CSG 15

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

Research and Development

Final Project Report

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Project title	Review on the possible interactions of pests, diseases and weeds in cereals grown in organic and conventional agriculture.
MAFF project code	**OF0194**
Contractor organisation and location	Central Science Laboratory Sand Hutton York, YO41 1LZ
Total MAFF project costs	£ 24,729
Project start date	01/03/01
Project end date	31/05/01

Executive summary (maximum 2 sides A4)

Background

The demand for organically produced food is outstripping the ability of UK farmers to supply it and the majority is imported. Furthermore, there is a major shortfall in home-produced organic cereals and cereal products, including straw. In response to this need, the consequences of increasing the area of organically produced cereal crops on pests, diseases and weeds require evaluation. Furthermore, as the area of organic cereals increases, crops may be grown more in the major cereal production regions. This could have consequences for both the organic producer and farmers growing cereals conventionally.

Objectives

(i) review the current state of knowledge on the status and distribution of pests, diseases and weeds in organic and conventionally grown cereals,

(ii) assess the likely rate of expansion of organic cereal production and the areas where this is most likely to occur, together with any likely or consequent change in the distribution of conventionally grown cereals,

(iii) assess the distribution of specific cereal cultivars and species in organic and non-organic production in relation to their impact on disease, pest and weed distribution. A specific sub-objective will be to assess the likely impact of the increased use of organically produced seed on seed-borne diseases,

(iv) try to forecast whether or not the changes in cereal production will affect the current status and distribution of pests, diseases and weeds, and, if so, in which major directions,

(v) make recommendations for future research, both to ensure that the forecast under paragraph (iii) is correct and that any negative trends are highlighted and, if possible, dealt with.

Methods
A literature review was undertaken to identify potential risks to conventional and organic production cereals on an extension of the organic area on risks of pests, diseases and weeds.

Pests
Organic production may lead to an increase in some pest populations though pest dispersal is often limited in extent. Nevertheless, in some cases, such increases could create a greater risk of pest attack on neighbouring conventional farms. However, expansion of organic farming practices and the occurrence of pests in organic systems could also enhance the prevalence of natural enemies, the migration and activity of which could counteract negative effects of pest outbreaks, and help encourage the practice of Integrated Crop Management (ICM) on conventional farms.

Diseases
The major diseases of cereals are powdery mildew, septoria leaf blotch and glume blotch, yellow and brown rusts, eyespot, sharp eyespot, take-all and BYDV.
For the foreseeable future the balance of pest disease and weed interactions between non-organic and organic cereal crops will be to favour non-organic at the expense of organic crops. The major reason for this imbalance is that the expansion of organic cereals will take some considerable time to reach a level at which it can be regarded as a significant proportion of the total cereal crop. In addition, however, there are important differences in the production systems that make non-organic cereals more prone to infection and epidemic increase. These include, for non-organic cereal systems, a greater degree of monoculture (shorter rotations), higher levels of excess soil nitrogen, earlier autumn sowing dates, and greater reliance upon disease susceptible cultivars.

Weeds
Long periods of organic farming lead to the build up of specific weeds and the demise of others and weed levels in organic fields are high enough to contribute significantly to economic yield losses in organic crops. The major problems appear to be perennial weeds such as thistles, couch and docks. Problems arise from weeds already in the field, and those imported, such as in seed.
There should be little weed transfer between organic and non-organic agriculture. Most risk is from wind dispersed seeds, such as thistles, ragwort and docks. The risk to non-organic agriculture is unlikely to be much different from that which already exists from low input grazing or uncultivated land, such as roadsides or railway embankments and land awaiting development, particularly since the area involved is likely to be relatively small for some considerable time.

Seed production
From January 2004, all organic crops must come from certified organic seed, defined as deriving from a minimum of one generation of production under organic conditions. However, it is likely that, for some years to come, the seed that initiates the organic production chain will come from non-organic sources.
Development of seed-borne diseases as problems in organic production may be constrained by various factors. In the first place, the current small scale of production largely from clean seed originating from non-organic production helps to minimise the possibility of any initial build-up of the diseases. However, over the next few years, it is expected that the scale of production will increase and that non-organic origins for seed production will diminish. These developments may increase the potential for seed-borne disease. Against this are the effects of the organic production system itself, with, in particular, concentration on the importance of rotations and on diversity among cereal species and cultivars.

Economic impact

The benefits of this review will be to inform the industry of current thinking in an important area of economic expansion for farming and to identify potential risks. The review also provides information on areas for appropriate research to allow resource to be targeted most effectively.

Future work

Monitoring of the more important pests and diseases in organic production would be prudent. Any problems for non-organic cereal producers are unlikely to arise for several years because of the small scale and slow increase of organic cereal production, but this should be regarded as a ‘grace’ period to allow for development of appropriate solutions before any potential problems become important in practice.

Problems for organic producers may emerge more quickly; these need to be monitored so that cultivar and other recommendations can be developed. It is likely that the best spectrum of cultivars for non-organic and organic production will differ, which would help in restricting disease interactions between the two production systems. Any constraints on production of seed for organic cereal growing should be removed so far as possible.

Development of the system of bi-cropping, both for organic and non-organic production, should be continued since there are good indications that this can restrict problems due to slugs, aphids and BYDV, septoria leaf and glume blotch, and probably take all.

The importance of using disease resistant cultivars needs to be still further stressed for both organic and non-organic production. The influence of sowing date on disease development, particularly in the autumn, needs more attention. Renewed efforts to develop and introduce production of cultivar mixtures, particularly for organic cereal production, would help to restrict disease development.

Fundamental studies on the biology of the major perennial weeds are still needed. Although seed spread can be minimised by frequent cutting, the effects of this on the spread of roots and rhizomes is poorly understood.

It is important to maintain a regular watch or survey for indications of any increase in the key seed-borne diseases that may occur in organic cereal production and to determine the reasons for any such increase.

Technology transfer

The report will be suitable for wider dissemination among researchers and the agriculture industry. All contributing organisations have means by which this information can be made available through press briefings, Web-sites and at farming events.

Scientific report (maximum 20 sides A4)

1.0 INTRODUCTION

The demand for organically produced food is outstripping the ability of UK farmers to supply it and the majority is imported. Furthermore, there is a major shortfall in home-produced organic cereals and cereal products, including straw. In response to this need, the consequences of increasing the area of organically produced cereal crops on pests, diseases and weeds require evaluation. Furthermore, as the area of organic cereals increases, crops may be grown more in the major cereal production regions. This could have consequences for both the organic producer and farmers growing cereals conventionally.

The degree to which organic cereal crops may impact on non-organic and vice versa depends on the rate of expansion of organic cereals (predicted to be slow), and the effect of organic production systems on the generation of pests, diseases and weeds. This report attempts to summarise our expectations based on limited information and specialised experience. Because of the novelty of the situation and the continuing evolution of both sectors, we have found it impossible to produce accurate forecasts or to be certain of the most outstanding problems. It is clear that some form of continuous monitoring, particularly of diseases, is necessary so that potential problem areas can be signalled and dealt with.

Currently, weeds are considered to be a major constraint to profitable organic cereal production while diseases and pests are of relatively minor concern. However, dispersal of weeds from organic to non-organic fields is unlikely to be of significance. Our view is that, potentially, the most likely area for concern in terms of interaction between organic and non-organic crops is that of seed-borne disease, particularly as the organic sector moves towards complete integration of seed production.

The demands on the farming industry for pesticide free produce by the wholesale markets and consumers of food are increasing (Taylor *et al*., 2001). This includes cereals and their products. The demand for organically produced food is outstripping the ability of UK farmers to supply it and the majority is imported. Furthermore, there is a major shortfall in home-produced organic cereals and cereal products, including straw. A Private Member’s Bill, ‘Organic Food and Farming Targets Bill’ was presented to the House of Commons on 15 December 1999, which called for 30% of Britain's farmland to convert to organic management by 2010. This had the support of Sustain, Friends of the Earth, Henry Doubleday Research Association, Pesticides Trust, UNISON, Transport and General Workers Union, Elm Farm Research Centre and the Soil Association. The House of Commons Select Committee on Agriculture produced a report on 17 January 2001 on organic farming, which recorded that there is a huge opportunity and market for expansion of the organic sector. In their conclusions, members of the committee stressed the need to treat the organic and conventional production systems as part of the same spectrum. It is clear that there is both political and economic pressure for an expansion of the area of organically grown crops.

1.1 Risks to crops

The consequences of increasing the area of organically produced crops and thus of the rotational proportion of cereals on pests, diseases and weeds require evaluation. Currently, pests and diseases are not considered to be a major constraint to profitable organic cereal production. Taylor *et al*. (2001) in survey of 32 growers of organic winter wheat reported that the major problem was perceived to be weeds (75%), with diseases and pests to be of relatively minor concern (19% and 9%, respectively). However, as the area of organic cereals increases crops may be grown more in the major cereal production regions. This will have significant consequences for both the organic producer and farmers growing cereals conventionally. The genetic make up of the crops and the different agronomic inputs to each is likely to produce a different pest (*sensu lato*) profile. As the area sown to organic crops expands and becomes contiguous, the pest profile will remain unchanged but the pressure will increase. As soon as the distance between the organic and conventional areas decrease there is likely to be an interaction at the interface. The organic producer will lose the buffering effect of either large tracts of land without the presence of a major concentration of cereals or of heavily sprayed crops suppressing invertebrates, diseases and weeds

(Figure 2.1). The DEFRA-funded cereal disease survey has reported that 99% of the winter wheat crop grown in England and Wales is sprayed with an average of 2.5 fungicide applications. Insecticides were applied to 62% of crops in 1999, the majority being in the autumn for control of the aphid vectors of barley yellow dwarf virus. Herbicides were applied to 98% of crops, with the majority (87%) being treated in the spring.

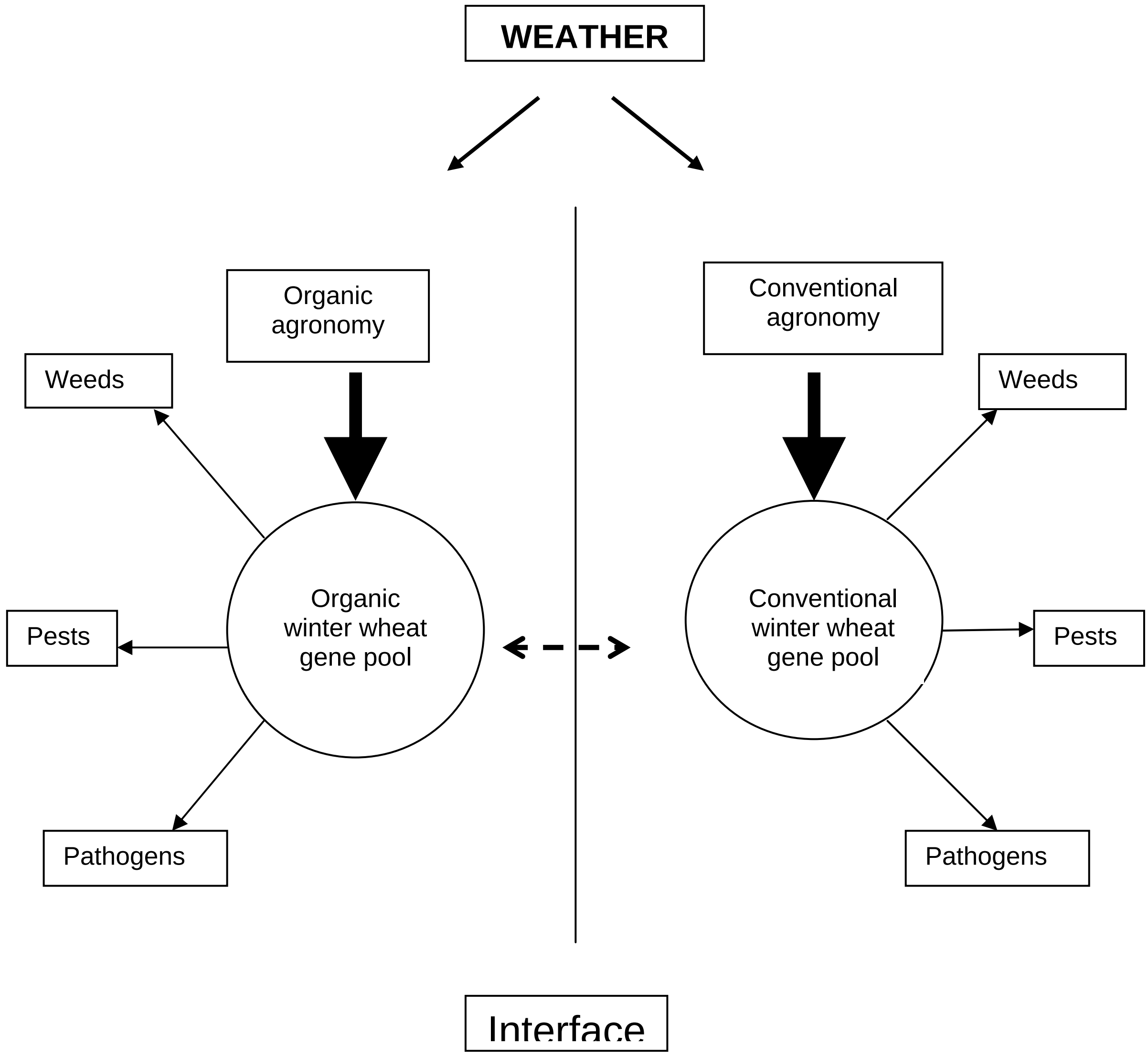

Figure 1.1 Diagram of the generation of distinct pest populations and possible interactions.

An increase in the area of cereals grown organically may thus increase the pest, disease and weed pressure for the organic producer but the conventional grower will have at hand increasingly large areas of untreated crops or crops with reduced protection. These may harbour a range of invertebrates, pathogens and weeds, which could have significant effects on pest pressure and subsequent treatment decisions. There are also implications for pesticide resistance and cultivar diversification.

1.2 Pesticides

Pesticide inputs into non-organic arable crops are increasing (Bradshaw *et al*., 2000; Hardwick *et al.*, 2000; Turner *et al*., 2000), partly because of the need to ensure high yields and partly because of the cultivars that are currently popular. The pesticides used clearly limit development of pests, diseases and weeds, although significant amounts of, for example, disease inoculum, are still being produced (Hardwick *et al.*, 2000). Pesticides are not used in organic production (Anonymous, 2000). Instead pests, diseases and weeds are kept in check, for example, by crop rotation, cultivations and the lack of surplus nitrate.

1.3 Pest problems

The most important and frequent pests of cereals are aphids acting as vectors of *Barley yellow dwarf virus* in the autumn or causing direct-feeding damage in the summer, slugs, leatherjackets and wheat bulb fly. There are many other pests of cereals including some which frequently cause severe localised damage, for example, frit fly, orange wheat blossom midge and the yellow cereal fly (Gratwick, 1992). Pest species such as wireworm, gout fly and swift moth can also cause concern, however, they tend to occur more sporadically.

Pest control in organic systems of crop production is based primarily on cultural and, to a lesser extent, biological methods of control. These methods must seek to prevent pest attacks by exploiting all aspects of crop agronomy, whilst not conflicting with the overall requirements of growing organic crops. Additionally, these techniques must take account of any possible effects or interactions on other pests, diseases and weeds, as well as wider environmental consequences, such as nutrient leaching. There are also potential benefits to be gained in the organic production of field crops from the integration of cultural control measures with management strategies to optimise the impact of natural enemies on pest populations.

1.4 Disease problems

Differences in crop physiology and in the disease resistance profiles of the cultivars concerned may mean that the relative importance of the various diseases differs between organic and conventional crops.

By choosing to grow cultivars with good disease resistance, the organic farmer should be able to keep disease problems within acceptable limits. However, the choice of suitable cultivars for organic systems is limited, as plant breeding has been largely directed at providing cultivars adapted to conventional farming (Bayles, 1997). Moreover, for the organic grower, disease resistance is only one consideration and choice of cultivars may be strongly influenced by other factors such as grain quality, ability to compete with weeds, availability of organically produced seed, etc. The result is that organic farmers may often grow cultivars with limited resistance even to the recognised important diseases. Levels of resistance within organic crops may well be inadequate as the area of organic cereals increases and crops are grown in increasing proximity to one another, with less protection from surrounding fungicide-treated crops. Furthermore, the increasing area of organic cereals may be an expanding source of inoculum of particular diseases for conventional crops.

Several major diseases of cereals, principally the powdery mildews and rusts, are highly race-specific i.e. they exist as a large number of distinct ‘races’, adapted to overcome the resistance of different cultivars (Anonymous, 2001). Cultivars with similar resistance genes are susceptible to the same races, whilst those with different genes are susceptible to different races. This relationship between cultivars and races governs the risk that a disease will spread from one cultivar to another (Finckh & Wolfe, 1998; Bayles *et al.*, 1997). The extent to which organic and conventional farmers use cultivars with the same or different genetic resistances is likely to influence the risk of disease spreading between organic and conventional crops. There is a possibility that increasingly large areas of unprotected cereal crops may hasten the emergence of new races capable of overcoming the resistance of cultivars that are popular with organic growers, with implications for conventional farmers wishing to grow the same, or related, cultivars. Equally, the widespread growing of highly susceptible cultivars in conventional systems, on the assumption that fungicides will provide the necessary disease control, becomes a threat to organic growers in circumstances where fungicides prove less effective than expected (Hardwick *et al.*, 2000). The risk to organic crops will be greatest if the same, or related cultivars, are involved and least if the cultivars are genetically diverse. Changes in pathogen races are currently monitored by the UK Cereal Pathogen Virulence Survey (Bayles *et al*., 1997; Clarkson, 2000), which also identifies the specific resistances present in current cultivars and assesses the risk of pathogens spreading between different groups of cultivars. Recent indications from work on risks to crops from volunteers in set-aside fields produced no firm evidence that suggested these acted as major sources of disease for adjacent crops (Yarham & Symonds, 1992). However, potential interactions were not evaluated.

It is probable that, for the foreseeable future, much of the untreated C1 seed which initiates the organic production chain will itself have been produced conventionally. The production of 'organic cultivars' selected from organic breeding nurseries, and organic production of seed from breeders' seed to pre-basic, basic, C1 and C2, is some years away. Sowing conventionally produced C1 on organic land requires acceptance on the part of organic certifying authorities that this step can take place (since the C1 is not itself organically produced), probably on designated parts of the farm which are set aside for seed production rotations. Some growers may opt to produce their own 'C2' seed by farm-saving from C1, rather than purchasing C2 from merchants. While this practice may present problems for the commercial production of organic seed, the underlying consequence of two untreated generations of seed before ware production remains the same.

From January 2004, derogation on the use for organic production, of cereal seed produced non-organically will no longer be allowed (EU Regulation 2092/91). Production and distribution of organic seed, without the use of non-organic fungicides could raise problems in relation to seed-borne diseases, which will also need to be assessed (Thomas, 2000). Diseases such as bunt, smut, and leaf stripe, which increase rapidly with successive generations of seed (Paveley *et al*., 1996), could reach significant levels in organic seed, since at least two untreated generations will be sown (Nielsen *et al*., 2000). There is a risk that the supply of organic seed to growers may be limited by disease, and that the use of seed with low levels of infection will increase the background level of inoculum. This has significant implications for non-organic producers who are seeking opportunities to minimise seed treatment costs by a combination of seed health tests and improved targeting of treatments. The release of spores from smutted and bunted crops into a mixed organic/non-organic area may reduce these opportunities. Since seed-borne diseases have traditionally been controlled by virtually universal application of seed treatments, there has been little conscious breeding for resistance, and current material may be mostly susceptible. There are a number of other seed-borne diseases, usually regarded as minor (e.g. seedling blight and loose smut on oats and stripe smut on rye) but which may increase as untreated seed production increases. Ergot in seed crops can be relatively easily controlled by cleaning, and certification standards are in place. However, ergot in organic ware crops may become a problem if grass weed control is poor and return of ergots to the soil at harvest could in turn increase the risk of infection in neighbouring crops.

Other seed-borne diseases which do not show a generational increase but which are more dependent on within season conditions (e.g. *Stagonospora nodorum*, *Microdochium nivale*, *Pyrenophora teres*) may become more prevalent in organic seed because of the lack of growing season controls. There is a risk that any increase of pathogens on seeds could contribute to a greater inoculum potential to threaten neighbouring crops as well as the organic crop. This is probably particularly relevant for *S. nodorum* and *P. teres*. Increased infection of seed with *M. nivale* could pose a serious threat to germination and establishment (Cockerell, 1995).

1.5 Weed problems

Weed problems are largely a feature of the crop rotation, which is in turn influenced by soil type. Weeds remain predominantly within one field but they may move between fields by several mechanisms. Seedbank is a good measure of the potential annual or biennial weed species, but perennial weeds will be affected by the amount of root or rhizome material present. The size and spatial distribution of the seedbank and incidence of perennial roots will be determined by the subsequent management of the field (crop rotation, cultivations, sowing dates, within crop weed control, mowing). However, there is also scope for the seed burden to be added to by external seed. Weeds usually represent the most difficult problem in these systems (Yarham & Turner, 1992).

1.6 Organic versus conventional cropping

So far, the two systems, non-organic and organic, have been considered separately in terms of their outputs of invertebrates, pathogens and weeds. This is largely because, up to now, the organic sector has been relatively small and concentrated in the west and south where mixed farms are more common under both systems. However, as the area of organic production expands (Lampkin, 1990; Lampkin & Measures, 2001), organic cereal crops are likely to be produced increasingly in areas that are considered currently as intensive non-organic cereal areas. If this does happen, then there is likely to be a greater interaction between the two types of cropping which could have consequences for each in terms of pests, diseases and weeds. So far, this has not been considered or assessed. We believe that to try to anticipate or forestall any problems that might develop, it would be prudent to try to forecast the likely cropping changes, and the probable effects that these might have if allowed to develop.

1.7 Conclusions

Because cereal diseases are spread largely by air-borne spores, there are understandable concerns from non-organic producers, that disease problems could worsen generally if organic cereal crops, not treated with pesticides, become more widespread in the major cereal-growing areas. However, the likely outcomes of an increase in organic cereal production are by no means clear because of the many differences between the two systems including, for example, differences in rotation, fertilisation, cultivations, sowing dates, range of cultivars and species used. We believe that a review of the developments and differences will help to establish the range of key factors that might affect pest, disease and weed development as crop areas change. From this, it should be possible to rationalise the range of observations that might be needed to confirm the effects of the changes that do occur. With this background it should then be possible to develop recommendations both to encourage positive aspects of any interactions that occur and to discourage any negative aspects.

Systems and expertise are already available that would help in identification of major problems and their distribution in terms of diseases, pests and weeds. Particularly for diseases, assessment of relative epidemic development under different regimes, and broad scale and stratified surveys should also be feasible in the longer term (Yarham & Turner, 1992; Hardwick, 1998). Cereal species and cultivar trials are well-established under non-organic conditions and have now been started under organic regimes to allow relevant comparisons for pest, disease and weed control (Wolfe, 2000). Cereal seed production for organic cropping is also under development and will therefore be available for evaluation.

1.8 Objectives

The objectives of this review are to:

(i) review the current state of knowledge on the status and distribution of pests, diseases and weeds in organic and conventionally grown cereals,

(ii) assess the likely rate of expansion of organic cereal production and the areas where this is most likely to occur, together with any likely or consequent change in the distribution of conventionally grown cereals,

(iii) assess the distribution of specific cereal cultivars and species in organic and non-organic production in relation to their impact on disease, pest and weed distribution. A specific sub-objective will be to assess the likely impact of the increased use of organically produced seed on seed-borne diseases,

(iv) try to forecast whether or not the changes in cereal production will affect the current status and distribution of pests, diseases and weeds, and, if so, in which major directions

(v) make recommendations for future research, both to ensure that the forecast under paragraph (iii) is correct and that any negative trends are highlighted and, if possible, dealt with.

2.0 GROWTH IN ORGANIC CROPS AND PEST, DISEASE AND WEED INTERACTIONS

2.1 Future expansion of the organic crop

The growth of organic farming as measured by the numbers of farms and area has accelerated over the last three years. The growth in the number of registered organic producers increased by 28.5% in 1997/98, 47% in 1998/99 and 83% in 1999/00. The growth in land area increased by 140% in 1998/99 and by 73% in 1999/00. The growth in organic arable area in 1999/00 was 12%.

While the actual growth rate may stabilise there will, in all likelihood, continue to be significant growth in the area of land under organic management. However, the majority of this land (approximately 70%) is classed as ‘rough grazing’, i.e. not cereal producing land.

The proportion of land farmed organically that is classed as arable land has slipped from 18% of the total in 1997/98 to 16% in 1998/99 and down to 10% in 1999/2000. Thus while arable land converting to organic has grown it has been at a much lower rate than livestock farming and most notably ‘hill’ enterprises. The 10% in 1999/2000 figure represents approximately 41,600 hectares of land. Three quarters of this area is land in-conversion to full organic status, with one quarter being fully certified organic.

There is no indication to suggest that this trend will alter in the short to medium term. If the proportion of organic land that is arable is to rise it will take a dramatic increase in the area of arable land converting. The increase of arable as a proportion of total organic land appears unlikely given current trends and market conditions and the limiting factors identified below.

The major proportion of organic arable production is wheat, which accounts for around 40% of arable land area with half of the wheat being sold into human consumption markets. While the proportion of the total which is wheat has declined slightly in the last few years (46% in 1997 to 40% in 1999) it will continue to be the major organic cereal crop for the foreseeable future as demand for it remains strong and the infrastructure of the industry is biased in favour of it. Oats and barley are the second and third most popular crops, respectively, with the latter showing good market growth in recent seasons.

The arable sector is likely to continue to lag behind total organic growth and the gap between UK demand and supply will widen for the foreseeable future. Growth of organic arable land area is likely to be between 10% (pessimistic) and 30% (optimistic). The prime limiting factors are AAP; market versus production performance; lack of research; farmer understanding and of knowledge. The growth in area down to organic production will be predominantly in the Eastern Region with growth likely to be mainly through specialist arable farms.

2.2 Trends in agronomic practices

Crop agronomy differs from typical non-organic practice in several ways that will influence the incidence and severity of pests, diseases and weeds, and hence their possible impact on neighbouring non-organic farms. Under development are companion cropping systems that bring new sets of challenges.

The type of crop rotation, the position of the cereals in the rotation, the species grown and the proportion of the rotation in cereals will all influence pest, disease and weed challenges. Current arable organic rotations are dominated by cereals, grain legumes, potatoes and some vegetables. As organic markets for new crops develop, crops such a sugar beet and oilseeds will be grown more widely. These bring new challenges, particularly in the control of volunteer crops as weeds and disease sources, for instance potatoes in sugar beet and cereals, and oilseed rape in several crops. Sowing date , row width and seed rate will influence the incidence of pests, diseases and weeds through manipulation of the canopy structure. The reduced methods of cultivation are generally not employed on organic farms because of the benefits of ploughing in burying trash and weed seeds.

2.3 Seed production

The principles of organic production have always included all aspects of the crop production chain, including seed. However, due to the difficulties of producing organic seed, both commercial and technical, growers have been able to purchase untreated conventionally produced seed for organic crop production, and save further seed generations from this for their own use if they wished. However, the EU derogation covering this terminates in December 2003, and from January 2004 all seed for organic ware production must itself be grown organically for at least one generation. For major cereal crops, i.e. wheat (including triticale), barley and oats, seed of the first certified generation (C1) must therefore be sown in approved organic land to produce second generation seed (C2) which is normally sold for ware production. For rye, the first generation will be basic seed, and the second is certified seed. Further generations of seed may be saved from C2 according to individual grower preference, and subject to the same rules governing royalty payments on farm-saved seed which apply to conventional growers. C1, C2 and any further generations cannot be treated with any of the standard chemicals used prophylactically on nearly all conventional seed, though organically approved products could be used.

It is probable that, for the next 10 to 15 years, nearly all the untreated C1 seed which initiates the organic production chain will itself have been produced conventionally. The production of ‘organic cultivars’ selected from organic breeding nurseries, and with organic production of seed from breeders’ seed to pre-basic, basic, C1 and C2, is some years away. Sowing conventionally produced C1 on organic land requires acceptance on the part of organic approval authorities that this step can take place (since the C1 is not itself organically produced), probably on designated parts of the farm which are set aside for seed production rotations. Some growers may opt to produce their own ‘C2’ seed by farm-saving from C1, rather than purchasing C2 from merchants. While this practice may present problems for the commercial production of organic seed, the underlying consequence of two untreated generations of seed before ware production remains the same.

Nationally, about 26% of wheat crops are sown from farm–saved seed and only 2.8% of crops are sown with untreated seed.

Conventional cereal seed has been protected against seed-borne disease by the routine application of highly effective chemical treatments which cannot be used on organic seed. The use of a single generation of untreated seed in conventional production is becoming more common as a means of reducing seed costs and improving targeting of agrochemicals. Organic seed will require the use of two generations of untreated seed from sowings after January 2004. There is little information on whether it will be possible consistently to produce organic seed with acceptable health standards, or whether seed-borne diseases will increase to damaging levels. The extent to which current trends in the use of untreated seed for conventional crops, and the forthcoming requirement for organic seed, will interact in terms of seed-borne disease levels in the UK is unknown.

2.4 Pests

Field pests of organic cereal production are considered in the context of their biology and control, their severity and incidence, and their impact on and interaction with conventional systems of crop production. This discussion focuses on the main invertebrate pests, in the form of insects, slugs or nematodes (eelworms), which are likely to be encountered in the production of organic cereal crops.

The most important and frequent pests of cereals are aphids as vectors of BYDV in the autumn or causing direct-feeding damage in the summer, slugs, leatherjackets and wheat bulb fly. There are many other pests of cereals including some which frequently cause severe localised damage, for example, frit fly, orange wheat blossom midge and the yellow cereal fly. Pest species such as wireworm, gout fly and swift moth can also cause concern, however, they tend to occur more sporadically.

Pest control in organic systems of crop production is based primarily on cultural and, to a lesser extent, biological methods of control. These methods must seek to prevent pest attacks by exploiting all aspects of crop agronomy, whilst not conflicting with the overall requirements of growing organic crops. Additionally, these techniques must take account of any possible effects or interactions on other pests, diseases and weeds, as well as wider environmental consequences, such as nutrient leaching. There are also potential benefits to be gained in the organic production of field crops from the integration of cultural control measures with management strategies to optimise the impact of natural enemies on pest populations.

In organic systems, fields at risk of pest attack must be identified at an early stage and the most appropriate control strategy planned well in advance. Pest attacks should be avoided or minimised by cultural practices and by enhancing the activity of natural enemies, but much depends on implementing the most suitable crop management measures to prevent or suppress pest outbreaks before they occur.

Many cultural practices have a profound effect on the prevalence and severity of cereal pests. Crop rotation, time of destruction or harvest of previous crops, disposal of straw and crop residues, soil conditions, pre-sowing cultivations, sowing date, sowing depth and crop cultivar (cultivar) are all cultural factors which can influence the incidence of pests. For example, sowing before mid-October increases the risk from problems such as *Barley yellow dwarf virus* (BYDV), frit fly and gout fly. Conversely, late-autumn or early-winter sowing increases the vulnerability of crops to slugs and wheat bulb fly. Sowing cereals after grass, grass weeds or volunteer (self-sown) cereals presents a range of potential ‘ley’ or ‘green-bridge’ pests, including leatherjackets, frit fly, aphid-borne BYDV and wireworms. Where summer fallows are used in the management of rotational set-aside, wheat crops sown the following autumn are at risk from wheat bulb fly attack in areas where the pest is established. Likewise, first wheats sown after crops such as potatoes, sugar beet, vining peas and onions may also be at risk of attack by wheat bulb fly in eastern areas of the UK, where this pest is endemic.

Control of invertebrate pests in organic cereals can be achieved through careful implementation of a range of cultural control techniques. Crop rotation, cultivation methods and time of sowing are the most important considerations. Habitat manipulation strategies and cultivation techniques to enhance the activity of naturally occurring biocontrol agents is also of key importance in organic rotations. However, resistant cultivars are generally not currently available for most cereal pests.

The use of grass and grass/clover mixtures as fertility-building crops is a feature of some organic rotations which will increase the risk of attack by ‘ley’ and ‘green bridge’ pests when cereals are sown after grass. Heavy infestations of grass weeds or cereal volunteers also poses a similar threat. The choice of which cultural control methods are adopted will depend on careful assessment and prioritisation of risk at a local level to avoid conflicting objectives. For example, early autumn sowing may reduce the risk of damage by slugs and wheat bulb fly will increase the risk of BYDV infection. Early ploughing to reduce the risk of direct transfer of BYDV vectors and frit fly could increase the risk of wheat bulb fly damage. Non-inversion tillage or direct drilling may preserve soil-dwelling predators which help suppress the aphid vectors of BYDV but could increase the risk of slug damage. However, if grass, grass weeds or cereal volunteers are allowed to survive non-inversion tillage, there could be an increased risk of 'green-bridge' aphids transmitting BYDV to cereals.

New techniques for improving the efficacy of natural enemies in the benign control of cereal pests will be of greatest value if they are integrated with cultural control measures in an integrated strategy designed specifically for organic systems. Measures taken to enhance the biological control of pests under organic production are likely to enhance its value as a source of natural enemies to spread out to help control crops in areas remaining in conventional cultivation.

An increase in the area of organic sown cereals is unlikely to affect the national incidence of cereal pests. However, there could well be subtle shifts or changes in the occurrence and importance of the various pests of cereals at a more local level. An increase in grassland could provide a greater natural reservoir of cereal aphids and BYDV, which could increase the threat to surrounding cereal crops. Grassland pests such as leatherjackets, wireworm and other ley pests could also assume renewed importance in grass-based organic rotations, but would not pose a threat to any neighbouring farms practising an all arable rotation.

An increase in the area of organic cereals is, therefore, unlikely to have a great impact in the west of the country where grassland and mixed farming are already widespread. However, in eastern areas of the country where pure arable rotations predominate, a strong shift to organic rotations, with associated increases in the area of grass, could have a more marked effect on the incidence and distribution of cereal pests. Further research is required to establish the relative importance of these changes and to develop practical and benign systems of pest control for use in the organic production of cereals.

An increase in the area of organic sown cereals is unlikely to affect the national incidence of cereal pests. However, there could well be subtle shifts or changes in the occurrence and importance of the various pests of cereals at a more local level. An increase in grassland could provide a greater natural reservoir of cereal aphids and BYDV, which could increase the threat to surrounding cereal crops. Grassland pests such as leatherjackets, wireworm and other ley pests could also assume renewed importance in grass-based organic rotations, but would not pose a threat to any neighbouring farms practising an all arable rotation.

An upsurge in the area of organic cereals is, therefore, unlikely to have a great impact in the west of the country where grassland and mixed farming are already widespread. However, in eastern areas of the country where pure arable rotations predominate, a strong shift to organic rotations, with associated increases in the area of grass, could have a more marked effect on the incidence and distribution of cereal pests.

New techniques for improving the efficacy of natural enemies for the natural suppression of cereal pests will be of greatest value if they are implemented in conjunction with cultural control measures in an integrated strategy designed specifically for organic systems. On a positive note, measures taken to enhance the biological control of pests under organic production are likely to improve the value of organic land as a source of natural enemies, the more mobile species of which (e.g. hymenopterous parasitoids) could migrate to and augment the natural suppression of pests in neighbouring areas of conventional cultivation.

2.5 Diseases

Winter wheat is the most important of the cereal crops. It was suggested that the balance may change as other markets, such as organic malt for brewing and distilling, develop.

The national status of winter wheat diseases has been surveyed in England and Wales since 1970 (with the exception of 1983 and 1984). Fungal diseases are less severe in organically grown cereal crops essentially because of lower nitrogen inputs.

Of the top ten cultivars grown in organic and conventional systems only four are common to both systems: Hereward, Claire, Rialto and Malacca. The top five places in the organic group are dominated by bread-making wheats whereas those in conventional production are generally of biscuit quality.

Sulphur and copper are the only permitted fungicide for use on cereals. These are not effective when applied against established disease and so disease control is generally effected by use of disease avoidance, escape mechanisms and crop manipulation such as late sowing, use of resistant cultivars, cultivar mixtures and crop rotation. NIAB in their trialling system compare the yields of cultivars untreated with fungicide and with a programme intended to provide disease free plots. Yield differences range from 20% to 41% for cultivars such as Shamrock and Riband, respectively, indicating a wide range of disease susceptiblility, assuming that the yield differences are strictly related to disease control.

Results of a single year's survey examining 54 crops of organically grown winter wheat in 1991 indicated that disease levels were not markedly different from those in conventionally grown crops, excepting for glume blotch which was present in 57% of organic crops compared with 80% on conventional crops. In a further project on monitoring crop protection problems in organic crops glume blotch was the most common disease found in 77% of crops but septoria leaf blotch was the most severe affecting 2% area of the second leaf. Both the incidence and severity of ear diseases was low. Eyespot was the most common of the stem base diseases, affecting 92% of crops with 9.5% of stems affected by moderate and severe symptoms. For comparison, results from the national disease survey of conventionally grown crops in 1994 recorded that septoria leaf blotch reached a level of 1.2% area leaf 2 and moderate and severe lesions of eyespot affected 8.9% of stems. This was despite 95% of crops being treated with a fungicide with a mean number of applications of 1.9 per crop. Fifty six percent of crops were sprayed at the first node growth stage (GS 31), the eyespot timing, and 65% at flag leaf emergence (GS 37), the optimum timing for the control of septoria leaf blotch reached control.

Organic and conventional cereal crops are vulnerable to the same spectrum of foliar diseases, although there is evidence that disease levels are generally lower in organic crops. If the proportion of the national cereal acreage grown organically were to increase, there would be an increased opportunities for disease to spread between organic and conventional crops. Disease spread may potentially take place in either direction, i.e. organic to conventional or conventional to organic. The likelihood of both is discussed and it is concluded that the risk is probably greatest for the mildews and rusts and the main direction of spread is likely to vary at different stages of the season. Cultivar is a major factor governing the risk of disease spread. Two aspects of a cultivar's disease resistance are critical 1) its 'background' resistance as indicated by a 1-9 disease resistance rating and 2) its specific resistance as given in cultivar diversification schemes. The greater the genetic diversity between the cultivars grown organically and those grown conventionally, the lower is the risk that disease will spread between them.

2.6 Weeds

Weed problems are largely a feature of the crop rotation, which is in turn influenced by soil type. Predominantly weeds remain within one field but they can move between fields by one of several mechanisms. Seedbank is a good measure of the potential annual or biennial weed species, but perennial weeds will be affected by the amount of root or rhizome material present. The soil type and crop rotation therefore determine the underlying seedbank for a field. The size and spatial distribution of the seedbank and perennial roots will then be determined by the subsequent management of the field (crop rotation, cultivations, sowing dates, within crop weed control, mowing). However, there is also scope for this seed burden to be added to by external sources.

Since organic cereals are only one crop within a rotation this section therefore considers weeds issues related to a whole rotation and how certain crops may influence weed populations within the rotation. There are many operations which affect weed numbers and species. Not all weed species are as competitive with cereals as each other.

The spectrum of the most common weeds of organic crops will initially be very similar to that of conventional crops and specific weed problems build up after several years of organic farming. Particular problem weeds include perennial species, such as couch, thistles, docks. The most likely problem annual weed is wild oats, but brassicas could also become important. Weed levels in organic situations can be high enough to contribute significantly to economic yield losses. Particular attention will need to be paid to prevent importing weed seeds into arable rotations. The key problem is predicted to be weed seeds imported in seed. Brassica species could become important weed species for seed producers, or if oilseed rape becomes more widely grown in organic rotations. Similar problems could arise with sugar beet. The biology of perennial weeds is poorly understood, however, if rotations can be evolved with only minimal intervals without soil disturbance perennial weeds in the arable context could be minimised.

3.0 RECOMMENDATIONS FOR FURTHER WORK

3.1 Pests

a) The ‘adoption’ of a commercial farm about to undergo organic conversion, where observations on the incidence of key pests and their natural enemies may be made. The cereal pest control regime would be implemented and supervised in close collaboration with the host farmer. The farm would then function as a demonstration ‘workshop’ for organic crop protection issues and also form the basis for local technology transfer activities such as farmer discussion groups, field meetings/demonstrations and newsletters.

b) A comparative, multi-disciplinary, system study on a farm about to undergo organic conversion, where conventional and organic areas will be available for manipulation and in-depth assessment. In relation to pest control, the objective will be to develop a practical integrated pest management system for organic cereals, utilising biological and cultural control. The changes in biodiversity that take place during the establishment of organic cropping and the impact on pest and natural enemy populations would be monitored and compared with conventional management.

c) A three-year observation of two areas, one with a low and one with high density of organic cereal crops among non-organic crops, to determine whether the various aspects of pest interactions noted in this report do occur in practice. Owing to the sporadic and seasonal nature of pest attacks, comparative observations would need to be made on organic and conventional farms in both areas.

3.2 Diseases

a) Three-year observation of two areas, one with a low and one with high density of organic cereal crops among non-organic crops to try to determine whether the various aspects of disease interactions noted in this report do occur in practice.

b) Seed-borne disease study to compare the incidence of seed-borne diseases in non-organic cereals, organic cereals and organic cereal seed crops.

c) Monitor the development of disease epidemics in nearby organic and conventional cereal crops at several locations in the UK. Examine evidence for spread of disease from organic to conventional and conventional to organic and compare with the spread between conventional crops and between organic crops. Approaches would include sampling the pathogen populations in the different crops and comparing them using virulence phenotyping and DNA profiling.

d) Investigate the degree of genetic disease resistance required by a cereal cultivar to provide adequate disease control in organic situations and whether this changes with the proximity of the organic crop to conventional crops.

e) Compare the fungicide resistance of mildew and yellow rust isolates collected from organic and conventional crops to test the hypothesis that organic crops provide a refuge for fungicide-sensitive strains of the pathogens.

3.3 Weeds

a) Early adopters of organic cereal production should be monitored for developing weed problems as an early indicator of problems for others.

b) Perennial weeds are an increasingly important problem. More work should be undertaken to develop management strategies by exploiting their ecology.

c) Seed producers should be alerted to weeds issues related to them and informed of means of reducing the impact,

d) All the industry need to be made aware of the needs to demand clean seed to reduce the risks of introduction of new weed species.

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