Spring barley	2.6	(0.7-4.2, 21)	3.7
Oats	3.2	(1.2-5.0, 36)	3.9
Rye	3.2	(0.8-5.2, 52)	3.8
Carrots	40.5	(6.0-80.0,)	42.3
Early potatoes	13.8	(7.0-20.0, 20)	18.5
Main crop pots.	16.5	(5.8-40.0,120)	22.6
Beetroot	29.9	(5.0-62.5,)	32.6

Source: Böckenhoff et al (1986)

Prices

Prices for organically produced food vary greatly, but it is possible to get premiums of up to 150% for cereals and vegetable crops (Table 2). However, marketing costs are also high, and premiums may be reduced due to failure to meet quality specifications and high gradeout percentages in the case of vegetables.

TABLE 2. Ex-farm prices* (£/t) for selected organically produced cereals and vegetables (1989/90)

	Typical	*Range*	*Premium (%)*
Bread wheat	230	210-250	100+
Other milling wheat	180	-	70
Malting barley	170	-	60
Oats	175	165-180	70
Field beans	195	190-200	20
Maincrop potatoes	200	160-250	100
Carrots	330	200-530	50-150
Swedes	200	110-260	0-50
Onions	440	330-500	30-50
White cabbage	200	130-330	0-50

* prices as sold, after gradeouts. Prices in 1989/90 were generally better than the previous year but might not be maintained in 1990/91.

Costs

Low variable costs, for items such as seed, fertilisers and sprays, can result in impressive gross margins for organically produced crops (Table 3). However, these are not usually achievable throughout the rotation; the fertility building phase involving livestock is often a significant weak point. In addition, higher fixed costs resulting from diversification of enterprises and, in horticulture, the need for more labour-intensive practices, may be significant.

Profits

The combination of higher prices and lower variable input costs may compensate for lower yields and possible higher labour costs to yield incomes which are comparable or slightly lower than on comparable conventional farms. This depends to a considerable extent on the type of farm - grassland based farms are most likely to maintain incomes, while intensive arable farms are most likely to have difficulties financially. Organic farmers therefore need to reconcile financial objectives with other, more altruistic objectives such as protection of the environment. Hence many organic producers can be said to be internalising external costs which would otherwise be borne by society at large.

TABLE 3. Gross margins for selected cereal and vegetable crops - 1989 estimates (all £/ha unless otherwise stated)

Crop	*Winter wheat milling*	*Milling oats*	*Field beans*	*Carrots*	*Cabbage*	*Maincrop Potatoes*
Market. yield (t/ha)*	4.5	4.5	3.5	24	16	24
Premium (%)	100	55	10	100	40	100
Convent. price (£/t)	110	110	180	120	140	100
Premium price (£/t)	220	170	200	240	200	200
By-products	80	70	0	0	0	0
Output (premium)	1070	835	700	5760	3200	4800
Output (no premium)	575	565	630	2880	2240	2400
Variable Costs						
Seed/Plants	60	45	60	130	470	430
Fertilisers	0	0	0	25	25	25
Crop protection/drying	-	-	-	55	30	25
Casual labour						
planting/weeding	-	-	-	275	120	45
harvesting/grading	-	-	-	600	180	600
Packaging	-	-	-	210	650	150
Marketing (15% output)	-	-	-	865	480	720
Other	5	5	5	-	-	-
Total	65	50	65	2160	1955	1995
Gross Margin						
with premium	1005	785	635	3600	1245	2805
without premium	510	515	565	1152	429	735

Note: prices and costs for vegetable production can vary widely, so these estimates should be interpreted with caution. Allowances should be made for good and bad harvest years, including crop failures, and high gradeout percentages if selling to multiples.

Conversion

There are, in addition, significant potential financial difficulties during the conversion period. Lower yields while new systems are becoming established and techniques are being learnt combine with higher costs and an inability to qualify for the organic premium to result in often significantly lower incomes during this period. It is difficult to see this as a form of investment in future higher returns because there is no guarantee of improved incomes in the long run.

Again, there is little information on the cost of conversion, but models (Lampkin et al, 1987; Lampkin and Midmore, 1988) indicate that the reduction in income during the five year period which is usual for a whole farm to convert may amount to as much as £200 per farm hectare per year on an intensive arable farm in the absence of livestock and any organic premium, but this can be reduced considerably where livestock are involved to less than £100/ha and less than £50/ha and year on extensive hill and upland farms.

FUTURE DEVELOPMENT OF THE ORGANIC SECTOR

Organic farming, supported by a better developed marketing structure and improved research and extension support, is set to expand further and to become an increasingly important part of the agricultural industry. The future development of the organic sector will depend on a number of factors, including consumer demand and government support for research and extension as well as the possibility of grant aid to organic producers. Critical to this will be policies at European Community level, including the new EC Regulation defining organic farming as well as organic options under extensification and under the new marketing structures legislation. The implications of large-scale conversion to organic production for food security and the costs agricultural policy deserve some detailed consideration.

The implications of large-scale conversion

The economic implications of a shift to organic agriculture in Britain has been discussed in general qualitative terms in Bateman and Lampkin (1986). Lampkin (1989) attempted to create a model of the implications of large-scale coversion based on the subdivision of the UK into 'regional farms' which coincide with the standard MAFF statistical regions. Estimates were then made as to the likely organic cropping patterns and average yields in each of the regions if they were fully converted. Lack of good quality data meant that a more sophisticated modelling process could not be justified; it is recognised that the results obtained are of necessity speculative. Using the model, however, tentative predictions can be made as to the effect of a 10% conversion of UK agriculture to organic farming (Table 4).

TABLE 4. Changes in cropping areas and output resulting from a 10% conversion of UK agriculture to organic farming.

Land Use	*Relative area change (%)*		*Relative output change (%)*
Cereals	-2		- 3.0
Potatoes	1		- 1.3
Sugar beet	-4		- 5.8
Grain legumes	18		17.4
Oil seed rape	-5		- 6.1
Leys < 5 yrs	5	Milk	- 1.9
Leys > 5 yrs	-1	Beef	- 1.3
Rough Grazing	0	Sheep	- 1.9

The main features which emerge are a 3% fall in UK cereals production, a substantial fall in sugar beet and oil seed rape production and a fall of nearly 2%, in spite of additional production in predominantly arable areas, in the total output of milk, beef and sheep. These reductions are accompanied by a large increase in the output of grain legumes, which will to a large extent be used for stockfeed substituting for imported protein sources such as soya beans. Although the overall change in output is likely to be quite small, there will still be some impact *at the margin* on attempts to reduce surplus production.

The impact on existing levels of organic production, however, is likely to be highly significant, with output increasing by a factor of as much as 100. Predicting the effect of this level of increase on the market, and in particular prices, in quantitative terms is virtually impossible as a number of factors including price elasticities of demand and supply, import substitution, reduced processing and distribution costs due to economies of scale, and the increasing level of food prices generally as supplies tighten are likely to interact. It is not necessarily the case that lower percentage premiums paid by consumers will be passed down the line to producers.

One conclusion is clear. Even if 100% conversion to organic production were being considered, which is unlikely to happen, the levels of output reduction are not likely to be so severe as to place food security at risk.

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ALTERNATIVE AGRICULTURE - A VIEW FROM BRUSSELS

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ABSTRACT

Recent developments in the Common Agricultural Policy (CAP) of the European Communities, indicate a change of emphasis at least as far as structural policy in agriculture is concerned. Several measures either within the frame of improving the efficiency of agricultural structures or with a view to protecting the environment have been introduced leading to an expansion of alternative types of agriculture. Both regulatory and incentive measures exist with main objectives to improve the efficiency of farms, to maintain a viable agricultural Community and to contribute to the safeguarding of the environment and the preservation of the countryside including the long-term conservation of natural farming resources, thus restoring the balance between production and market capacity. A general outline of these measures is presented in this paper so as to indicate the possibility for an alternative agriculture in Europe through existing or envisaged actions at the Community level.

INTRODUCTION

After three decades of a Common Agricultural Policy (CAP) having as its major objectives a) to increase productivity; b) to ensure a fair living of farmers; c) to stabilise offer and demand; d) to guarantee the supply of foodstuffs; and e) to keep low consumer prices, the picture in the European Community has started to change.

As a result of budgetary pressure as well as increasing environmental concern, since the beginning of the 1970's (De Soet, 1974) important steps have been already made towards the direction of the introduction of an alternative agriculture in the European Community.

In the framework of the sociostructural Policy in Agriculture, funded by the Orientation branch of the European Agriculture Guidance and Guarantee Fund (EAGGF) several measures have been introduced since the mid 1980's in an effort to adapt the CAP in the new situation. These measures provide incentives to farmers who are willing to give up modern intensive farming, as developed mainly after the end of World War II, for another type of farming which respects the environmental requirements with a major objective to stabilize the market especially in the surplus sectors (cereals, milk, meat, etc).

AGRICULTURAL STRUCTURES POLICY

A very important Community Scheme in application since 1987 (having its origin in national schemes allowed in 1985) is farming in Environmentally Sensitive Areas.

This scheme, the broad guidelines of which were laid down in Regulation (EEC) N° 1760/87 (Official Journal of the European Communities N° L 167 of 26.6.87) mainly concerns arable and livestock farming, featuring aid for farming practices compatible with the requirements of the protection of the environment and of natural resources in particularly sensitive areas designated by Member States. Farmers in these areas undertake for instance to decrease the use of pesticides and chemical fertilizers, reduce the stocking rate or even forego the right to drain land to convert to arable farming or to grub unwanted young trees, hedges etc. Up to 1989 participation in this scheme was limited to only 3 countries, United Kingdom with 21 projects, Germany with 7 and Netherlands with 1. It is hoped that a recent increase in the Community's financial contribution for the most structurally undeveloped areas will encourage the application of this scheme in other countries as well.

Under the same Regulation (EEC) N°1760/87 on the efficiency of agricultural structures, two other measures have been introduced a) set-aside and b) extensification. Though they are both market targeted measures aiming at a reduction of surpluses and a restoration of market balance they also reflect to a certain extent the Community's concern over the protection and conservation of the environment, by laying down detailed rules concerning the necessary measures to take in order to avoid environmental damage.

Overall it can be stated that in the light of the reform of the structural funds, including EAGGF, the measures proposed in Agriculture "enable the financing of investments for the diversification of activities, the improvement of setting up aid for young farmers, the strengthening of environmental protection measures, improved targeting of resources in less-favoured agricultural areas and the adaptation of processing and marketing aids, using the new methods of assistance provided for in the reform" (European Communities, 1990).

In a recent modification of this structures regulation part-financing is foreseen by the Community of national aid schemes including among others:

"- measures relating to investments in agricultural holdings, in particular to reduce production costs, to improve the living and working conditions of farmers, to promote the diversification of their activities, including the marketing of products on the farm, and to preserve and improve the natural environment;

- measures to protect the environment and safeguard the countryside by encouraging appropriate farming methods".

In addition a Common Scheme for investment aids has been also introduced including aids for the protection and improvement of the environment as well as a launch aid for recognized farmer groups which have as their object among others:

"- mutual aid between holdings, including the use of new technologies and practices for safeguarding and improving the environment and preserving the countryside;

- the introduction of alternative farming practices;

- the more rational joint use of agricultural means of production".

The above measures should be coupled shortly with measures related to a policy for rural development as already announced in the Commission's Communication on the future of the rural Society (European Communities, 1988a). Two important aims of this policy are:

"(1) to promote the structural adjustments necessary to make agriculture more competitive and efficient without however encouraging increased production which would not be in line with current and foreseeable market requirements and;

(2) to enable farmers to convert or diversify their agricultural activities towards more profitable enterprises".

It is therefore important to note the above fundamental changes which agriculture in the Community has been undergoing since the beginning of the 1980's and which define the principal lines of action of the CAP in the 1990's:

(1) maintaining balance in the markets;

(2) observance of budgetary discipline;

(3) reform of agricultural structures and rural development measures (European Communities, 1990).

REGULATORY MEASURES

In addition to the above measures a series of regulatory measures have also been announced by the Commission (European Communities, 1988b) with a view to integrate Agriculture and Environment Policies.

Probably the two most important ones with respect to an alternative agriculture in the Community are:

a) the proposal for a directive on the protection of fresh coastal and marine waters against pollution caused by nitrates from diffuse sources (European Communities, 1988c) and;

b) the proposal for a council Regulation on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs (European Communities, 1989).

The purpose of the first is to lay down rules on the spreading of livestock and chemical fertilizers in a way as to avoid nitrate leaching and transport through surface run off leading to water pollution. Should this proposal be accepted it would result in a "milder" agriculture, not only in arable farming but also in animal farming where in some cases certain limits should be imposed to the rate of livestock units per hectare.

The purpose of the second is to "set up a harmonized framework for the labelling production and inspection of agricultural products and foodstuffs bearing or intended to bear indications referring to organic production methods". This proposal is of particular interest for the development of alternative farming practices and it would be useful to give here an overview of what the situation seems to be with respect organic farming in the different Member States.

ORGANIC FARMING IN THE EEC

According to a report published by the Commission (European Communities, 1988d) on the basis of 1987/1988 estimates important differences exist with respect to both numbers of organic farmers and surface area cultivated in Member States. Overall it is estimated that organic farming represents 0.1% to 0.6% of farming in the Community though recent developments indicate a constant progress at least in those countries where a more positive attitude exists vis-à-vis this type of farming and its products.

As far as the market is concerned it seems that cereals and vegetables attract much of the attention in the agro-food sector, while products of animal origin have not yet had a great success either from a production or from a distribution and marketing point of view. It is of interest however to note that distribution channels have now been established even covering large supermarkets in certain countries (UK, Ireland, Denmark) though the traditional direct relationship between producers and consumers and sales in specialised stores still have a high market share.

For a large number of Producers Organisations organic farming still needs particular attention, especially as far as the following points are concerned:

a) Specific legislation is needed providing the necessary guarantees to consumers, protecting farmers and clarifying the market;

b) Increased efforts to help farmers with respect to

- adequate training;
- technical support and dissemination of acquired knowledge;
- applied research on organic farming.

c) Organisation of the market with respect to different types of products (cereals, vegetables, fruits etc.)

As far as national legislation is concerned only France, Denmark and recently Spain have introduced specific rules covering organic farming products.

In France inspection and granting of the official label is left with the farmers' associations once the technical production rules are accepted. In Denmark on the contrary a frame is established as far as production rules are concerned and government bodies are charged with inspection procedures. Spain is oriented towards the system of Denmark.

The remaining countries are waiting for the developments at the Community level though some (e.g. the Netherlands) have already advanced work in preparation after discussions with all professionals involved. It is of interest to note that in Italy, although there is no national legislation the region of Lazio already has its own rules on organic farming products.

Besides legislation several other fields of action already exist with respect to organic farming which constitutes a concrete form of alternative farming:

Training - Technical support

In certain countries (e.g. Germany, Denmark, France, Netherlands and recently Belgium) there now exists formal training in established institutions on organic farming. This type of training is offered to both experts of specialized services and farmers.

Research

Research on organic farming and more generally on low input agriculture is gaining momentum though still far from being satisfactory. At the Community level an important shift is reflected by the new specific Community Research and Technological Development Programme in the field of Competitiveness of Agriculture and Management of Agricultural Resources (1989-1993) approved by the Council Decision 90/84/EEC (Official Journal of the European Communities N° L 58 of 7.3.90).

Indeed in the fist sector of research activities with the title "Conversion, diversification including extensification of production, cost reduction and protection of the rural environment" the following fields are proposed:

"- alternative livestock production systems, involving in particular goats, sheep, suckler cows, equidae and game, with the aim of avoiding surpluses;

- improvement of the profitability of farm woodlands, development of integrated forestry-livestock systems and identification of potential alternative undergrowth crops;

- development of alternative farming practices, particularly organic farming with the aim of conserving natural resources and the countryside.

Taking into account these developments in Member States as well as the consumer interests related to the need to distinguish products obtained organically from other products, the Commission has proposed the above mentioned Regulation (European Communities, 1989), the basic principle of which is that products composed of or incorporating one of more synthetic chemicals may not be used as plant protection products, detergents, fertilizers, soil conditioners, or animal feedingstuffs.

In addition minimum inspection requirements and precautionary measures in a well defined regular inspection scheme are laid down which all Member States have to observe. For an effective inspection the inspection bodies to be established in Member States are required to be able to check every stage of production, making it necessary for the farmers to keep very close contact with the competent authorities.

Furthermore in a recent regulation concerning the processing and commercialization of agricultural products (Council Regulation EEC N° 866/90, Official Journal of the European Communities N° L 91 of 6.4.90) specific mention is given to organic farming as an alternative type of agriculture which may provide products of quality contributing to the improvement and rationalisation of processing and treatment of agricultural products.

CONCLUSIONS

Important steps have been made during these last years in the European Community towards the introduction and establishment of alternative agricultural practices. Farming systems more compatible with environmental requirements and organic farming in particular are increasingly becoming more important. Recently launched research is expected to contribute positively to these developments.

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2.
Weed Control

Chairman: MR. R. J. MAKEPEACE

POPULATION THRESHOLDS AS AN AID TO WEED CONTROL

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ABSTRACT

Population thresholds as an aid to weed control seem a logical approach to good husbandry. Indeed, farmers and advisers do make a qualitative visual assessment of potential weed problems before deciding what action to take. However, a structured system based on weed counts and their effect on current and future crops has not been accepted in the UK. Such an approach should provide both a standard and the most economic approach within the industry. The reasons for the reluctance of farmers to accept a quantitative system are discussed and the development of a more flexible system is suggested.

INTRODUCTION

There are three main approaches to weed management in field crops; eradication, prophylaxis and containment (Cousens, 1987). It is widely accepted that eradication of weeds is not possible except for a limited range of species and that prophylaxis could result in higher costs and/or more herbicide use than is necessary to prevent weeds causing any affect on present and future crops. Containment accepts some level of yield loss but should result in the use of weed control measures only when truly justified. It is in the context of the containment strategy that farmers and their advisers have often discussed weed populations or thresholds above which weed control measures are justified. Despite this, there is little or no on-farm decision making based on thresholds in the UK. Thresholds are often the subject of "armchair agronomy" and it is a concept that has, as yet, not fully faced up to the realities of field decision making in this country. On the other hand, it is claimed that in Germany a system of weed management, based on thresholds, has been successfully tested in the field (Wahmhoff, 1990).

The need to improve in field decision making has never been more acute. The returns from many arable crops are currently low and the environmental pressure on farmers dictates that each pesticide input is justified. Indeed, the recently published Code of Practice for the Safe Use of Pesticides on Farms and Holdings requires reference to economic damage thresholds, if available (Anon., 1990). This requirement challenges the knowledge that has been acquired over recent years on crop/weed competition. We are not yet in a situation where the effect of a weed population on present and future crops can be predicted. More information exists on the effect of weeds on winter wheat and possibly winter barley than for other field crops.

The threshold concept applies equally to "herbicide" and to "no herbicide" systems of farming. The judgement as to whether or not to control the weeds applies to both forms of production. It is very likely that thresholds will be different for the two systems as the costs of control, the efficiency of control measures and the long term implications of weed seed shedding are also different. This paper concentrates on the adoption of the concept in conjunction with herbicide use.

DEFINING A THRESHOLD

The first problem is to define what is meant by a threshold. Many definitions have been put forward to take into account the differing views and requirements for field decision making (Cussans et al, 1986; Cousens, 1987). Obviously, the need to list the different types and definitions of thresholds shows that the requirement of a simple solution is already compromised. However the situation in the field is complex. For example, a farmer would take a different view on the seed of a weed returning to the soil if it could be easily controlled in the future crops in the rotation, rather than if it was either difficult or expensive to control. Similarly, some farmers would like to prevent weeds from having any kind of effect on the crop while others might accept that a herbicide is only justified in a crop where the benefits exceed the costs involved. If the aim of legislation in this country is to ensure that pesticides are used only where necessary there has to be a concerted effort to change farmers' perceptions to achieve a commonality of purpose. To this end, it would seem logical for farmers to accept that a few weeds flowering above the crop in June and July is a tribute to rational assessment of herbicide requirement rather than a failure of husbandry.

INFORMATION REQUIRED TO CONSTRUCT THRESHOLDS

Theoretically, the accuracy of any adopted system is dictated by the fact that herbicide costs represent a few percent of the value of the crop. Cussans et al. (1986) listed the information required to construct thresholds. In addition to predicting the effect of the weeds on the crop, there is the need to predict the yield and returns from the crop as well as the cost and success of the herbicides which may be applied. Some of these requirements are relatively easy to satisfy whilst others will take a considerable amount of research before prediction can be attempted with any confidence.

The requirement is for the prediction of the effect of a population of a range of weed species on the current and future crops. Each species will vary in its competitiveness which in turn will be influenced by the competitiveness of the crop, date of emergence in relation to the crop, weather conditions and soil type and nutrient status. In addition, there is more to think about than yield alone. Weeds are controlled for a variety of reasons. These include ease of harvest, to meet quality standards of cleanliness of the harvested product and to avoid insects and diseases that are harboured by weeds or may spread from weeds to the crop. It may be that the non-yield requirements are met where weed populations are below the threshold adopted for yield. However, these aspects should be subject to rigorous assessment in any future development of thresholds. A further complication is that farmers correctly take into account likely weed levels in future crops when making decisions. This means that thresholds have to take into account the effect of shed weed seed on future crops. This requires that the population dynamics of all uncontrolled weeds are well understood.

There are further factors to add to an already complex situation. It is well recognised that the competitiveness of weeds and the dormancy of their seeds depends to a large extent on soil type and the weather conditions that follow the time when weeds have to be removed in order to prevent or minimise yield loss (Kaiser & Wahmhoff, 1986). Therefore, there is a need to predict the weather if there is a demand for absolute accuracy. Perhaps this latter point highlights the difficulties if not impossibility of developing the perfect threshold system. It has to be accepted that compromises have to be taken. The debate must centre around how a system should be developed in the absence of the detailed implications of the effect of weeds on the current crop and of shed weed seed on future crops.

PRACTICAL DIFFICULTIES IN THRESHOLD MANAGEMENT OF WEEDS

Once a threshold method has been decided the problem of implementing it in the field has to be faced. Precise assessment of low populations of weeds is very time consuming. As well as being difficult to assess accurately, low populations tend to be very variable within a field. Very intensive methods for the assessment of field populations are still likely to give high errors (Proven, 1990). This is particularly true for annual grass weeds which often have a patchy distribution.

There is the added complication of weeds germinating after the counts have been taken. Large work peaks can result if assessments are delayed until the time when the weeds have to be treated in order to prevent yield loss. An early assessment may not result in the decision to treat with a herbicide. However, subsequent germination can result in the decision to spray at a later date, when the initial population of weeds may be more difficult and expensive to control. A practical example of what could occur is in winter cereals. An establishment of a low population of annual grass weeds in the autumn may not exceed a threshold. However, with a further germination in the spring, a threshold may be exceeded. Annual-grass weeds are more difficult and/or more expensive to control in the spring and those that establish in the spring are less competitive and/or will shed less seed.

OVERCOMING SOME OF THE SHORTCOMINGS OF DECISION MAKING BASED ON WEED THRESHOLDS

It is clear that present knowledge and the absence of a reliable medium term weather forecast means that any threshold will not be precise in predicting the advantage in the short and long term of controlling the weeds present in the crop. However, this fact should not deter us from producing the structure of a system which can be developed in time with more knowledge.

To have the confidence of farmers, the threshold should be based on "worst case" competition data and aim to optimise returns over a number of years. It should also take into account the possibility of a partial herbicide failure by including a safety margin. It has been possible to identify a threshold for winter wheat which takes into account these requirements and indeed a system is currently being evaluated (Proven, 1990). There is a need to include, if possible, aspects of the "art" of weed control. For instance, in a rotation that includes oilseed rape, it has been important to prevent the shedding of *Papaver rhoeas* (common poppy) seed in any intervening crop. This prolific seeder has been expensive to control in oilseed rape. Another example of common sense overriding a calculated threshold occurs with the control of volunteer oilseed rape. Seed return from these plants could result in volunteers in future oilseed rape crops and thus may have a significant effect on the glucosinolate levels of the harvested product. Hence, it is necessary to control all volunteers in the intervening crops unless they emerge too late in the spring to produce seed in the same calendar year.

The criticism that the time taken to assess weed populations in every field presents a major limiting factor has to be tempered with practical realities (Sim, 1987). In the majority of fields it is clear, without intensive assessment, whether a crop is above or below the threshold and then resources can be focused on the minority of fields which have populations around the threshold.

The problem of subsequent germination can only be partially overcome by ensuring that a record of weed populations is kept for each field. In addition, the level of seed shed in the previous crop will give some indication of the eventual population, particularly with the all important annual grass weeds (Cussans *et al*., 1986). Seed bank studies could be used to predict weed numbers but there are reservations about how accurate such an approach would be (Post, 1986). In addition, it would seem impractical to adopt this approach on an individual field basis.

ALTERNATIVES TO DECISION MAKING BASED ON WEED THRESHOLDS

Weed management based on thresholds is not practised in the strict sense in the UK. Other approaches in an attempt to reduce herbicide inputs are, however, widely practised.

Visual assessments of weed populations are always made but the lack of a common structure and a clear objective for decision making and the fear, in many cases, of leaving any weed uncontrolled means that some over-use of herbicides occurs. However, recent research work on the competitiveness of weeds has had an impact on improving the assessment of the potential effects on the winter wheat crop and should not be undervalued (Wilson, 1986; Wilson & Wright, 1990).

An obvious alternative is to treat perceived low populations of weeds with a cheaper herbicide than the one considered necessary to give the highest level of weed control or to use a dose of the more expensive herbicide which is appropriate to both the risk of the negative effects of the weeds and the weather conditions prevailing at the time of application. In either case, the perceived least troublesome weed species in the current and future crops are those which may be allowed to survive. The appropriate dose used in such an approach may be below that recommended by the manufacturer of the pesticide. The limitations with lower than recommended doses are that they are more unreliable (Davies & Whiting, 1990) and that lower than recommended doses do not carry the manufacturer's warranty. On the other hand, lower than recommended doses reduce any potential risk of phytotoxicity from herbicides (Davies & Whiting, 1990).

However, trials have shown that the regular use of lower than recommended doses can be successfully adopted in winter wheat, provided that weed levels are relatively low. The same trials indicate that this approach may be more appropriate in achieving low input weed control than a system based on thresholds (Proven, 1990). There are exceptions to this statement, notably the control of *Alopecurus myosuroides* (black-grass) and perhaps, *Galium aparine* (cleavers). *A. myosuroides* produces a large quantity of viable seed and the dose response curves of many of the herbicides used against this weed are not conducive to the use of lower than recommended doses. The use of lower than recommended doses against *G. aparine*, a very competitive weed, is only successful if the prevailing weather conditions are particularly suitable to herbicide activity.

DISCUSSION

The need to minimise costs is now one of the major objectives of the arable farmer. In addition, the industry needs to demonstrate that it is using pesticides only when necessary. Theoretically, weed thresholds correctly identified and used could be a significant help in achieving these objectives.

The lack of adoption by the industry of an approach based on weed thresholds is due to the lack of a practical system that is easy to manage. Researchers perhaps feel constrained by a lack of knowledge and farmers and advisers by the difficulty in assessing weed populations in the field and by a lack of confidence in the concept.

It has to be accepted that any threshold system will depend on decisions being taken without the full knowledge of the likely implications of controlling or not controlling a given population of weeds. Therefore, to retain the farmer's confidence, thresholds should aim at maximising returns in the long term and be very cautious and include a significant safety margin. In addition, the method of assessment of the fields that have weed populations close to a threshold should be relatively simple.

To achieve a more practical system, the courses of action open to the farmer should be extended beyond a simple "to spray or not to spray principle" that is perceived to be implicit in threshold management. A more desirable approach is to ask what is the optimal treatment strategy for a given weed population, where one of a range of options is to do nothing (Pannell, 1988). Such an approach opens up the philosophy of overall weed management within a rotation. This would take into account which weeds should be more intensively controlled within a particular rotation and judge within each crop whether action is necessary and if so, what level of weed control is desirable for each species present. This approach inevitably includes the use of appropriate doses of herbicides which may often be lower than those recommended by the manufacturer.

Opening up the options from a simple "spray or not to spray" decision reduces the accuracy required for assessing the effect of a weed population on the present and future crops and also the accuracy required in assessing a weed population.

More flexibility could also be introduced in the assessment of populations. This could be by adopting an approach where initially a few visual assessments are made in a field. No further weed counts would be required where populations were clearly very high or extremely low. However, weed counts should be carried out for intermediate populations to dictate the course of action from a range of options. The intensity of counts should be based on a structured approach which suggests further counts over a bare minimum are only made in specified circumstances.

With the current more rigid systems being evaluated, trials are indicating that the regular use of low doses is more appropriate to minimising expenditure than a rigid, "treat or not treat" threshold system. Desk studies have also questioned the financial benefits of a rigid threshold system (Doyle *et al*., 1986; Cousens *et al*., 1986). However, the regular use of low doses may not meet the demands of minimising damage to the environment. This objective is more likely to be met with not using herbicides wherever possible. The more flexible approach proposed is not likely to reduce applications to the theoretical minimum but if it creates farmer confidence, it could result in significant progress towards reducing herbicide input. A comprehensive programme will be required if this approach is to be accepted by the industry. A significant research and development input into assessing field populations of weeds, crop/weed competition, population dynamics of weeds and information on the efficacy of herbicides in a range of conditions is necessary. However, the vast amount of information required means that the field experience of farmers and advisers should be included in the development of such a system. There is perhaps sufficient knowledge already within the industry to attempt a pilot exercise which, if successful in reducing herbicide input whilst retaining yield and quality of crop, could be developed in time. Indeed, the acceptance of such a programme could act as a framework for future research on and acceptance of an integrated method of weed management.

Future technical developments may aid the quest for a more effective weed management system. Remote sensing of weed cover or computer systems which memorise the position of high weed populations in a field used along with direct injection of herbicides into spray lines opens up many possibilities. Such opportunities should be incorporated into the decision making process at the earliest opportunity.

However sophisticated the development and assessment of thresholds becomes, there may always be a need for the farmer and the adviser to ensure that the full implications of not controlling the weeds are taken into account. It is difficult to envisage any system which takes into account all the factors that influence the need to control or not control the weeds present or expected. This "art" of weed control is likely to be with us for some time to come.

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EFFECT OF SEED RATES AND WITHIN CROP CULTIVATIONS IN ORGANIC WINTER WHEAT

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ABSTRACT

A series of field experiments on organically grown winter wheat was started in the autumn of 1987. The effects of seed rate and within crop cultivations in the spring, on weed growth and crop yield were studied. Harrowing the plots in the spring reduced weed numbers; but by harvest there was no difference in weed biomass. Crop density had the greatest effect on final weight of weeds in the plots.

Spring cultivations had little effect on final grain yield. There was a small yield increase in the first year when the weed population was high. In the second year weed numbers were low and cultivations caused a slight yield reduction. Only changes in seed rate significantly affected crop yield.

INTRODUCTION

Little information is available on the importance of weeds and their competitiveness in organically grown cereals. Are weeds as important in organic systems with lower available N levels as in conventional systems? What crop husbandry factors can affect weed populations and growth?

There are several examples of the effect of crop seed rate on weed growth in the absence of a herbicide. In conventionally grown winter wheat increasing seed rates above the standard rate reduced the biomass of broadleaved weeds and increased grain yields (Andersson, 1986). Similar results have been found with blackgrass, Alopecurus myosuroides (Moss, 1985).

Another husbandry factor which can affect weed growth is the traditional technique of harrowing winter cereals in the spring. There is no information on the effect of within crop cultivations on weed and crop growth using modern varieties and machinery in organic winter cereals.

This series of experiments on organically grown winter wheat was started in the autumn of 1987. The effect of five seed rates and spring harrowing on weed growth and crop yield was studied.

MATERIALS AND METHODS

Three years of replicated field trials were carried out on organically grown winter wheat at Harnhill Manor Farm, Cirencester. The farm is share farmed by the Royal Agricultural College. The trials were carried out on land certified by the Soil Association (The Soil Association, 1989) for organic production. The crops in all three experiments were first wheats following a crop of forage legumes and grass. The soil type in the first 2 years of trials was a stony calcareous clay loam (Sherborne series) and in the final year a clay loam (Evesham series).

A split plot design with 4 replicates was used. Cultivation treatments formed the main plots and the five seed rates were the sub-plots. The within crop cultivation treatments were carried out at right angles to the drilled plots using a light trailed finger tine harrow. (A Tearaway was used in the last 2 years of the trials). There was only one pass with the harrows at each cultivation timing. Cultivation treatments were compared with untreated controls, which were wheeled at each treatment timing.

TABLE 1. Details of crop and treatments

Treatment	Year 1987/88 1	1988/89 2	1989/90 3
Variety	Avalon	Mercia	Mercia
Date of drilling	4 November	29 October	18 October
Sub plot treatments			
Seed Rate		kg/ha	
200 seeds/m²	90	78	90
300 seeds/m²	134	117	135
400 seeds/m²	179	156	180
500 seeds/m²	224	195	225
600 seeds/m²	268	233	271
Main plot treatments			
Cultivations			
Early-GS 22-30	31 March	23 April	9 March
Late-GS 32	-	11 May	27 April
Harvest date	17 August	28 July	

The trials were drilled with an Oyjord plot drill with an effective plot size of approximately 2m by 10m. Weed populations were assessed at 4 points per plot in spring (pre-treatment) and summer using $0.1m^2$ or $0.125m^2$ quadrats. A $1m^2$ destructive sample of weeds was taken from each plot a month before harvest for dry matter determination. Crop plant population and tiller numbers were counted at 3 points per plot using 0.5m lengths of a double row. The trials were harvested using a Claas Dominator plot combine. The whole plot was combined. Grain samples were taken from each plot for moisture and grain analysis.

RESULTS

Crop establishment

The established plant populations were fairly low in all three years of the trials especially in year one as shown in Table 2. The main problem was seed borne diseases affecting the untreated seed with some additional damage by slugs and frit fly (Oscinella frit).

TABLE 2. Plant population established plants/m^2

Seeds sown/m^2	Year 1	Year 2	Year 3
	SED ±9.1	SED ±11.5	SED ±12.6
200	57	107	146
300	92	141	179
400	127	192	218
500	159	236	237
600	166	260	229
Mean	120	187	202

Weed populations, species and weed growth

Weed populations and species were very different in each trial, Table 3.

TABLE 3. Weed populations/m^2 (assessed prior to cultivation treatments in years 2 and 3)

Seeds sown/m^2	Year 1	Year 2	Year 3
	SED ±16.3	SED ±2.2	SED ±13.5
200	138	18	128
300	116	16	132
400	122	16	123
500	106	18	138
600	129	19	132
Mean	122	18	130

In 1988 Trifolium pratense and Poa annua were the main species followed by Stellaria media, Veronica persica and Lamium spp. Weed numbers averaged 122/m^2. In 1989 Veronica hederifolia was the main species and average weed numbers were low at 18/m^2. In 1990 the main weeds present in fairly high numbers (average 130/m^2) were Sinapis arvensis, V.persica and P. annua.

In 1989 cultivations reduced the weed population, mainly V. hederifolia by as much as 90%. By harvest the V. hederifolia had died back and there were only 4 weeds/m^2 in the untreated blocks compared with 3 weeds/m^2 in those that were cultivated. There was also no significant difference in weight of weeds under the various cultivation treatments, Table 4. In 1988 and 1990 there were problems obtaining adequate penetration with the harrows and only seedling weeds were affected. There was no reduction in S. arvensis in the final year. In the first year more T. pratense and P. annua germinated after the cultivation treatment. In July there was a small but significant reduction in weeds in the cultivated compared with the untreated plots (110 weeds/m^2 compared with 134 weeds/m^2). There was no significant difference in weed biomass.

In the spring there was no difference in weed numbers in the different seed rate plots. By harvest there was a trend for a lower weed biomass at the higher seed rates. There was a statistically significant difference in the second year. There was no significant interaction between seed rate and cultivations.

TABLE 4. Pre-harvest weed biomass in g/m^2 (d.m.)
Mean effect of seed rate or cultivations

Treatment	Year 1	Year 2
Seeds sown/m^2	SED $\pm$19.5	SED $\pm$2.45
200	92	12.4
300	82	13.3
400	28	10.4
500	58	9.8
600	50	8.2
Cultivations	SED $\pm$13.3	SED $\pm$3.19
No cultivations	47	10.1
Early cultivations	77	13.2
Late cultivations	-	8.3
Early and late cultivations	-	11.7
Mean	62	10.8

Crop yield

The mean yield response to seed rate was similar in these trials as obtained in conventionally grown wheat trials on one of the other College farms. (Cromack et al., 1987). In 1988 there was little yield difference between seed rates. In 1989 there was a significant yield increase from sowing 500 seeds/m² compared with each of the lower and higher rates. There was no yield benefit from cultivating the wheat in the spring. In 1988 there was a small yield increase (non significant) from harrowing the crop, but the spring cultivation in 1989 gave a yield reduction. There was no significant interaction between seed rate and the cultivation treatments. Cultivations in 1988 increased fertile tiller numbers whereas in 1989 cultivations reduced fertile tillers.

TABLE 5. Grain yield t/ha at 85% d.m.
Mean effect of seed rate or cultivations

Treatment	Year 1	Year 2
Seeds sown/m²	SED ±0.17	SED ±0.11
200	2.74	5.70
300	2.89	6.08
400	2.97	6.14
500	2.88	6.51
600	2.75	6.27
Cultivations	SED ±0.11	SED ±0.25
No cultivations	2.74	6.29
Early cultivations	2.95	6.11
Late cultivations	-	6.24
Early & late cultivations	-	5.92
Mean	2.85	6.14

DISCUSSION

Crop seed rates had the greatest effect on weed growth in this series of experiments. Weed populations were not signficantly affected by crop seed rate but there was a difference in the biomass of weeds before harvest. The plots at the higher seed rates contained the lowest weight of weeds. These results are similar to those obtained in conventionally grown crops (Andersson, 1986; Easson et al., 1989).

Within crop cultivations in the spring reduced the population of some weeds particularly the shallow rooting weeds such as V. hederifolia. By harvest there was no visual difference between the cultivated and uncultivated plots and there was no difference in biomass of weeds between treatments. One problem was achieving adequate penetration with the light harrows to remove the overwintered weeds. Only one pass was made with the harrows. Recent work has shown that more than one pass with harrows has given better weed control in spring cereals (Rasmussen, 1990). Yields were little affected by cultivations. There was a small yield increase in the first year when weed numbers were high. There was a yield decrease in the second year. This yield reduction could have been due to the cultivations reducing the soil moisture content in a year when there was a severe summer drought and weed numbers were very low.

ACKNOWLEDGEMENTS

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INTERCROPPING AUTUMN-SOWN FIELD BEANS AND WHEAT: EFFECTS ON WEEDS UNDER ORGANIC FARMING CONDITIONS

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ABSTRACT

Autumn-sown field beans (*Vicia faba*) and wheat (*Triticum aestivum*) were grown on an organic farm, using a wide range of densities of both crops. Crop yield and weed biomass production was compared under sole crops and intercrops.

Intercropping, with both the beans and wheat at 75% of their optimum sole crop density, gave a substantial yield advantage (L.E.R. = 1.29).

In both the sole crops and the intercrops the growth of weeds, and the amount of nitrogen that the weeds accumulated per unit area, was reduced as the crop density was increased. The lowest weed biomass was recorded in the intercropped treatments, followed by sole cropped wheat; sole cropped beans had the highest weed biomass. The amount of nitrogen accumulated per unit area by the weeds followed the same ranking. The nitrogen concentration in the weeds growing under the wheat was lower than that of the weeds under the beans.

INTRODUCTION

Intercropping i.e. 'The growing of two (or more) crops simultaneously on the same area of ground' (Willey, 1979), is reported to offer advantages over sole cropping in terms of: increased yields, reduced incidence of disease, reduced insect pest infestation, reduced growth of weeds, increased yield security and reduced soil erosion. These advantages are gained without the use of high levels of inputs as they rely on making more efficient use of natural environmental resources (Willey, 1979; Francis, 1986; Ofori and Stern, 1987). Intercropping, therefore, would appear to fit well within the principles of organic farming (IFOAM, 1989; Soil Association, 1989). The effect of intercropping on the growth of weeds is, however, equivocal (Moody and Shetty, 1981; Shetty, 1982; Mohler and Liebman, 1987), and little of the available data comes from temperate regions. One of the reasons for the ambiguity is that crops differ in their competitive ability against weeds.

Field beans are vulnerable to weed competition and are difficult to grow without effective weed control (Hewson *et. al.*, 1973; Glasgow *et. al.*, 1976). Wheat, however, is less vulnerable to such competition (Williams, 1972). This study therefore investigated weed growth in sole crops and intercrops of field beans and wheat, as well as crop yield, nitrogen accumulation in crops and weeds, disease incidence and production economics.

The yield and the competitive ability of both sole crops and intercrops can be influenced by many factors including: crop density; spatial arrangement; cultivar selection; time of sowing; and cultivation techniques (Willey, 1979). It was not possible to investigate all of the above in this experiment. However, crop density was varied as it can be manipulated by the farmer and is known tc affect the growth of weeds and the yield of the crops (Willey and Osiru, 1972; Shetty, 1982; Walker and Buchanan, 1982). Factorial combinations of the densities of the two crops were used because the optimum densities of the crops grown together are often difficult to predict from those of sole crops (Willey and Osiru, 1972).

The crops were sown and harvested mechanically in order to make the results relevant to practical organic farming situations in Britain.

METHOD AND MATERIALS

The experiment was carried out on an organic farm near Pangbourne, Berkshire, on a clay loam soil. The field had been ploughed and rolled in mid October, following a wheat crop which had in turn followed a four year grass ley. Organic crop husbandry was used, as defined by the Soil Association (Soil Association, 1987).

The beans (cv. Bourdon) were sown on the 4 Nov 1987 to a depth of 15cm with a row spacing of 20cm using a 'Gibbs' farm drill. The bean density was later adjusted by hand as required. The wheat (cv. Maris Wigeon) was sown at the required densities on the 5 Nov 1987, at a depth of 2.5cm and a row spacing of 15cm with rows at right angles to the beans, using a self-propelled trial plot seed drill. The densities of both crops were varied (Table 1) relative to the recommended sole crop densities (MAFF, 1981; MAFF, 1982) i.e. 28 and 400 seeds/m^2 for beans and wheat respectively. In order to ensure that the range of densities actually included the optimum for the sole crops of beans and wheat they were also sown at 150% of their recommended seed rate. The plots were 1.8m x 10m with an additional 1m discard at each end and were arranged in three fully randomised blocks.

No weed control practices were carried out during the growing season. Weed biomass was measured in three 0.25m^2 random quadrat samples per plot on the 17.6.89. Dried samples were then analysed for total nitrogen content.

The plots were harvested on the 3.10.88, using a trial plot combine harvester. The beans and wheat were later separated using a hand-held sieve; on a farm scale, a pre-cleaner could be used to separate the beans from the wheat.

TABLE 1. The matrix of crop density treatments used in the 1987/88 autumn sown experiment.

		Wheat, % of recommended density					
		0	25	50	75	100	150
	0		*	*	*	*	*
Beans,	25	*	*	*	*	*	
% of	50	*	*	*	*	*	
recommended	75	*	*	*	*	*	
density	100	*	*	*	*	*	
	150	*					

RESULTS

The highest yields of sole crops of beans and wheat were obtained when they were sown at 100% of the recommended density (Table 2).

TABLE 2. Yield of sole cropped beans and wheat (t/ha) as affected by bean and wheat density.

	% of recommended sole crop density				
	25	50	75	100	150
Beans	1.66	2.03	3.08	3.68	3.25
Wheat	1.90	3.12	3.66	3.72	3.48

The performance of the intercrops, expressed as land equivalent ratio (L.E.R.), was based on a comparison with the highest yield of beans and wheat when sole cropped, as recommended by Huxley and Maingu (1978). The highest intercrop yield (4.39t/ha) was obtained when both crops were planted at 75% of their recommended sole crop density which gave an L.E.R. of 1.29. This indicates that sole cropping would require 29% more land to produce the same amount of beans and wheat as the intercrop. When the wheat was included in the intercropping treatments at more than 25% of its recommended sole crop density then intercropping consistently showed an advantage over sole cropping in terms of L.E.R. (Table 3). Intercropping also showed a clear economic advantage after adjustments had been made for the different values of the two crops and the cost of seed (Table 4).

TABLE 3. Land Equivalent Ratio (L.E.R.) as affected by bean and wheat density.

		Wheat, % of recommended density				
		25	50	75	100	x̄
Beans,	25	0.67	1.06	1.02	1.27	1.03
% of	50	0.86	1.08	1.05	1.25	1.06
recommended	75	0.94	1.16	1.29	1.27	1.17
density	100	0.97	1.15	1.24	1.16	1.13
	x̄	0.88	1.11	1.15	1.23	

L.S.D. (P<0.05) mean wheat density = 0.14

TABLE 4. Financial return (£/ha), after the cost of seed, as affected by bean and wheat density.

		Wheat, % of recommended density					
		0	25	50	75	100	x̄
	0	-	272	440	510	504	432
Beans,	25	241	498	549	506	604	480
% of	50	282	456	543	504	600	477
recommended	75	429	449	547	628	583	527
density	100	506	446	554	574	542	524
	x̄	365	424	527	544	567	

L.S.D. (P<0.05) mean wheat and bean density = 79.97
Beans @ £156/tonne, wheat @ £150/tonne, spot prices for organic crops late September 1988.

The dominant weed was fumitory (*Fumaria officinalis*), other species included: creeping buttercup (*Ranunculus repens*); docks (*Rumex spp.*); creeping thistle (*Cirsium arvense*); corn poppy (*Papaver rhoeas*); redshank (*Polygonum persicaria*); cleavers (*Galium aparine*); annual meadow-grass (*Poa annua*); rough stalk meadow-grass (*Poa trivialis*); common couch (*Elymus repens*).

Increasing the density of both beans and wheat reduced weed biomass in both sole crops and intercrops, but the wheat density had a greater effect than the bean density (Table 5).

TABLE 5. Weed biomass (g/m^2 dry weight) as affected by bean and wheat density (all values are geometric means).

		Wheat, % of recommended density					
		0	25	50	75	100	$\bar{x}$
	0	434	302	146	97	124	187
Beans,	25	398	168	148	96	93	154
% of	50	346	162	133	80	100	143
recommended	75	284	138	151	75	36	110
density	100	169	117	72	83	62	94
	$\bar{x}$	310	168	126	86	76	

L.S.R (P<0.05) mean wheat and bean density = 1.31

The nitrogen content (N%) of the weeds decreased as the density of wheat increased, increasing the density of beans, however, resulted in an increase in the N% of the weeds (Table 6). The amount of nitrogen accumulated per unit area by the weeds depends on both biomass production and N%. Increasing the density of wheat, therefore, greatly reduced the total nitrogen accumulation of the weeds per unit area, but increasing the density of the beans had less effect (Table 7).

TABLE 6. Total nitrogen content of the weeds (% of dry matter) as affected by bean and wheat density.

		Wheat, % of recommended density					
		0	25	50	75	100	$\bar{x}$
	0	-	1.39	1.14	1.32	1.21	1.27
Beans,	25	1.63	1.47	1.28	1.26	1.39	1.41
% of	50	1.74	1.47	1.67	1.49	1.24	1.52
recommended	75	1.77	1.74	1.68	1.61	1.50	1.66
density	100	2.09	2.77	1.63	1.68	1.75	1.98
	$\bar{x}$	2.09	1.77	1.48	1.47	1.42	

L.S.D. (P<0.05) mean wheat and bean density = 0.199

TABLE 7. Total nitrogen accumulated by weeds per unit area (kg/ha) as affected by bean and wheat density.

		Wheat, % of recommended density					
		0	25	50	75	100	$\bar{x}$
	0	-	56.3	16.7	13.3	15.4	25.4
Beans,	25	63.7	24.6	19.6	12.1	13.0	26.6
% of	50	58.4	31.3	21.8	8.9	13.6	26.8
recommended	75	49.0	24.3	31.6	12.2	5.4	24.5
density	100	34.9	23.6	11.2	14.7	10.9	19.1
	$\bar{x}$	51.5	32.0	20.2	12.4	11.7	

L.S.D. (P<0.05) mean wheat and bean density = 7.7

DISCUSSION AND CONCLUSIONS

In this experiment intercropping of field beans and wheat produced advantages in terms of yield, financial return and weed control when managed using organic crop husbandry. Both the beans and the wheat grew well in this experiment and produced yields which are typical for organically grown crops, following a cereal crop, after grass (M. Measures, personal communication).

The results clearly show the yield advantage of intercropping field beans with wheat under the conditions of this experiment. The high plant densities that were sustained in the intercrops resulted not only in yield advantages but also in greater suppression of weed growth. This supports Shetty (1982) who reported that weed suppression was greatest when the density of the intercrops was higher than that of the sole crops. This probably reflects the ability of the intercrop to make more efficient use of environmental resources, thus leaving less available for the growth of weeds (Igbozurkie, 1971; Plucknett *et. al.*, 1976).

Weed biomass was less under the wheat than under the beans; this is in accordance with the results of Williams (1972). Increasing the density of the wheat not only reduced the biomass of the weeds but also their N%. Increases in the bean density while having a less marked effect on weed growth also increased the N% of the weeds. Competition for nitrogen, a limiting resource in most agricultural systems (Postgate, 1987), is therefore likely to be part of the explanation for this difference in competitive ability. Gliesman (1986), however, stresses the need for caution when identifying a limiting factor in competition studies, as uptake and utilization of all resources is interrelated. Further experimentation under more controlled conditions is required in order to establish the mechanism of competition between crops and weeds in both sole crops and as intercrops.

An experiment is currently being conducted, also on an organic farm, to compare autumn-sown and spring-sown intercrops and sole crops of beans and wheat for both productivity and weed control.

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PATTERNS OF WEED EMERGENCE FOLLOWING SOIL CULTIVATION AND ITS IMPLICATIONS FOR WEED CONTROL IN VEGETABLE CROPS

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ABSTRACT

In studies made over several years, flushes of weed seedlings that emerged following soil cultivations made at intervals through the growing season were recorded. Within each year, the species composition of a flush varied with time of cultivation but differences in total seedling numbers showed few consistent trends. The pattern of weed emergence was greatly influenced by rainfall. When conditions were moist 50% of weed seedlings emerged within 6 weeks of cultivation. However, under dry conditions 50% emergence was sometimes delayed until 13 weeks after cultivation depending upon when rain fell. Applying irrigation after cultivation gave more consistent patterns of weed emergence. To gain the maximum benefit from weed control systems that rely upon optimum timing of weed removal, adequate soil moisture must be made available to encourage prompt weed emergence.

INTRODUCTION

Variations in the timing and pattern of emergence of the flush of weed seedlings that appears following seedbed preparation can influence both the interaction of crops and weeds leading to weed competition and the success of weed control measures in preventing loss of yield. Competition studies have shown that in some crops a single weeding, made at the ideal time, will prevent loss of yield (Roberts & Hewson, 1973), but optimum timing of weed control to eliminate competition depends on when the weeds emerge in relation to the crop. Similarly the success of the stale seedbed technique in reducing weed numbers depends upon delaying the destruction of emerged weeds until after the main flush of seedlings has appeared.

Many factors influence the timing, size and duration of the weed flush that emerges following soil disturbance. The content of the soil seed-bank will determine the likelihood of seedlings of particular species occurring, although some other propagules may be introduced later. The time of year that disturbance takes place will also influence the species composition of the weed flora since conditions at and prior to cultivation will prime certain species ready for germination while inducing dormancy in others (Roberts & Feast, 1970). Whenever temperatures are not limiting, the most important factor which determines when a flush of weed emergence will take place is the presence of adequate soil moisture (Roberts & Potter, 1980).

Records of weed emergence in seedbeds prepared at regular intervals through the growing season have been taken at IHR - Wellesbourne for many years. The results of this work and some of the implications for weed control in vegetable crops are discussed.

METHODS

The soil was a sandy loam, and the experimental area was ploughed in the autumn and allowed to weather before plots were marked out in early spring in randomised blocks of 3 or 4 replicates. Commencing in March, separate plots (2 x 1.5 m) were cultivated to a depth of 10 cm every 2 weeks through the growing season. Each plot was cultivated once only and two plots in each block were left undisturbed. A permanent quadrat 1.0 x 0.5 m was established at the centre of each plot and all weed seedlings within it were recorded and removed each week. The experiments were sprayed with paraquat on occasion to prevent seed production. All the trials from 1974-1981 were made under conditions of natural rainfall. In each of the years 1986-1988 two adjacent trials were prepared, one maintained under natural conditions and the other having irrigation applied to the whole trial when the soil was dry at the time of a cultivatioin. The experiments were carried out in a different field each year, following winter wheat. Since 1950, crops at Wellesbourne have been grown in a four year rotation with three years of cereals followed by one of vegetables.

RESULTS AND DISCUSSION

In vegetables grown for a single season the first flush of weeds generally has the most effect on crop yield. Patterns of weed emergence in the first 16 weeks after seedbed preparation are given in Figure 1 for cultivations made at 2 week intervals during 1976, 1978, 1979 and 1980. Weekly counts are expressed as a percentage of the total seedlings emerging during the 16 week period. Rainfall was frequent in the years 1978 & 1980 and most of the seedlings emerged within 6 weeks of seedbed preparation. In the drier years, 1976 and 1979, emergence was delayed through lack of moisture and when weed flushes did appear these were related to rainfall events. In 1976, 50% seedling emergence was sometimes not achieved until 13 weeks after cultivation. Patterns of emergence in the other years were also related to the occurrence of rain particularly when conditions were dry at the time of cultivation.

The patterns of emergence of weeds developing under natural conditions and with irrigation applied after cultivation during the experiments made in 1988 are given in Figure 2. The use of irrigation generally gave more consistent patterns of weed emergence and tended to reduce the spread of seedlings emergence over time.

The mean number of seedlings per m^2 that emerged during the 16 week period after cultivation ranged from 375 to 1803 in 1975 and from 12 to 144 in 1986. The experiments were situated in different locations each year and seedling numbers would be expected to differ between fields due to separate cropping histories. The mean seedling numbers per m^2 that emerged during the 16 weeks after cultivation were ranked in increasing order for the 13 cultivation dates that most closely coincided in the different years. The two highest ranked flushes in each year occurred following cultivations made from mid-June onwards but apart from this there was no other consistent trend linking time of cultivation and relative abundance of weed seedlings.

Differences in seedling numbers between cultivations made at different times will be controlled, in part by the species composition of the weed seed

FIGURE 1.

Patterns of weed emergence during 1976, 1978, 1979 and 1980 under natural weather conditions. Seedbeds were prepared at 2 week intervals beginning in March. Weekly seedling counts are expressed as a percentage of the total numbers recorded in a 16 week period after cultivation (Modified from Roberts & Potter, 1980; Roberts, 1984).

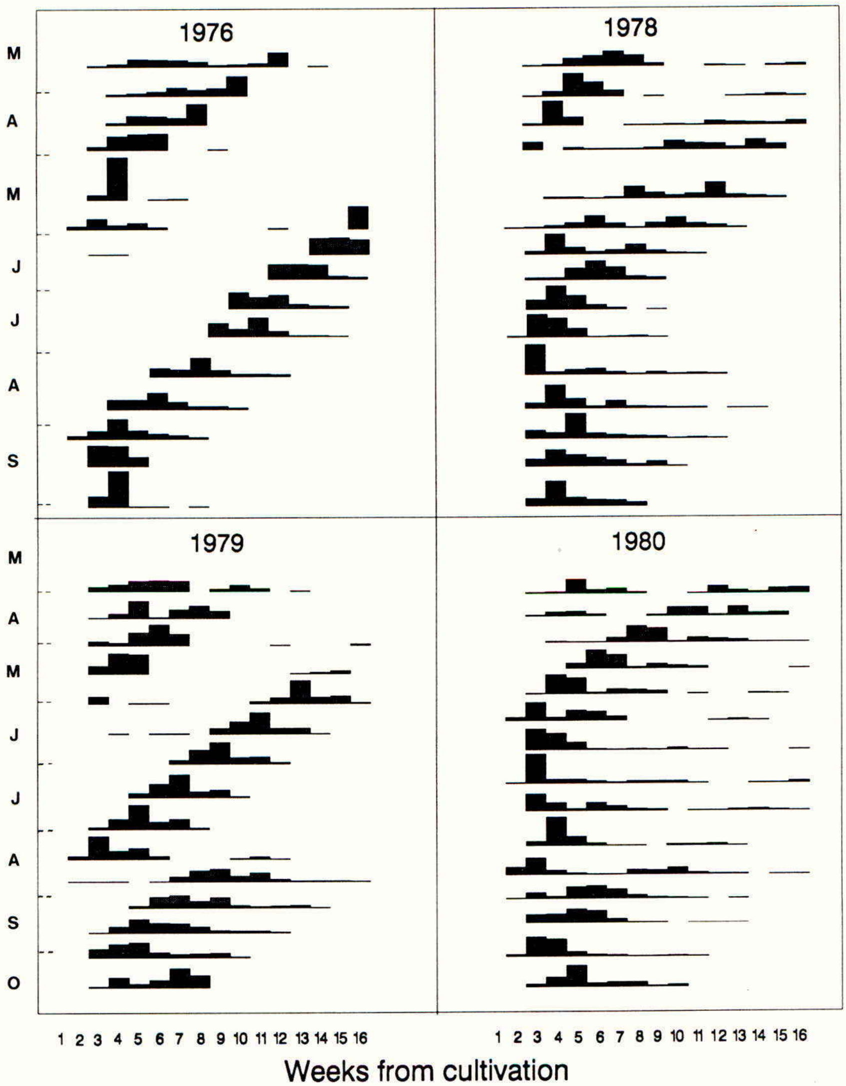
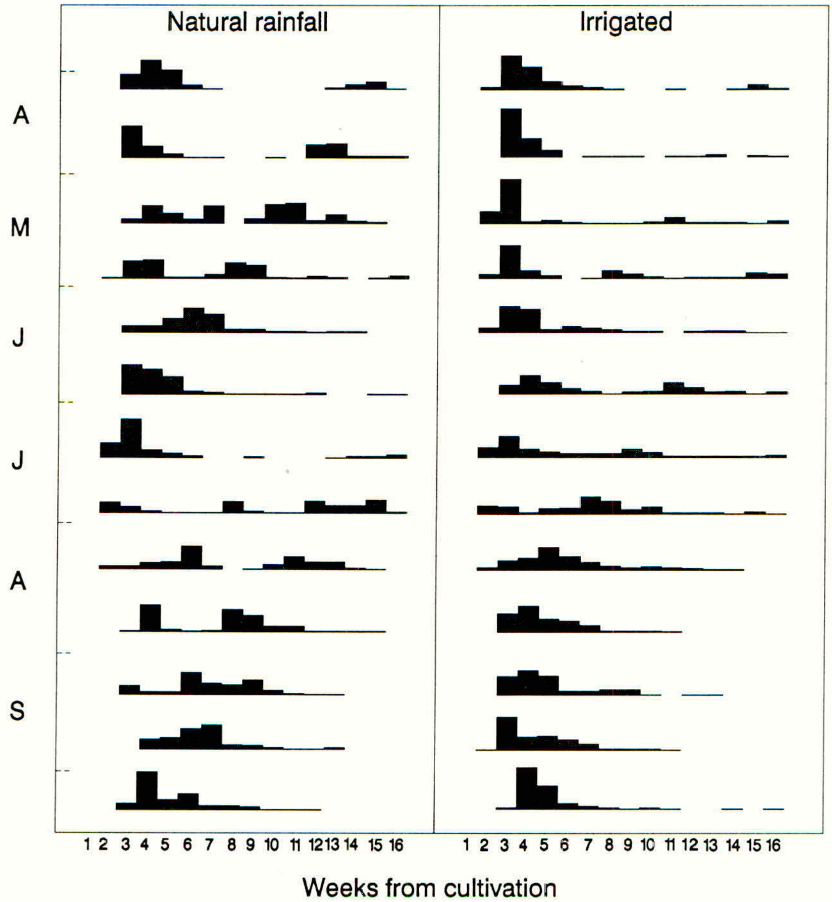


FIGURE 2.

Patterns of weed emergence during 1988 under natural rainfall and with irrigation. Seedbeds were prepared at 2 week intervals beginning in April. Weekly seedling counts are expressed as a percentage of the total numbers recorded in a 16 week period after cultivation.



bank. Table 1. shows the change in composition of the seedling flora following cultivations made at intervals during 1980. The four main species present did not exhibit marked differences in abundance with time of cultivation but others such as *Polygonum aviculare* and *Veronica arvensis* only emerged early in the season while *Papaver* spp. appeared after early and late cultivations. The increase in *Senecio vulgaris* and *Sonchus* spp. was due to an influx of wind borne seeds from nearby headlands. Other factors likely to affect seedling numbers include differences in mortality due to rapid drying of the soil in warm conditions and water logging when the weather is cold and wet.

TABLE 1.

Species composition of the weed flora that emerged following cultivations made at 2 week intervals during 1980

	Seedlings as % total									
Date of Cult	Poa ann	Ste med	Lam amp	Ver per	Lam pur	Pap spp	Pol avi	Ver arv	Sen vul	Son spp
4 Mar	15.6	14.8	25.0	22.8	6.2	2.4	2.7	4.6	0.3	0.3
20 Mar	21.9	13.2	20.2	17.9	22.0	0	0.3	0.5	0.2	0
2 Apr	31.3	10.9	11.9	21.7	14.9	0.4	1.0	0.4	0.4	2.3
16 Apr	32.0	11.0	7.6	29.3	10.4	0.1	0.4	0.1	1.3	1.5
1 May	28.6	13.5	13.9	23.2	15.1	0.1	0.4	0	0.2	1.3
14 May	24.0	12.5	11.6	21.5	22.8	0	0.1	0	1.1	0.8
28 May	44.1	5.8	9.1	21.9	8.8	0.4	0.2	0	1.4	3.1
12 Jun	23.6	17.6	14.3	20.7	16.6	0.1	0	0	3.0	0.1
25 Jun	16.1	16.9	10.6	22.2	19.6	0.1	0	0	3.5	8.2
10 Jul	17.1	12.1	2.6	27.0	16.1	1.2	0	0	8.9	10.7
22 Jul	31.4	6.0	12.0	16.5	5.9	0.6	0	0	10.6	12.8
5 Aug	28.8	8.2	13.7	18.3	12.4	1.5	0	0	3.7	10.1
19 Aug	36.5	5.9	7.2	19.3	3.9	1.6	0	0	0.4	21.0
2 Sep	21.5	15.4	27.4	18.6	0	2.3	0	0	0.3	8.4
16 Sep	27.1	13.6	11.8	18.2	11.5	2.8	0	0	0.3	8.1
30 Sep	31.0	14.5	8.8	26.9	6.4	5.5	0	0	0.1	2.5

Key to abbreviations: Poa ann (*Poa annua*), Ste med (*Stellaria media*), Lam amp (*Lamium amplexicaule*), Ver per (*Veronica persica*), Lam pur (*Lamium purpureum*), Pap spp (*Papaver* spp.), Pol avi (*Polygonum aviculare*), Ver arv (*Veronica arvensis*), Sen vul (*Senecio vulgaris*), Son spp (*Sonchus* spp.).

Although weed density and species composition will affect the level of weed competition in vegetable crops, the timing and pattern of weed emergence has the greatest influence in determining when competition will begin to reduce crop growth. In weed competition studies it has been demonstrated that weeds can be left for a time following crop emergence without affecting crop yield providing they are removed after a specific period and the crop subsequently kept weed free (Roberts & Hewson, 1973). Conversely, yield of a crop kept weed free for a given interval after emergence will not be reduced by weeds allowed to develop after that time. Depending upon the relationship of these two periods a single weeding may suffice to prevent a reduction in crop yield, or the crop may need to be kept weed free for a specific, short period of time. The problem of putting this into practice has always been the difficulty of defining in advance the optimum stage to remove weeds from the crop, mostly due to variations in the pattern of weed emergence as seen in these trials. The main flush of weeds must have passed before weeding takes place if further weed emergence is not to affect crop yield. The developing crop should then suppress the growth of low numbers of later emerging weeds.

It is clear from the results of these experiments that soil moisture level is an overriding factor determining how soon after cultivation a flush of weed seedlings will emerge. It is essential to ensure the prompt emergence of both crop and weed if the results from weed competition experiments are to be used reliably to forecast the optimum time of weed removal in field vegetables.

Delays in weed emergence will also reduce the effectiveness of the stale seedbed technique where it is essential to encourage the germination and emergence of the maximum number of weed seeds. Ensuring adequate soil moisture is probably the most important factor but the fineness of the seedbed (Bleasdale & Roberts, 1960) and prevention of soil capping (Roberts *et al*, 1981) will also increase the number of seedlings that emerge. The use of floating polyethylene covers in the spring encourages weed emergence (Bond & Walker, 1989), but this is unlikely to prove economic for use in stale seedbeds on a large scale.

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3.
Pest Control

Chairman: DR B. R. KERRY

INTERCROPPING FOR PEST CONTROL

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ABSTRACT

Intercropping is a traditional method of crop production in the tropics which has potential as a cultural control method for insect pest suppression in low-input farming in temperate regions.

The reduction in insect pest populations in diverse systems compared to simple ones is explained by higher numbers of natural enemies and/or reduced herbivore colonization. Most published work on this topic fails to demonstrate the effects of reduced herbivore numbers on crop yield and explain the ecological mechanisms responsible for reduction.

To develop successful intercropping systems will require a better theoretical understanding of the mechanisms involved in reducing pest numbers and to introduce it as a cultural control method will require a similar development in research technology as for monocultures.

INTRODUCTION

Intercropping, that is growing two or more crops in association with one another is a traditional practice in the tropics. Estimates suggest that 98% of cowpeas grown in Africa and 90% of beans grown in Columbia are intercropped. Land devoted to intercropping varies from 17% in India to 94% in Malawi. Even in temperate North America before modern varieties and mechanization took over, intercropping was not uncommon. For example, 57% of the soya bean acreage in Ohio was sown in combination with maize. The diversity and distribution of crop combinations used in intercropping are considerable (Vandermeer, 1989), and the spacial patterns used can range from having no distinct row arrangement (mixed intercropping) to being planted in rows (row intercropping) or strips (strip intercropping), but essentially the crops are grown simultaneously during all or part of the life cycle of each (relay intercropping) (Andrews & Kassam, 1976).

The reasons for intercropping are better use of resources e.g., water and nutrients, reduction in pest and disease damage as well as various socio-economic advantages (Perrin, 1977). Such multicropping systems are thought to possess a great potential for improved crop productivity and provide "some lessons that temperate agronomists could usefully learn" (Norton & Conway, 1977). Intercropping is unlikely, however, to find a place in modern agriculture until the research technology for intercrops is as well developed as it is today for monoculture and sole crops.

It is also the case that cultural control methods for insect pest suppression were abandoned with the development of high input crop production as they appeared unnecessary when compared with the high level of control obtained from insecticides alone. Such methods also suffer from growers' lack of interest since they are usually preventative and need to be applied well in advance of the pest attack rather than to control existing problems. It can nevertheless be argued that effective cultural control measures should be adopted as a baseline for insect pest management programmes to reduce or delay pest numbers from reaching damaging levels and thereby contributing to the overall reduction in pesticide use and of their consequent side effects.

There are many different types of cultural control practices that can be applied to most areas of pest management. Those that fall within the concept of ecosystem management attempt to a greater or lesser degree to introduce complexity into an over simplified crop system, thereby interfering with ovipositional preferences, host plant location and discrimination by making the crop unavailable to the pest in space and time. Others manipulate the crop environment to make it less favourable to the pest, by enhancing natural enemies or by altering crop suitability (Coaker, 1987). Intercropping includes some of these features.

ECOLOGY CONCEPTS

A basic and central concept relating to insect abundance is the idea that their population biology and behaviour is in some way dependent on the dispersion of their resources. For instance, we usually expect to find insects concentrated and thriving where resources are abundant and easy to find such as herbivores on plants growing at high density and low diversity (Cromartie, 1981) and the aggregation of predators in regions of high prey density thereby having a potentially stabilizing influence on predator-prey interactions (Hassell, 1978). Such evidence reflects the view that ecosystem texture - the pattern caused by interweaving such characteristics as plant diversity, density and patch size - should influence herbivore abundance (Kareiva, 1983). This has led several authors to take note of the potential for suppressing pests by manipulating cropping patterns (Perrin, 1977; Risch _et al_., 1983; Hare, 1983; Coaker, 1988).

INTRA-CROP DIVERSITY: PROTECTION FROM PESTS

There have been many studies on the effects of intra-crop diversity, i.e. mixed and row intercropping and weedy culture systems, on insect herbivore populations. From a survey of 150 studies on 198 insect species, Risch _et al_. (1983) revealed that 58% of the populations of monophagous species on annual crops showed a decrease, 3% an increase, 23% a varied response and 15% no change compared to populations on simple systems e.g., monoculture and sole crops. Polyphagous species showed no equivalent differences. Although there was considerable variation in the types of crop diversification and plot sizes used in the experiments and because the examples did not represent a random selection of herbivores and agroecosystems, such aggregate percentages must be treated with caution. Nevertheless, they do highlight some important unanswered questions such as did a decrease in pest abundance give better crop yields? Unfortunately only 19 of the 150 studies reported on crop yields but their interpretation is difficult since none used land equivalent ratios, a measure of yield per unit of land area (Willey, 1979), a conventional method for comparing yield from intercrops and sole crops. Another question concerns the ecological mechanisms involved that accounted for the differences in pest abundance. The understanding of these is important for developing a predictive theory of how diversity affects pest populations and also to allow finer tuning of the agronomics of the crop mixture with respect to timing of planting of the associated crops, their relative growth rates and spacial arrangements to maximize pest suppression.

The enemies hypothesis

Of the several hypotheses proposed (Aiyer, 1949; Trenbath, 1976; Vandermeer, 1989) those of Root (1973) are the most comprehensive. His enemies or predation hypothesis, suggests that intercropping encourages a greater number of natural enemies by the more favourable resources provided which include; improved temporal and spacial nectar and pollen sources which attract natural enemies, increased ground cover important for diurnal predators, increased alternative prey valuable when the pest species are scarce or at appropriate times in the predator's life.

There are numerous examples demonstrating an increase in predator species in intercrop systems compared with monocultures. For example, Gavarra & Raros (1975) found spiders to be more effective against corn borers in a corn/groundnut intercrop system, and Dempster & Coaker (1974), O'Donnell & Coaker (1975), Ryan et al. (1980) recorded higher populations of carabids and staphylinids in brassicas intercropped with clover or Spegula arvensis (Theunissen & Den Ouden, 1980) or Phaseolus beans (Tukahirwa & Coaker, 1982). The increased numbers of predators correlated with the reduction in cabbage root fly, Delia radicum, eggs laid around the intercropped brassicas. Using exclusion barriers Tukahirwa & Coaker (1982), however, found no significant difference between the number of eggs around brassica plants with and without predators although 60% fewer eggs were recorded from intercropped brassicas than from brassicas grown alone. Evidence for increased predation from intercropping, therefore, requires further elaboration with different pest insects and cropping systems.

The resource concentration hypothesis

Evidence in favour of Root's resource concentration hypothesis is probably stronger than that for the enemies hypothesis. This hypothesis, alternatively called the disruptive crop hypothesis by Vanderveer (1989), suggests that the associated plant species may have a direct effect on the ability of the herbivore to find and utilize its host plant. Tukahirwa & Coaker (1982) found that similar numbers of female D. radicum arrived at plots of brassicas and brassicas mixed with clover, but on entering them their activity was highest in the mixed plot and this activity was directly proportional to the number of flies leaving. The female cabbage rootflies host finding behaviour was disrupted by alighting on the non-host clover plants. A similar behaviour was observed by ovipositing tomato hornworm moths, Manduca quinquinaculata, in a tomato/bean mixture (Vandermeer, 1989).

The resource concentration of the habitat is, therefore, likely to be determined by the total strength of the stimuli resulting from the different interacting factors such as density and spacial arrangement of the host plant and the disrupting effects of the non-host plant. So the lower the relative resource concentration the more difficult it will be for the pest insect to locate its host plant. A lower relative resource concentration also increases the probability that the pest will leave the habitat once it has arrived, for instance, it may tend to fly sooner and further after landing on the non-host than on the host plant which results in a higher emigration rate from the intercrop than from the monoculture.

A reduction in colonization and increase in emigration obviously results in fewer pests on the host crop. Evidence to support the resource concentration hypothesis has been obtained, for example, from several beetle pest species of corn and beans (Risch, 1980; 1981), the cucumber beetle, Acalymma vittatum, in cucumbers, broccoli and maize polycultures (Bach, 1980) and the flea beetle, Phyllotreta cruciferae, on crucifers grown against different vegetational backgrounds (Cromartie, 1975). Uvah & Coaker (1984) interpreted the reduction of carrot fly, Psila rosae, attack on carrots intercropped with onions to be due to the onion volatiles disturbing their host plant finding behaviour. In this case relative resource concentration was defined by the carrot/onion plant ratio, the lower the proportion of carrot plants the lower the carrot fly infestation.

Resource concentration can also be reduced when an intercrop breaks up the sharp silhouette of the plant against the soil, causing immigrating aphids to be less efficient in locating their host plants (Smith, 1969; 1976; O'Donnell & Coaker, 1975; Halbert & Irwin, 1981; Tukahirwa & Coaker, 1982; McKinlay, 1985).

The resource concentration hypothesis is more likely to apply to specialist herbivores rather than polyphagous species. It is also possible that host plants in intercrops may be smaller due to competition, with lower quality and palatability than those in monoculture, thereby making them less attractive to pest attack (Bach, 1981). For a more extensive review of the general effects of plant patterns on the movement of insects see Stanton (1983) and Kareiva (1983).

CONCLUSIONS

Experimental evidence and current theoretical considerations suggest that intercropping has potential as a cultural method for pest control, but this potential cannot be reached until a number of technical problems are solved. These include:

1. Studies to show that reductions in herbivore populations in diverse systems cause increases in yield. This could be achieved by comparing intercrops and monocultures treated with and without insecticides to deduce whether the yield differences were caused by differences in herbivore populations.
2. Exploration of the underlying mechanisms that account for the differences in herbivore populations between intercrops and monocultures and the development of simple models of herbivore movement patterns and predator-prey interactions in these systems to enable prediction of what will happen in untried systems (see Vandermeer, 1989).
3. Examination of the scale and experimental design necessary to identify real effects. Small plots may allow herbivore preference for sole crops over intercropped host plants, which may on a large scale accumulate similar numbers. Small scale experiments may reflect no more than choices of a particular habitat over neighbouring ones.

If research demonstrates that intercropping can play an important role in pest management, converting present systems of agriculture to these alternatives will be difficult: new machinery would have to be developed which would be expensive. Perhaps it will be the smaller organic producer that will be the pioneer in this development and in the reintroduction of cultural practices for pest control.

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USE OF REDUCED RATES OF PESTICIDES FOR APHID CONTROL: ECONOMIC AND ECOLOGICAL ASPECTS.

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ABSTRACT

Field studies between 1984 and 1989 showed that in seasons with moderate and late increases in cereal aphid numbers, efficient control of the pest could be achieved using reduced rates of insecticides. However the need for very exact timing of the treatment bears a higher risk for advisers and farmers, particularly when the population development of the aphids cannot be predicted precisely. From an ecological point of view treatments with reduced rates of selective ingredients like pirimicarb seem to offer a distinct improvement in protection of non-target invertebrates.

INTRODUCTION

The importance of aphids as key pests in various crops has increased during recent years, certainly favoured by a series of extremely mild winters. In winter wheat, sugar beat, potatoes and field beans large areas were regularly treated with insecticides. Particularly in winter cereals, multiple treatments will increase in autumn, early spring and summer to prevent either transmission of BVDV or direct damage by the insect pest - a very critical situation not only from an ecological point of view. Any approach to reduce the frequency and intensity of spraying against aphids is desirable.

For example in winter wheat, which is the best investigated crop, treatments are often applied without any clear relation to aphid population levels. For the autumn and spring treatments to prevent virus transmission, no thresholds based on long term scientific investigations are available today or in the near future for the specific circumstances in Germany. Therefore prophylactic applications will persist for some years. However, concerning the summer treatments, a more sophisticated control may be possible to prevent direct damage by aphids between ear emergence and the milky ripe stage. But extremely low and fixed thresholds (1 aphid/ear and flag leaf - Basedow et al., 1989) are used today in Germany, which were developed under the philosophy "to eliminate aphids as far as possible and as long as possible and to avoid any risk for farmers". Such thresholds pay no attention to the very different population patterns in different years, as other forecasting systems do (Entwistle & Dixon, 1987; Mann et al., 1987; Reinink, 1986). As a result spraying is often done too early and with high (i.e. the recommended) dose rates (Poehling, 1988).

On the other hand the public demand for more ecologically orientated plant protection will increase in the FRG. These questions will more and more develop a political dimension. Therefore the urge to reduce the intensity of protection and to incorporate more ecological aspects in control strategies will strengthen. Scientists as well as farmers have to consider these trends (Schönbeck, 1989).

In the case of aphid control in general the use of selective pesticides may be a convenient tool to improve ecological safety. With pirimicarb an interesting ingredient is available (Helgesen & Tauber, 1974; Poehling, 1989) and fenvalerate has proved to be less toxic to some non-target invertebrates (De Clercq, R. & Casteels, 1988; Poehling, 1989). The fact that in the FRG besides these ingredients parathion is still licensed for control of aphids in cereals reflects the current conflict of economy and ecology.

Concerning the importance of saving non-target organisms, even the use of selective pesticides is sometimes only partially satisfying for various reasons:

- they are normally more expensive than broad spectrum ingredients, and
- although a lot of harmless non-target invertebrates as well as polyphagous predators are saved by the use of selective chemicals, aphid specific antagonists are more often impaired on a long term basis by the elimination of their prey and hosts (Stern et al., 1959; Cavalloro, 1983; Metcalf, 1980; Poehling, 1989). Reducing the degree of efficiency towards the target may only decrease such secondary impairment.

Several authors (Bode, 1981; Metcalf, 1980; Hellpap and Schmutterer, 1982; Storck-Weyhermüller, 1987, 1989; Smith et al., 1985) have drawn attention to economic benefits as well as selectivity from reducing the "inflated" (Metcalf, 1980) dose rates normally used to achieve sufficient long term control of the pest. Combined with a more sophisticated timing of application this may be a relatively simple means of achieving a better economic return, improved preservation of non target-organisms and a lowered input of chemicals in the whole agroecosystem. This "philosophy" stimulated us in 1983 to undertake a series of laboratory and field trials with reduced rates of pirimicarb, fenvalerate and today also with other pyrethroids in order to control summer aphid infestations in cereals and field beans. Some selected representative results are presented and discussed here.

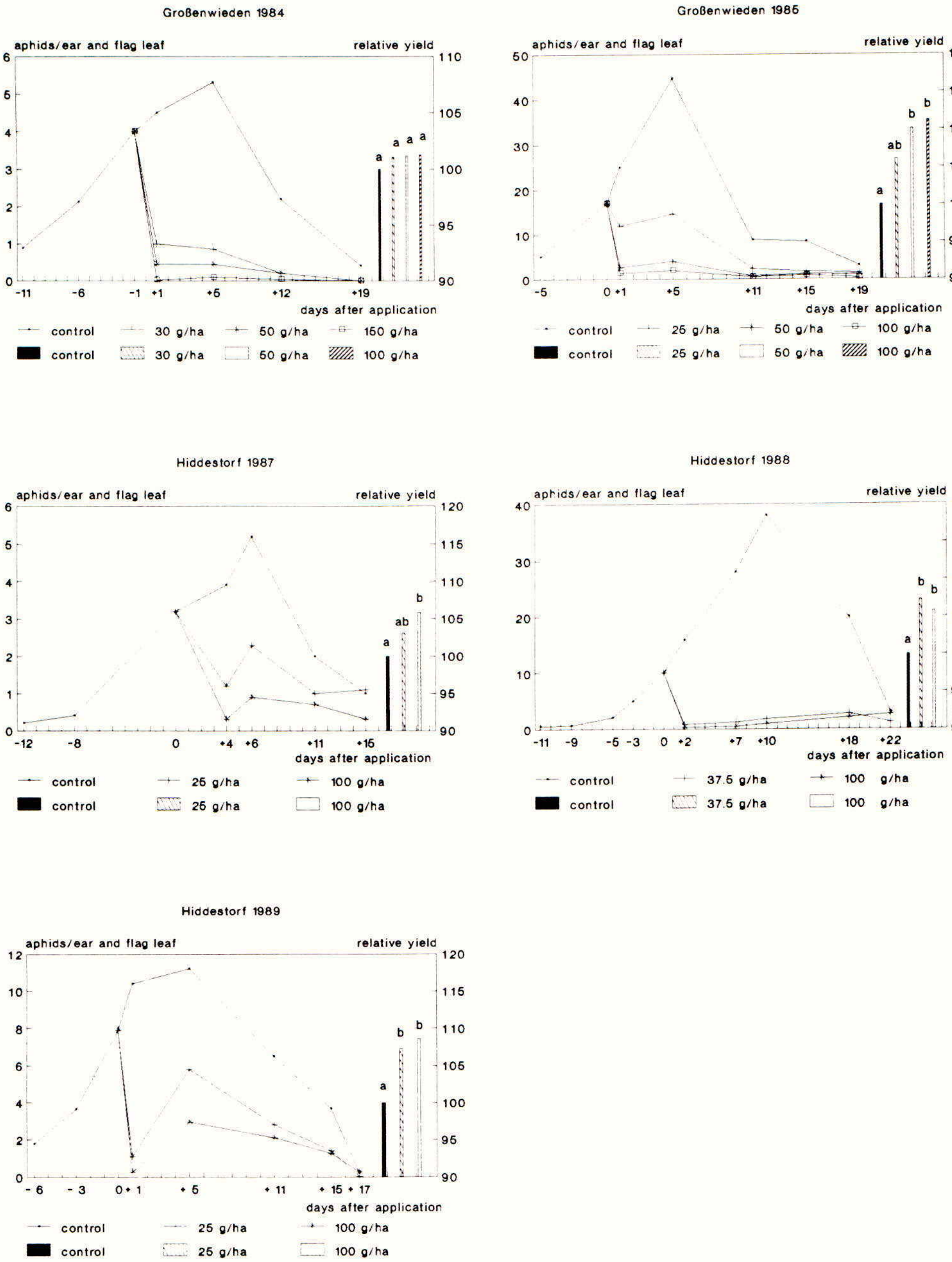

Figure 1 : Influence of different dose rates of pirimicarb on cereals aphids. Selected field trials between 1984 and 1989.

EXAMPLE 1: CONTROL OF CEREAL APHIDS IN WINTER WHEAT.

Effects on aphids and yield

The following presents a brief outline of a sequence of experiments between 1984 and 1989 considering only the effects of using reduced rates of pirimicarb. The influence of different dose rates of pirimicarb on cereal aphid populations and relative yields is shown in Fig 1. Spraying was always performed late, i.e. between the mid and end of flowering (EC 65-69), using a threshold of 3-5 aphids per ear and flag, which was exceeded every year. Due to bad wheather conditions aphid densities sometimes (for example in 1985) reached much higher numbers immediately before treatment. In most years, except in 1989 and 1985 the increase in aphid densities occurred relatively late, but peak densities differed to a large extent. The application of pirimicarb at recommended rates (i.e. 100 - 200 g/ha) always initially reduced aphid density very effectively. Dose rate reductions caused a generally lowered efficacy. However there were only very small differences between recommended and reduced rates in certain years. But in 1985 when aphid densities reached nearly 20 aphids per shoot before treatment the efficacy of the lowest rate of 25 g/ha was strongly reduced. Below a critical dose rate of 50 g/ha a close relationship between the numbers of surviving aphids and the aphid density before treatment could quite often be observed. Therefore it can be considered as a more general rule that the efficacy of reduced rates was high when treatments were applied at pest densities not greater than 8-10 aphids per plant and relative late (EC 65-69). Under these conditions it was less likely that the aphid populations would recover after spraying, especially if the period of aphid immigration had finished before treatment.

The figures for relative yields show that the degree of yield increase achieved by the insecticide treatments tended to depend on the aphid densities in the post-spray period, with greater benefits in years of heavy aphid pressure. A simple calculation of net profit for 4 years is shown in Table 1. In years with aphid population exhibiting a low rate of increase and exceeding critical densities (threshold) slightly and late (before EC 69) as in 1984 and 1986 (not shown here), dose rates as low a 25 g/ha gave the best economic returns. On the other hand in years with stronger aphid infestations as in 1985, full rates or only moderately lowered rates proved to be more profitable. But even in such years dose rates between 37.5 g and 100 g/ha could give sufficiently good results if the treatment was optimally timed as it was in 1988. The low aphid densities in 1987, accompanied by extraordinarily high yield increases due to spraying were an exception to this general trend.

Table 1

Profit gained by pirimicarb treatments in winter wheat with different dose rates, calculated at DM 35.- / dt wheat (treatment EC 69)

	dt/ha	profit* (DM/ha)	cost of treatment (DM/ha)		net profit (DM/ha)	
1984						
			A	B	A	A+B
30 g/ha	64.87	24.5	5.9 /+	30	18.9/	-11.4
50 g/ha	64.93	26.6	11.9 /+	30	14.7/	-15.3
150 g/ha	65.00	29.05	35.6 /+	30	- 6.8/	-36.8
control	64.17	-	-	-	-	-
1985						
25 g/ha	62.01	124.6	5.9 /+	30	118.6/	88.7
50 g/ha	64.35	206.5	11.9./+	30	194.6/	164.6
100 g/ha	65.00	229.3	23.7./+	30	205.5/	175.5
control	58.45	-	-	-	-	-
1987						
25 g/ha	77.92	82.2	5.9./+	30	76.3/	46.3
100 g/ha	80.00	155.1	23.7 /+	30	131.3/	101.3
control	75.57	-	-	-	-	-
1988						
37.5 g/ha	81.10	193.6	8.9 /+	30	184.7/	154.7
100 g/ha	80.00	153.7	23.7 /+	30	130.0/	100.0
control	75.61	-	-	-	-	-

A: cost of insecticides /ha (1989 prices); B: additional costs of treatment/ ha

* Yield was obtained from small selected harvested plots. This resulted in an overestimation of "real" yield. The calculations presented are corrected values using the yield obtained by combine harvesting larger areas treated with 300 g/ha pirimicarb as a reference.

Effects on natural enemies

In earlier studies in laboratory and semi-field tests, it was documented that increased differences in effects of insecticides between target and non-targed species could be generated by dose rate reductions. Dose rates could be selected which were still toxic to the pest but less harmfull to the beneficials (Poehling, 1989). Using pirimicarb the predatory larvae of syrphids were a good example of this.

An example of the effects of insecticides on specific predators is shown in Fig. 2. It became obvious that not only was the initial impact on coccinellid and syrphid larvae (which could be interpretated as a direct toxic effect) reduced in low dose rate plots, but also the long term abundance of these specific predators increased here in relation to the numbers of surviving aphids. Detrimental starvation effects could be avoided to a certain extent by the limited efficacy of the insecticide towards the pest. Therefore at least a part of the predator population could finish development in contrast to areas where aphids were completely elimated by the treatment.

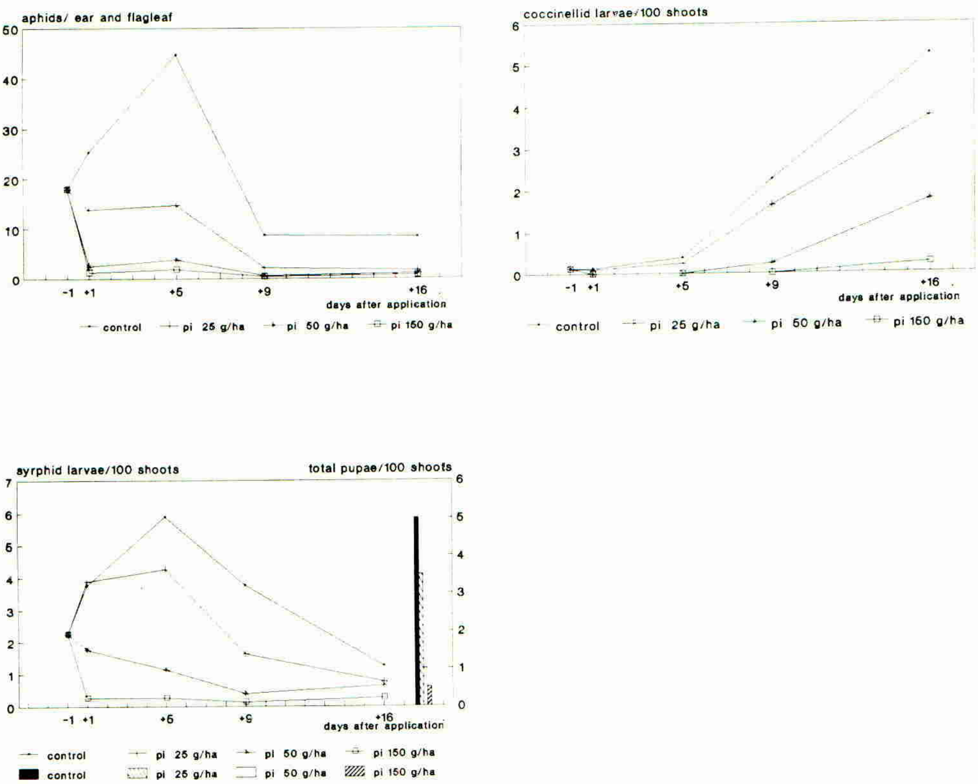

Figure 2 Effects of different dose rates of pirimicarb on cereal aphids and aphid specific predators in winter wheat (Großenwieden 1985)

The time of application seems to be quite important for the use of reduced rates, all succesful treatments in the northern parts of Germany were applied late, between EC 65 and 69/71. In 1987 and 1988 the effects of such an early treatment on aphids and syrphid larvae were investigated in the south of Germany (Stuttgart-Hohenheim), a typical non-outbreak area. Low rate applications with 25 g /ha pirimicarb resulted only in a short delay in aphid population growth followed by higher rates of increase compared to untreated control areas. One of the main reasons for this effect was a strong retardation of the establishment of syrphids in the treated areas. This can be interpreted as a result of the well-documented numerical response of syrphids to different aphid densities by means of egg-laying intensity and the survival rate of larvae (Chambers & Adams, 1986). The well balanced ratio between the pest and this key natural enemy was disturbed to the benefit of the pest. Similar experiments have to be repeated under the conditions of northern Germany, but the problematic nature of reduced dose rates is clearly demonstrated. In phases of rapid growth of the pest population, one can only achieve a long-term regulating effect if an efficient, well balanced predator-prey relation can be established.

EXAMPLE 2: CONTROL OF APHIS FABAE IN FIELD-BEANS

In 1989 a first attempt was made to control Aphis fabae in field beans with reduced rates of pirimicarb. The results are presented in Fig. 3.

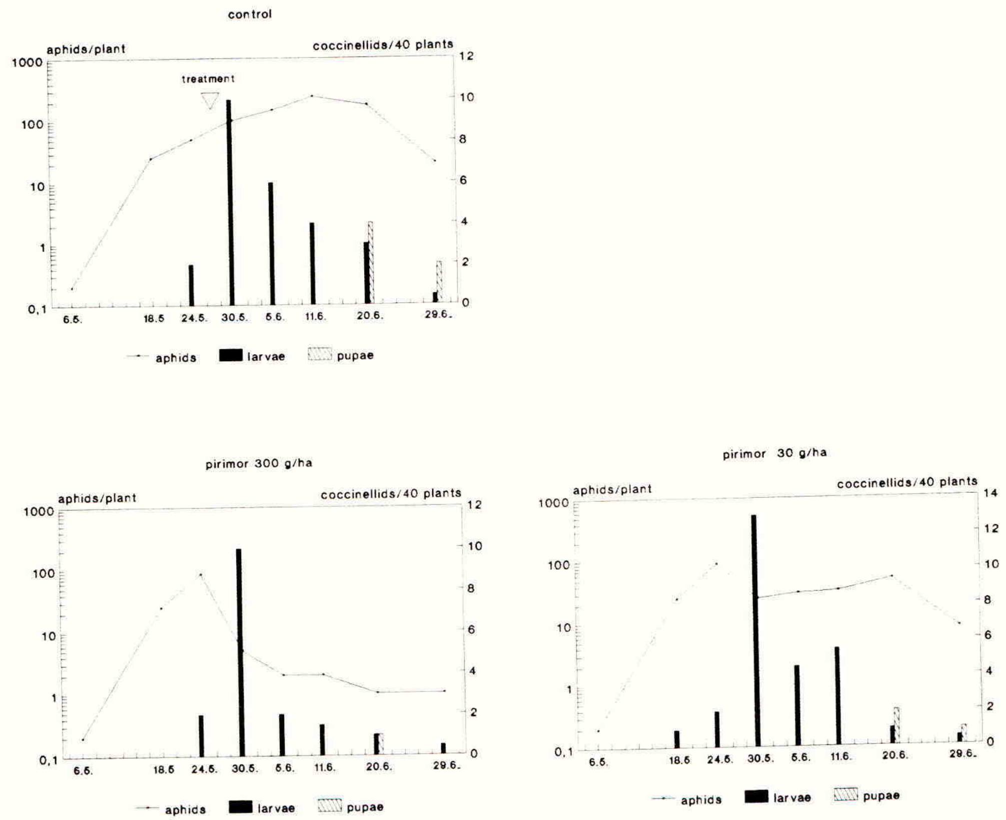

Figure 3 Effects of different dose rates of pirimicarb on Aphis fabae and coccinellid larvae in field beans (Hohenheim 1989).

Similar tendencies to those in cereals could be observed: relatively high efficiencies in aphid control with rates of 50 or even 15 g/ha and beneficial effects to specific predators. Treatments increased yield by about 16 % but there were no significant differences within treatments. Altogether the yield was extremely low due to the very hot weather conditions and the results shall be regarded as preliminary only. We will repeat these experiments in 1990.

CONCLUSIONS

In cereals, the experiments described here support the hypothesis that in seasons with moderate increases in aphid populations where the critical densities are reached late in the season (i.e. after the main immigration period) very efficient control could be achieved with reduced rates. In economic terms such treatments could often be more profitable than full-rate applications. Even in years with stronger aphid infestations, satisfying results could be obtained when the application was exactly timed. On the other hand this basic requirement is a major drawback of such a system as it is not easy for advisors and farmers to handle and bears a higher risk. The simple West German threshold system is not appropriate for the use of reduced rates for cereal aphid control. Only when the population development of cereal aphids can be predicted more precisely with the help of sophisticated forecasting systems can the use of reduced rates be incorporated in routine control of cereal aphids as well as for aphids in general. Furthermore detailed information is missing on the relationship between aphid population density and age structure and the degree of efficacy of different dose rates and ingredients.

Profitability depends on the costs of chemicals, the cost of application and, last but not least, on the price of the crop. Although there are no signs at the moment that chemical costs will rise considerably, it is more likely that the revenue from selling grain will decrease. Under these circumstances the differences in net profit between different treatments are further reduced. On the other hand the application costs of an additional treatment may be an important factor and may accelerate a tendency to use insecticides prophylactically since fungicides and insecticides can be sprayed together as a tank-mix. This tendency has undesirable ecological consequences. The use of well timed treatments with dosages as low as possible seems to offer a distinct increase in protection of non-target invertebrates. Reduced direct toxicity and decreased starvation effects especially favour aphid specific predators which can keep aphid populations in check if pest and antagonist densities are balanced. A well established balance between the pest and predators can only be achieved if, apart from direct toxic effects, the numerical responses of predators, including immigration, egg laying and survival, are not restricted by reducing aphid density too early in the season.

The "method" of reduced rates has been discussed here mainly using the examples of cereal aphids and to a far lesser extent bean aphids. However this approach of using moderate rates of insecticides could also contribute to the protection of beneficials and to the improvement of their efficiency in other crops. It could serve to enhance their contribution to integrated plant production systems. Additionally the input of more or less toxic, persistent or mobile (ground, air) chemicals in our environment can be reduced, a point which will certainly be of major importance in the near future.

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ENVIRONMENTAL MANIPULATION FOR THE ENCOURAGEMENT OF NATURAL ENEMIES OF PESTS

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ABSTRACT

The abundance and diversity of predatory insects within a field has been shown to be closely related the nature of the surrounding vegetation. Crop monocultures can reduce the densities of many indigenous biocontrol agents that are dependent on the presence and diversity of wild plants in the agricultural landscape.

Several attempts to diversify the agro-ecosystem using a variety of management practices have been carried out. In general, the results of these studies have shown that spatial heterogeneity in the agro-ecosystem can lead to increased community stability, and that predatory animals inhabiting newly created habitats have some ability to exert regulatory effects on their prey populations in the adjacent field areas.

Work at Southampton University has created grass-sown linear "island" habitats in the centres of three cereal fields. Within two years of establishment, high-density populations of polyphagous predators have been encouraged to overwinter in these new habitats. This has provided a nucleus population at the field centres from which dispersal into the crop can take place in the spring, the time when the predators' biocontrol potential is at its highest.

INTRODUCTION

The level of environmental heterogeneity within crops and in the surrounding uncultivated land will have impacts on the abundance and diversity of predatory insects within a field (Altieri & Letourneau, 1982). Some degree of plant diversity within the agro-ecosystem is fundamental to maintaining a biological component in pest control (van Emden, 1970).

The removal of hedgerows and other field boundaries associated with intensification in conventional arable systems is well documented. Furthermore the incidence of spraying herbicides to control weeds in hedgerows has increased (Boatman, 1989) reducing boundary quality as overwintering refuges for certain key species of polyphagous predators dependent on boundaries as overwintering sites (Sotherton, 1984, 1985). Subsequently, field sizes have increased and environmental diversity has decreased leading to higher incidences of pest attack (Speight, 1983). The net effect of these actions is the continuing degradation of the arable environment with a possibly associated reduction in the pest control efficiency of invertebrate predators. This has resulted in an increasing reliance on pesticides for pest control (e.g. Carter (1984) reported a doubling in the area of cereals treated with insecticide and molluscicide from 1977 to 1982, although many of these pesticides are not used rationally (Wratten et al., 1990)).

It appears therefore that the design of conventional agro-ecosystems emphasises the use of pesticides and limits the effectiveness of native natural enemies. Having identified this however, it may be possible to augment natural enemy efficiency within an integrated control programme by careful attention to complementary agricultural methods and thus raise the natural enemy:pest ratio.

Although increased intra-crop diversity such as intercropping or undersowing may cause decreases in pest numbers (Speight & Lawton, 1976; El Titi, 1987), there remains the possibility that management of adjacent non-crop habitats could make a significant contribution to pest control.

Von Klinger (1987) investigated the effects of margin-strips of Sinapsis alba L. and Phacelia tanacetifolia Benth. along a winter wheat field. Significantly higher numbers of species and individuals of different predatory groups were found in or near the margin-strips, compared with the wheat plot without margin-strip. In particular, polyphagous predators such as carabid beetles occurred in increased numbers in the margin-strips and adjacent parts of the wheat field.

Augmentation of beneficial arthropods by strip management was also studied by Nentwig (1988,1989). The effects of narrow unmown strips in a mixed grass meadow, and successional strips of vegetation in a field of winter wheat were analyzed in comparison with areas with conventional management. In combination with an increase in species number and diversity of beneficial arthropods, the degree of stability (defined as a relative constant abundance in successive years) increased in the strip managed areas.

Effects of increased spatial heterogeneity within the arable landscape were investigated by creating an experimental corridor system consisting of several small woodlots on intensively used agricultural land (Mader, 1988). The results suggested an increase in species richness and diversity in the new habitats compared with neighbouring fields, and there was an indication that predatory animals inhabiting the woodlots spread into the neighbouring fields and to some extent exerted regulatory effects on their prey populations. In general, this conclusion appears to be true for the other studies in habitat creation discussed above. Increased structural diversity within the agro-ecosystem tends to lead to community stability and enhanced biocontrol by indigenous natural enemies.

Current work at Southampton University has identified that inadequate overwintering habitat such as boundaries with grassy underbanks coupled with predators' limited powers of spring dispersal (Coombes & Sotherton 1986), can reduce the effectiveness of certain species of Carabidae (ground beetles) and Staphylinidae (rove beetles) as control agents of cereal aphids. The aim of this work (and the subject of this paper) therefore, is to attempt to redress the balance of hedgerow removal associated with farming intensification, by creating new habitats to provide improved overwintering conditions for polyphagous predators in arable land. Rather than just manipulate or create boundary habitats however, field size has been reduced by creating linear "island" habitats representing what are effectively facsimiles of boundary underbanks, at the field centres. Although three "island" habitats were created, data are presented here for only one.

MATERIALS AND METHODS

Creation of within-field habitats

The new within-field refuge took the form of a raised earth bank (0.4m high, 1.5m wide, 300m long) that crossed the centre of one cereal field (c.7 ha). The bank did not extend completely to link up with the existing field margins.

Six-meter long sections of the new bank were sown (spring, 1987) with various grass species in a linearly randomised block design with six blocks per bank and seven treatments per block. The treatments sown were (1) Dactylis glomerata L., (2) Lolium perenne L., (3) Agrostis stolonifera L., (4) Holcus lanatus L., (5) mixture of three species (A. stolonifera absent), (6) mixture of four species, and (7) bare ground control. Each replicate was 6m in length.

Assessment of predator community composition

During the winter of 1987/88, surface-searching for predators was carried out on the ridge and in the surrounding field. Six 0.1 m^2 quadrats were used per replicate per treatment on the ridge. Four blocks from the ridge were searched in this way. Twelve quadrats were randomly placed at least 40m away from the ridge or existing boundaries for each mid-field assessment, there being one open-field recording for each block searched i.e. a total of 48 mid-field quadrats. This method was repeated during the second winter (1988/89) but supplemented by destructive sampling. Turves of 0.04m^2 x 0.1m deep were removed, and their contents extracted by hand sorting. However, as the ridge was a finite structure and each plot was only 9 m^2 in area, only limited numbers of destructive samples could be taken. Two destructive samples were taken from each single-species replicate and from each bare earth replicate on the ridge i.e. twelve samples in total. Twenty open-field samples were taken.

Assessment of predator penetration of the crop in the spring

To assess whether the within-field ridge and its predator populations influenced spring penetration by predators, transects of vacuum-net samples progressing into the crop at 0m, 3m, 10m, 30m, and 60m from the bank were taken at weekly intervals from April to mid-May 1989. Samples at each distance in an individual transect comprised 15 contiguous samples of 10 seconds' duration each, parallel to the ridge. Samples were taken from five transects running at right angles to the ridge adjacent to the Dactylis glomerata treatments in five blocks.

RESULTS

Predator densities

Randomised block analysis of variance followed by Tukey's (1949) test revealed significantly different densities of total predators, carabids, staphylinids, and spiders between treatments in 1987/88. Surface-search data from the second winter showed a similar pattern with, however, increased predator densities in all sown plots compared with bare ground and the open-field (Table 1).

Destructive sampling revealed predator densities far in excess of those recorded by surface-searching, with D. glomerata and H. lanatus supporting significantly higher densities of all the predatory groups than did A. stolonifera and L. perenne (Table 2). However, plots of the latter two grasses nevertheless contained ten to twenty times the density of predators recorded in the open-field.

Predator emigration

Figures 1 and 2 show the results of the 1989 emigration study for the carabid beetle Demetrias atricapillus (L.) and the staphylinid beetle Tachyporus hypnorum (Fabricius), respectively. Asterisks beneath the figures denote significant differences at the 5% level between distances along transects for individual dates (one-way analysis of variance (√arcsin transformation of proportions of totals caught/date) followed by Tukey's test). Figure 1 shows significantly higher proportions of D. atricapillus immediately adjacent to the ridge up until 3/5/89, after which the proportions tended to become more evenly distributed with no significant differences between distances. Figure 2 shows two significant peaks of proportions (0m and 60m) of T. hypnorum until 18/4/89. Although no consistent spatial patterns occurred following this, significantly lower proportions of T. hypnorum were found on the ridge than in the crop by the end of the study.

Table 1. Mean densities of groups of polyphagous predators sampled by surface-searching, winter 1987/88 (year 1) and 1988/89 (year 2). Treatments within a year with the same letter do not differ significantly at the 5% level (randomised block analysis of variance followed by Tukey's test).

Treatment	Year	Carabids m^{-2}		Staphs. m^{-2}		Spiders m^{-2}		Total m^{-2}	
A. stolonifera	1	59.4	(a)	5.0	(ab)	11.3	(bc)	74.7	(ab)
D. glomerata	1	50.5	(a)	3.3	(b)	27.4	(ab)	88.4	(ab)
H. lanatus	1	37.8	(ab)	8.2	(ab)	51.1	(a)	94.4	(ab)
L. perenne	1	44.7	(a)	17.1	(a)	54.1	(a)	114.7	(a)
3 species	1	57.2	(a)	5.0	(ab)	24.4	(ab)	87.2	(ab)
4 species	1	58.9	(a)	13.5	(ab)	30.0	(ab)	100.0	(ab)
Bare ground	1	35.9	(b)	2.4	(b)	11.6	(bc)	45.6	(bc)
Field	1	21.4		3.8		8.3		35.2	
A. stolonifera	2	53.4	(a)	10.1	(a)	46.3	(a)	109.8	(a)
D. glomerata	2	70.5	(a)	13.1	(a)	43.3	(a)	126.9	(a)
H. lanatus	2	54.6	(a)	23.3	(a)	47.4	(a)	125.3	(a)
L. perenne	2	43.3	(a)	14.1	(a)	72.6	(a)	130.0	(a)
3 species	2	79.8	(a)	14.1	(a)	67.3	(a)	161.2	(a)
4 species	2	41.3	(a)	7.1	(a)	51.2	(a)	99.6	(a)
Bare ground	2	7.1	(b)	10.0	(a)	10.0	(b)	27.1	(b)
Field	2	11.0		0.0		10.1		21.1	

Table 2. Mean densities of groups of polyphagous predators sampled by destructive sampling, winter 1988/89. Treatments with the same letter do not differ significantly at the 5% level (randomised block analysis of variance followed by Tukey's test).

Treatment	Carabids m^{-2}		Staphs. m^{-2}		Spiders m^{-2}		Total m^{-2}	
A. stolonifera	157.5	(b)	160.3	(ab)	170.0	(bc)	487.8	(b)
D. glomerata	1112.5	(a)	152.5	(b)	222.5	(ab)	1487.5	(a)
H. lanatus	765.0	(a)	272.4	(a)	360.3	(a)	1397.7	(a)
L. perenne	107.4	(b)	50.6	(b)	117.7	(c)	275.7	(b)
Field	10.0		2.5		10.0		22.5	

DISCUSSION

The overwintering predator densities achieved during the first year of ridge establishment were comparable to those found in typical hedges in Hampshire (Sotherton 1985). There were no consistent significant differences between grass treatments.

Surface searching during the second winter, although indicating slight increases in predator densities in some treatments, still failed to identify any distinct differences between treatments. This was at a time when percentage cover for some grass species was as high as 90%, and areas of dense tussocky vegetation were well established. It was considered therefore that a reduction in sampling efficiency associated with this greater maturity was responsible for masking differences between grass species. This was verified by the destructive sampling, where D. glomerata and H. lanatus produced very high predator densities and appeared to provide the most suitable overwintering habitats for all of the predatory groups. Destructive sampling also showed that predator densities in certain treatments exceeded those recorded in the most favourable existing boundaries. Densities of $1000m^{-2}$ were considered to be very high by Sotherton (1985), yet in only the second year of this study, densities within D.

glomerata reached over 1500 m^{-2}.

The results of the spring study suggested that the ridge provided a nucleus predator population at the field centre from which emigration could take place. This was particularly apparent for Demetrias atricapillus, which following a period of close association with the ridge habitat appeared to penetrate the field resulting in a uniform dispersion through the crop. A similar pattern was observed for Tachyporus hypnorum, although as this species has a more rapid dispersal than D. atricapillus (Coombes & Sotherton, 1986) the influence of the natural hedgerow population as well as the ridge population could be seen. That is, the observed dispersion pattern was achieved via emigration from both ridge and hedgerow sources resulting in higher numbers away from, rather than adjacent to, the ridge habitat.

The system described here is not a working management strategy. As a "goal-orientated" project however, this study has gone some way towards showing the possibility of beneficially manipulating the arable environment in an ecologically short period. Beyond this, studies which have just begun aim to add pollen and nectar sources to the ridges and in strips around other arable fields, in an attempt to enhance numbers of aphid specific predators such as certain species of Syrphidae (hoverflies), Coccinellidae (ladybirds) and parasitoid wasps.

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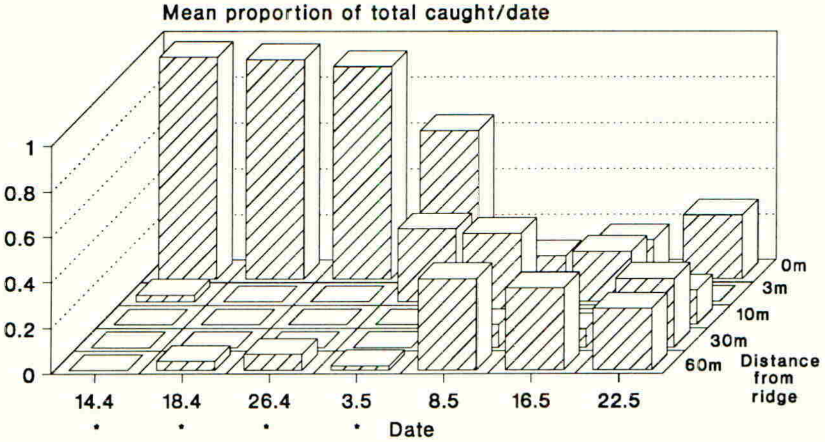
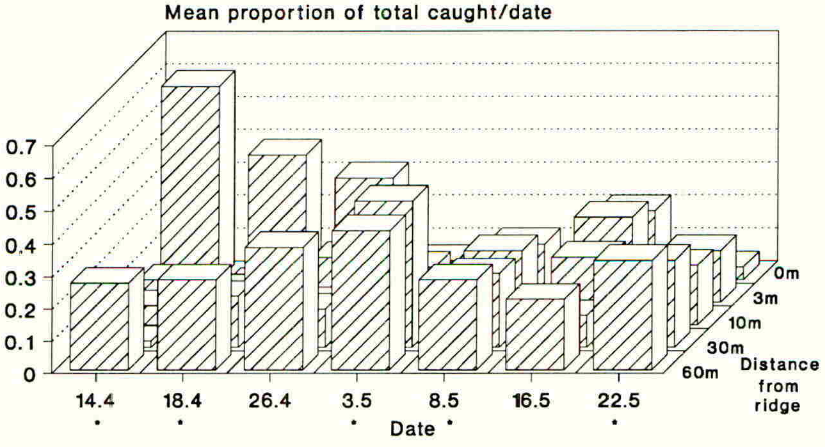
Figure 1.
Emigration of *Demetrias atricapillus*,
spring 1989



* Denotes significant between-distance differences at the 5% level.

Figure 2.
Emigration of *Tachyporus hypnorum*,
spring 1989.



* Denotes significant between-distance differences at the 5% level.