CONTROL STRATEGIES FOR SEED BORNE DISEASES

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ABSTRACT

Seed borne diseases are reviewed for their potential to reduce yield in agricultural and horticultural crops. The level of risk and ease of control is dependent on the efficiency of transmission of disease via the seed, the availability of other sources of inoculum and the rate of epidemic development in crops. Control strategies based on seed crop inspection, seed selection, seed treatment and foliar sprays are reviewed with type examples to illustrate and explain the fundamental concepts of control based on a fundamental knowledge of disease development.

The marketing of high quality seed within New Zealand is discussed as part of a disease management strategy for optimal production. The potential for export of high quality seed is reviewed.

INTRODUCTION

It has long been recognised that plant diseases are one of the important contraints to crop yield, due to a failure of crops to reach the yield potential which is determined by genetic and environmental limitations. The organisms causing disease (viruses, mycoplasmas, bacteria, fungi, nematodes and others) have been studied intensively for many years by microbiologists. More recently, greater emphasis has been placed on the applied aspects of disease prevention and control. For many diseases, survival of the pathogen between cropping periods is a weak point in the disease cycle and is often the point at which disease can be prevented or controlled by chemical or cultural practices. Many important pathogens are transmitted from crop to crop associated with the seed which often removes the weak point from the cycles as the system is usually an efficient means of survival. However, seed borne inoculum is often accessible to treatment by avoidance or chemicals, such that the level of inoculum entering a newly established crop is reduced or eliminated. Since most crops are propagated by seed they are subject to infection by a number of seed borne diseases unless appropriate strategies are implemented. The potential hazards to crop production attributable to seed borne diseases, the factors affecting the significance of inoculum transfer by seed, the methods of control based on fundamental knowledge of disease cycles and the potential for New Zealand seed production are reviewed in this paper.

ECONOMIC IMPACT

Seed borne disease may affect crop productivity in two ways. Firstly, seed containing viable inoculum may introduce new pathogenic species or races to areas at local, regional or national levels. For a relatively isolated country with well separated crop production areas such as New Zealand, this is an extremely important aspect of seed borne diseases, especially as a means of introducing new pathogens to the country. For example, bean seed imported from Holland was responsible for the first recorded outbreaks of common bacterial blight and fuscous blight in New Zealand (Watson, 1970). Seed exported from New Zealand probably introduced yellow slime disease of cocksfoot to the U.S.A. (Hardison, 1945) and blind seed of ryegrass to Oregon, U.S.A. (Hardison, 1948). Further possible introductions were avoided by the interception in Israel of seed from New Zealand contaminated with the pathogen causing blind seed of ryegrass (Neergaard, 1977) and by the interception in New Zealand of imported seed containing inoculum of the pathogens causing rust of snapdragon (Anon, 1954), race T. southern leaf blight of maize (Scott, 1971) and squash mosaic in rock melon (Thomas, 1973). Recently, with the increased interest and activity in international trade, cooperative plant breeding enterprises and assessment of new crop species, contaminated seed samples have been intercepted by the quarantine system operated in New Zealand. For example, leaf stripe of barley has been detected in breeding exchange material and leaf spot of chick pea in evaluation trials. There is therefore a need for constant vigilance by breeders and agronomists, in cooperation with pathologists and MAF quarantine personnel, to minimise the risks of introduction of some important seed borne diseases not present in New Zealand or the introduction of new races of important diseases.

Seed borne inoculum is also important as a source of initial inoculum for diseases which cause qualitative and quantitative losses to a wide range of important crops. Qualitative losses occur in cereals as reduced malting, milling or baking quality, in grasses as reduced digestibility, in ornamentals as flower or foliage spoilage and in vegetables and fruit as cosmetic effects due to blemishes on the marketed produce. Data on quantitative losses is often unreliable, being based on "guesstimates" or on field trial data which covers only a narrow spectrum of cultivar, production and/or location variables. Nonetheless, the available data does allow for global estimates of disease induced losses and specific examples illustrate the types of losses due to individual seed borne diseases. Global losses have been estimated as 12% of the potential production, representing an annual loss of 550 million tons of produce and $US 50 billion at present day prices (James, 1981 a,b). This loss in production can be related to a projected 145 million tons global food deficit in 1990 (F.A.O., 1977). Recent estimates showed that the seed borne disease common root rot of wheat was responsible for a 5-7% yield loss in Canada in 1969 - 1971 (Piening *et al.,* 1976). Blast disease has been estimated to cause 50% loss in rice in the Phillipines and most of the total yield loss due to disease in soyabean (14%) and Phaselous beans (20%) in the U.S.A. have been attributed to seed borne diseases (James, 1981a). In New Zealand there are no reliable estimates of national crop loss attributable to any seed borne disease but several diseases (e.g. blind seed in ryegrass, net blotch of barley, leaf and pod spot of faba beans, halo blight of Phaseolus beans and black rot of cabbages) have caused large economic losses in individual crops or field trials and these represent a potential constraint to crop production. Many other seed borne diseases (e.g. loose smut of wheat) are controlled by routine treatment, without which severe losses would be incurred.

SIGNIFICANCE OF SEED BORNE INOCULUM

For many years seed pathology has been dominated by studies of disease inducing pathogens, the identification of seed borne organisms and the development of methods for detecting organisms in seed material. This has led to the publication of lists and descriptions of seed borne diseases (Richardson, 1979; Neergaard, 1977) and recommendations for seed testing methods by the International Seed Testing Association. Until recently there has been much less emphasis on studies of the economic importance of such organisms and the associated diseases and on the epidemiological significance of seed borne inoculum. Although the role of seed borne inoculum in disease cycles is well established for many diseases (Hewett, 1978; Leach, 1977), much less is known of the quantitative relationship between inoculum, disease development and yield loss. This is partly due to the difficulties in relating disease intensity to yield loss (James and Teng, 1979; Gaunt, 1981) but also is due to a lack of investigation of yield losses in crops grown from seed with different levels of infection.

In some seed borne diseases there is a direct relationship between the amount of inoculum and the amount of yield loss. For example, between 80 and 100% of cereal seed embryo-infected with loose smut produce infected plants. In all infected plants there is a total yield loss and since the plants continue to compete with surrounding healthy plants for light, nutrients, water and other limiting factors there is no compensation by surrounding plants for the lost yield potential. Thus the level of seed infection can be equated with yield loss in a 0.8 - 1.0 ratio and a nil seed infection level guarantees a nil yield loss. This type of disease is, however, not typical of most seed borne diseases because of the direct loss of the harvested part of the plant, the monocyclic nature of the epidemic (Van Der Plank, 1963) and the fact that the inoculum in the embryo is the only source of inoculum. In most diseases, infection has an indirect rather than direct effect on yield, the epidemics are polycyclic with subsequent spread during the growth season and there may be other sources of inoculum.

Allen and Smith (1961) reported that control of seed borne inoculum of dry rot of brassicas did not reduce the incidence of disease in most years. They attributed this to an inefficient transmission of inoculum from seed to seedling (especially in dry years) and to the availability of ascospore inoculum from crop residues (Smith and Sutton, 1964). Similarly Sanderson (1963) suggested that ascospore inoculum from Australian flax in hedgerows was a more important source of inoculum for Pasmo disease of linseed than seed borne inoculum. On the other hand, some diseases spread so efficiently under field conditions that very low levels of inoculum are very significant in the development of epidemics. Schaad *et al.* (1980) showed for black rot of cabbage that infection levels of 0.05% led to severe levels of infection and large yield losses. Therefore an analysis of the significance of seed borne inoculum is a prerequisite for any control programme.

Work such as that by Schaad *et al.* (1980) leads to the recommendation of "maximum acceptable levels" of seed borne inoculum, an aspect which has been emphasized recently in research investigations. Below such an "acceptable level" there is a high probability that disease will not develop to economically important levels. The levels, e.g. no more than 1 in 10,000 cabbage seeds are specific for location and cropping practice in this case for Georgia, U.S.A. The levels must therefore be defined for specific cases and any extrapolated guidelines should be used with great caution. For example, Hewett (1973) suggested that 1% was an acceptable level for the pathogen causing leaf and pod spot of spring sown field beans in Britain, however, the value was shown to be too high for guaranteed production of winter sown field beans and broad beans in New Zealand (Liew and Gaunt, 1981). The definition of acceptable levels based on quantification of epidemic development and yield losses remains a priority as a basis for the control of many important seed borne diseases.

CONTROL OF SEED BORNE DISEASES

It has been shown above that one of the factors that influences the maximum acceptable levels of inoculum for seed borne diseases is the presence of alternative sources of inoculum in a disease cycle. Any manipulation of seed borne inoculum inputs to a cropping area may, in the long term, influence the level of the alternative inoculum sources. Thus the interaction of all factors must be analysed to fully appreciate the significance of seed borne inoculum. Two examples of recent disease problems in New Zealand illustrate the complexity of these interactions and the use of fundamental knowledge in disease control programmes.

Net blotch of barley is a seed borne disease, but inoculum may also enter crops from spores produced on stubble, volunteer plants and possibly from related weed species (e.g. barley grass) (Hampton, 1980). Barley seed was treated routinely with organomercurial fungicides up to 1973 to control a range of diseases including net blotch. Subsequent to the withdrawal of these fungicides from the market, for environmental conservation reasons, and their replacement with captan, the incidence of net blotch increased dramatically and the disease became an important constraint to production, especially in the North Island. Inoculum was found on stubble, volunteer plants and weed species and it was evident that crops established with non-infected seed were infected from these sources, with consequent reductions in yield. Thus the use of high quality seed did not guarantee disease free crops. After several epidemic seasons, captan was replaced by fungicide treatments which were known to be effective in controlling seed borne inoculum of net blotch. The disease intensity declined as a result of this change such that it was no longer commonly recorded at high disease severities on crops nor was inoculum so prevalent on the alternative sites of production. Thus control of the seed borne inoculum also controlled the other sources in the long term. One can conclude that, for net blotch, seed borne inoculum inputs are required to maintain the epidemic status of the disease in our production system and that other sources of inoculum are insufficient to cause epidemics. However, other sources of inoculum are sufficient to cause epidemics if some poor quality seed is sown each year in the production area. This example illustrates the need for constant surveillance of control strategies and continued awareness of the potential pathogens of crops which may become dominant if production systems are changed.

Field and broad beans grown in New Zealand have been infected spasmodically by leaf and pod spot. This disease can cause severe yield losses, especially in seed production crops and those intended for human consumption where the cosmetic effect of the disease may cause rejection of the produce (Gaunt *et al.*, 1978). Seed borne inoculum is the major means of continuance of the disease through successive seasons, though survival in the soil, in crop debris and on volunteer plants should not be ignored totally. In 1981/82 a severe epidemic developed on an agronomic field trial at Lincoln despite the use of seed with a low level of infection and seed treatment with a suitable fungicide (Gaunt, unpublished). The inoculum source was traced to a few infected volunteer plants approximately 100 m south of the trial plots; the distribution of infection in the trial area showed that there was an epidemic input from the south, presumably due to splash dispersal of spores associated with a southerly frontal system. If normal rotations are used, with both spatial and temporal separation of bean crops, the disease can be controlled by selection of seed with an acceptably low level of inoculum or by seed treatment. Gaunt and Liew (1981) concluded that seed selection was the most cost effective control strategy but that seed treatment was a useful insurance against the possibility of disease development. They suggested that foliar sprays should be necessary only in disease outbreaks or to specifically protect against pod and seed infection in vegetable or seed production crops.

It is evident that an understanding of inoculum sources and epidemic development are fundamental to any disease control programme. Diseases other than those reviewed above are described by Neergaard (1977) and by various publications by the International Seed Testing Association.

PRODUCTION AND MARKETING OF SEED

Many potentially damaging seed borne diseases are controllable by the implementation of known technology, usually by suitable seed selection and seed treatment programmes. However, successful control as indicated by the absence of the diseases often leads eventually to the need for control being forgotten or to the relaxation of infection standards. Thus boom and bust cycles over a long time period are often a characteristic of seed borne diseases in developed agricultural countries. In less developed areas these diseases cause regular and large yield losses since control strategies are not implemented satisfactorily. In the years 1951-60, losses due to wheat loose smut were only 0.8% in the U.S.A. but were 7% of national yield in India, the difference being attributed to seed certification schemes and the use of resistant varieties.

To aid the regular production of high quality seed, many production programmes are located in relatively dry areas of developed countries. This is due to the role of water and high humidity in splash dispersal, spore germination and penetration of host tissues by developing pathogens. Thus arid western states of the U.S.A. (especially Oregon and Idaho), the north of Italy (especially the Po Valley) and the Marlborough and Canterbury provinces in New Zealand have all been selected as suitable areas for specialist seed production. The particular combination of climatic conditions which favour seed production but which discourage the build up of seed borne diseases do not occur in many areas and is one of the reasons why New Zealand has a good reputation for seed production. To maintain and preferably increase the reputation and productivity of the New Zealand seed industry, it will be necessary to maintain high health standards as well as to keep abreast of production technology and cultivar development. For some seed types (especially herbage seed), New Zealand produced seed has lost some of the previous popularity and is attractive only because of the relatively cheap price of the seed on the overseas markets. The lack of popularity is related to the performance of New Zealand bred cultivars overseas, as illustrated by the absence of New Zealand cultivars from the N.I.A.B. Recommended Listings and the E.E.C. Common Catalogue. In the present climate of diversification I believe that there should be an increased effort to produce quality seed of acceptable cultivars of a wide range of agricultural and horticultural plant species. The potential is illustrated by the recent acceptance overseas of lucerne cultivars bred in New Zealand. The seed health programmes such as those in operation for bacterial blight and seed borne mosaic virus in peas are essential to an export programme to meet world market standards. Such programmes require the cooperation of plant breeders, agronomists, pathologists, commercial concerns and farmers. The aborted attempts to produce some seed types, such as the Phaseolus bean programme, emphasise the need for cooperation in the production of these high cash value crops but should not discourage further attempts to enter the market.

CONCLUSION

Seed borne diseases cause regular yield losses and impose severe constraints on some production systems. However, their very nature offer the possibility for specialist crops with adequate disease control programmes. The overseas seed market is competitive and demanding but New Zealand has several advantages for seed production by having a suitable climate, agricultural system and expertise. Thus "seed born diseases offer some the best investment opportunities because of the high investment return ratios associated with seed health programmes" (James, 1981). The statement applies both for export and home markets, where constant monitoring of control systems is required, especially with a rapidly developing and diversifying production system.

REFERENCES

Allen, J.D., Smith, H.C. 1961. Dry rot (*Leptosphaeria maculans*) of brassicas: seed transmission and treatment. *N.Z. Journal of Agricultural Research 4:* 676-685.

Anon., 1954. Incidence of antirrhinum rust (New Zealand). *F.A.O. Plant Protection Bulletin 2:* 121-122.

F.A.O. 1977. Production year book, F.A.O., Rome.

Gaunt, R.E. 1981. Physiological basis of yield loss. In *Proceedings Stakman Commemorative Symosium — Crop Loss Assessment. University of Minnesota Misc. Publications 7:* 98-111.

Gaunt, R.E., Liew, R.S.S. 1981. Control strategies for *Ascochyta fabae* in New Zealand field and broad bean crops. *Seed Science and Technology 9:* 707-715.

Gaunt, R.E., Teng, P.S., Newton, S.D. 1978. The significance of Ascochyta leaf and pod spot disease in field bean (*Vicia faba* L.) crops in Canterbury, 1977-78. *Proceedings Agronomy Society of N.Z. 8:* 55-57.

Hampton, J.G. 1980. The role of seed borne inoculum in the epidemiology of net blotch of barley in New Zealand. *N.Z. Journal of Experimental Agriculture 8:* 297-299.

Hardison, J.R. 1945. Bacterial blight of orchard grass observed in Oregon. *Plant Disease Reporter 29:* 600.

Hardison, J.R. 1948. Blind seed of perennial ryegrass. *Oregon Experimental Station Circular 177:* 11.

Hewett, P.D. 1973. The field behaviour of seed borne *Ascochyta fabae* and disease control in field beans. *Annals of Applied Biology 74:* 287-295.

Hewett, P.D. 1978. Epidemiology of seed-borne disease. *In* 'Plant Disease Epidemiology'' Scott, P.R. and Bainbridge, A. Blackwells, London pp. 167-176.

James, W.C., Teng, P.S. 1979. The quantification of production constraints associated with plant diseases. *Applied Biology 4:* 201-267.

James, W.C. 1981a. The cost of disease to world agriculture. *Seed Science and Technology 9:* 679-685.

James, W.C. 1981b. Estimated losses of crops from plant pathogens. *In* "Handbook of Pest Management in Agriculture". CRC Press, U.S.A. *1:* 79-94.

Leach, C.M. 1977. A theoretical consideration of the epidemiology of seed-borne plant pathogens. Proceedings Latin American Workshop on Seed Pathology, Brazil: 1-7.

Liew, R.S.S., Gaunt, R.E. 1981. Disease problems in the production of broad bean seed. *Proceedings N.Z. Weed and Pest Control Conference 34:* 55-58.

Neergaard, P. 1977. "Seed Pathology". MacMillan Press Ltd, London.

Piening, L.J., Atkinson, T.G., Horricks, J.S., Ledingham, R.S., Mills, J.T., Tinline, R.A. 1976. Barley losses due to common root rot in the Prairie Provinces of Canada, 1970-72. *Canadian Plant Disease Surveys 56:* 41-45.

Richardson, M.J. 1979. An annoted list of seed-borne diseases. *Phytopathological Papers* 23.

Sanderson, F.R. 1964. An ecological study of pasmo disease (*Mycophaerella linorum*) on linseed in Canterbury and Otago. *N.Z. Journal of Agricultural Research 6:* 432-439.

Schaad, N.W., Sitterby, W.R., Humaydan, H. 1980. Relationship of incidence of seed borne *Xanthomonas canpestris* to black rot of crucifers. *Plant Disease 64:* 91-92.

Scott, D.J. 1971. The importance to New Zealand of seed borne infection of *Helminthosporium maydis. Plant Disease Reporter 55:* 966-968.

Smith, H.C., Sutton, B.C. 1964. *Leptosphaeria maculans* the ascogenous state of *Phoma lingam. Transactions of the British Mycological Society 47:* 159-165.

Thomas, W. 1973. Seed-transmitted squash mosaic virus. *N.Z. Journal of Agricultural Research 16:* 561-567.

Watson, D.R.W., 1970. Bean common blight and fuscous blight in New Zealand. *Plant Disease Reporter 54:* 1068-1072.

Van Der Plank, 1963. "Plant Diseases: Epidemics and Control". Academic Press, London. p 349.