Paper 7
DISEASE PROBLEMS IN BARLEY

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INTRODUCTION

In New Zealand, spring-sown barley is subject to infection by a wide range of disease inducing micro-organisms. Approximately twenty diseases of barley occur in New Zealand and some may cause large yield reductions.

Control of these diseases requires a fundamental knowledge of the ways in which crops become infected, epidemics develop, and yield potentials are reduced by the potential pathogens. In this paper I review these fundamental aspects in responses to several questions commonly asked by farmers and agronomists. In a complementary paper Close reviews specific disease problems and the appropriate control strategies based on cultural, genetic, biological and chemical methods.

IMPORTANCE OF DISEASES

Why are diseases important?

Diseases most obviously affect barley by reducing yield, measured as the weight of grain harvested. In developed agricultural systems based on cereal monocultures, total losses due to disease have been estimated to average 5-15% (Jenkins and Lescar, 1980; Sheridan and Grbavac, 1982) though losses to individual crops may be greater than 40%. A less obvious effect of disease is on the quality of harvested grain. Depending on end usage, size variability, percentage germination, protein, mineral and vitamin content may be very important to the consumer (Ranaweera, Smart, this symposium). Some diseases are readily controlled by routine methods such as seed treatment, foliar sprays, rotation, and the use of resistant cultivars, but only at some cost to the industry. Chemical applications can be a significant cost factor, rotations limit the frequency of growing profitable crops such as barley, and the yield potential of resistant cultivars may be less than that of others in the absence of disease. The industry at large incurs further costs in terms of research, development of new chemicals and cultivars, and the extension work associated with their introduction. Thus some diseases, even though they may not be present in most crops, may still reduce overall profitability.

Which diseases are important?

"Important" in the context of this paper means having an effect on the profitability of barley production. Barley diseases may be categorised, from those at one extreme which are of academic interest only, to those which are frequently the cause of yield losses.

Ergot is rarely of any significance in barley production because nearly all commercial cultivars have flowers which open for only very short periods, thus providing a minimum opportunity for infection. Of greater relevance to farmers are a number of diseases which, even in the absence of specific control measures, do not cause economic losses at present in New Zealand. Management practices, climate and other factors are not conducive to the development of these diseases. However, any major changes in management practices could change the situation, so that these diseases become of greater significance, and this must always be borne in mind when such changes are considered. For example, scald is not economically damaging under present good management systems but a change in agronomic practices could render the crop more liable to severe infection, as has happened with several diseases in Britain with the recent emphasis on winter or autumn sowing.

Potentially damaging diseases do not cause losses in the present production system provided standard control strategies are implemented successfully. However, any relaxation or inefficiency in treatment leads to the rapid development of damaging levels of disease. An example of such relaxation was seen in the 1970's in New Zealand following the withdrawal of organomercurial seed treatment chemicals for environmental conservation reasons. The replacement chemicals (mostly Captan) were not effective against a range of seed borne diseases such as loose smut and net blotch. Net blotch, especially, increased rapidly to damaging levels with high levels of seed and crop infection, especially in the North Island (Matthews and Hampton, 1977). When chemicals effective against these diseases (Sheridan and Grbavac, 1982) were introduced the level of disease in crops and of inoculum in seed declined so that they were no longer the cause of yield losses.

Finally, some diseases such as powdery mildew, leaf rust, and barley yellow dwarf virus regularly cause yield losses in New Zealand despite attempts to control them.

Why are some diseases still damaging?

With current technology most crop diseases, including all those of barley, can be controlled provided that correct procedures are followed. However, in New Zealand and other developed agricultural countries some diseases continue to cause substantial yield losses despite large inputs to research, extension and control strategies. Over the last 20 years there has been relatively little progress with these diseases despite the inputs. This continued loss due to disease may sometimes be due to the deliberate adoption of a low target yield strategy by a farmer, who offsets his losses against the savings on fertilisers, fungicides and other inputs required for high target yields. This policy is acceptable to an individual farmer provided that good economic returns are achieved, though it may not be so acceptable to the country as a whole. Such decisions are based on the incentives available for a high production system, involving high cost inputs, and are controlled by consumer demand and in some cases price control by government or other bodies.

In high target yield systems large losses are sometimes incurred despite attempts at disease control, and this is of great concern to plant pathologists. Assuming that the recommended technology is applied, such losses are an indicator of our limited knowledge of the induction of yield losses by diseases. Though many studies have correlated disease with yield losses, often in complex statistical models, we are remarkably ignorant of the mechanisms by which diseases cause yield loss. In particular, there is very little information on threshold levels of disease, above which yield losses are induced but below which there is little chance of loss. In this context it is important to distinguish between the effect of disease on yield production (physiological reduction effect) and the relevance of infection to the development of disease later in the crop growth cycle (epidemiological potential effect) as discussed by Teng and Gaunt (1980). Disease must be controlled if it is known that yield potential will be reduced or if the presence of disease will lead to a severe and damaging epidemic later in the crop growth cycle.

More fundamental studies of yield loss, based on the physiology of production of yield, are required to enable further progress in this area. Without such knowledge economic losses may occur, either because disease is not controlled adequately to prevent yield reduction or because disease is controlled when losses are not likely to occur. At present, because of our lack of fundamental knowledge, we rely on "conventional wisdom", frequently based on overseas research, which may not be applicable to New Zealand barley.

Some examples may serve to highlight these problems. Often it is assumed that low levels of disease, especially if present on the lower leaves of the plant, do not cause yield losses irrespective of the time of infection. Recent evidence (Jenkins and Storey, 1975; Lim and Gaunt, 1981) indicates that at some growth stages (especially before flowering) barley crops may be extremely sensitive to constraints and that low levels of disease may cause significant yield losses. Similarly it is sometimes assumed that diseases present early in the crop growth cycle are less important than those occurring during grain filling, because the plant can compensate for early losses to yield potential by enhanced growth and development later in the cycle. In three years of research trials we have found no evidence of compensation for early losses in barley grown in Canterbury (Lim, 1982; Lim and Gaunt, 1981). In similar trials with wheat diseases we observed compensation in one season only, a season which was exceptionally wet for Canterbury during grain filling (Gaunt and Thomson, 1983). Water availability at late stages of crop growth may be relevant to compensation capacity and is one of several important differences between New Zealand and European barley crops. In New Zealand, spring sown barley is often subject to drought late in the season and this may limit the compensation capacity of the crops. Finally, it is often assumed that a given level of disease is equally damaging to all cultivars. Control decisions are made on the basis of this assumption. Our barley research indicates that this may not be true and that high-yielding cultivars may be more sensitive than low-yielding cultivars (Lim and Gaunt, 1981). The difference in sensitivity is most obvious in comparisons between "old" and "new" cultivars with widely differing production potentials, usually as a result of different harvest indexes (Austin *et al.*, 1980). Low-yielding cultivars are more limited in production compared to higher-yielding cultivars, because of genetic and/or environmental limitations to the number and size of grain sites rather than the ability to produce photoassimilated materials. Thus reductions in the supply of photoassimilates, because of disease effects on the production and export of carbon compounds, may be less relevant to yield in these cultivars than in high-yielding cultivars.

Thus, we may conclude that yield losses will continue to be caused by some diseases until a better understanding of the cause, mechanism, and time at which these effects occur is achieved.

PROSPECTS

Changes in barley production systems may cause a change in disease problems, for which new control strategies will be required.

Firstly, the availability of new cultivars, bred in New Zealand and overseas and possessing some degree of resistance, may create some complacency with respect to disease, although few are completely resistant. The new cultivars will also have high yield potentials, possibly rendering them more sensitive to any disease that may develop in the crop. Powdery mildew has developed from a disease which, before the increased nitrogen inputs in agriculture, was of little significance (Wolfe and Schwarzbach, 1978), to a disease which is often very damaging even at low disease severities. Though responses to fungicidal control measures for mildew have not always been gained, this may be explained by applications being too long after the initial development of the epidemic. Substantial yield responses were gained from early control of mildew (Lim and Gaunt, 1981). In Britain, Jenkins and Storey (1975) showed that yield responses to single sprays occurred if they were applied when less than 5% of the area of lower leaves was occupied by lesions (Fig. 1). Later applications were far less effective and lower yield responses were achieved.

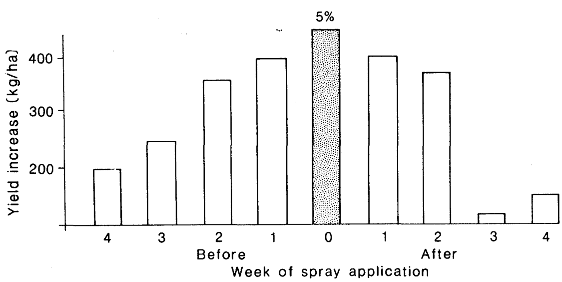

Figure 1: Increase in yield of spring barley with tridemorph sprays applied before or after the time when leaf 4 had 5% mildew (after Jenkins and Storey, 1975).

Secondly, the increasing availability of specific fungicides for control of powdery mildew and leaf rust may increase our dependence on these chemicals, and cultural control methods, such as stubble burning and the destruction of volunteers and weed hosts, may be ignored. This would be a retrograde step, since an increased size of pathogen population may increase the chances of selection of strains of pathogens insensitive to fungicides, or able to overcome some types of resistance mechanisms in the host plants. An increased reliance on fungicidal control, especially at late growth stages in high-yielding crops, may justify the use of tramlines for spray rig access; this technology may raise new agronomic and disease problems.

A change in agronomic practices in Europe towards winter or autumn sowing of barley has created new disease problems. If such a change occurs in New Zealand it is likely that net blotch and scald will become diseases of major significance. These and other diseases, which can survive on stubble and volunteer plants between successive crops, would be more likely to infect newly established crops in any system which reduces the time between the end of harvest and the first crop emerging for the next season. Scald and net blotch also develop well under cool, moist conditions, such as those experienced in New Zealand during autumn, winter and spring. Cultivar selection in winter barley should take account of resistance to these diseases if substantial losses or costly chemical control are to be avoided.

CONCLUSIONS

Finally, I believe there is an urgent need for a greater understanding of the physiology of yield loss, which will lead to the definition of the times and levels of disease at which crops are most, and least, sensitive to diseases. Empirical models of disease/yield loss relationships do not necessarily explain the cause of yield losses, and at present too much reliance is placed on information extrapolated from other systems. There is an urgent need for collaborative research by agronomists, physiologists, plant pathologists and others, and for recognition of the valuable contributions that each group could make towards acquiring this understanding.

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DISCUSSION

Gallagher: How do you rate the control strategy in the U.K., where they identify the particular genes for resistance to rust, and encourage farmers to spread the risk by growing cultivars with different resistance genes?

Gaunt: I feel it is a well thought out strategy, based on intelligent interpretations of the interactions that occur between pathogen and plant populations. As far as this country is concerned, it depends on which resistance genes are used. If New Zealand is going to have enhanced or continued use of vertical resistance genes, we should consider a mosaic or mixture strategy. But if we are going to use field or horizontal resistance genes, which are multigenic in their control, then that strategy is not relevant because the pathogens cannot adapt, as far as we know, to a multi-operational disease mechanism.

Coles: Where multi-line or mosaic crops are concerned, it is important to remember the low degree of our crop intensity.

McFadden: How does this decision on cultivar choice in relation to disease operate in the U.K.?

Gaunt: The system operates for only three diseases, stripe rust on wheat and powdery mildew on both wheat and barley. Cultivars are classified into resistant-gene types. Farmers are advised not to use cultivars from a single group. Groupings must be carefully considered. Spores from cultivar A of Group I, blowing into a paddock of cultivar X of a Group II, land but do not infect, thus diluting the inoculum. There is interest, particularly for powdery mildew in barley, in creating the same situation within a single paddock by mixing three or four cultivars. This has agronomic and end usage implications. I gather British maltsters were not accepting a product composed of several cultivars, but for the first time are now beginning to consider the implications. From a feed point of view it doesn't matter so much, and the major constraint in using a mixture in a single paddock would be harvesting considerations. It is no good having cultivars which mature two weeks apart.

Thompson: You said that, even though the farmer is not making a greater profit in your high input-output system, his use of chemicals benefits the nation. You also said there are many instances where chemicals shouldn't be used. Surely economics would be the farmer's criteria?

Gaunt: Yes, the deciding factor for these systems must be economic. Some systems may be acceptable to the nation, but not the individual farmer. This is where we need incentives for high production systems because low production systems can have repercussions. A farmer growing a susceptible cultivar on a low input system without chemical protection is providing an inoculum source for adjacent farms.