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The plant pathology contribution: collaboration for practical solutions

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Introduction

One of the tasks for those given leadership in the Australasian Plant Pathology Society is the presentation of a Presidential Address at a Biennial Australasian Plant Pathology Conference, which is always a difficult commission. Nevertheless, the opportunity to express some viewpoints is welcomed, from the perspective of a plant pathologist working in one of the world's smaller economies, in the southern extremities of the Southern Hemisphere, and the south-eastern corner of Australasia. The views expressed are personal.

This paper attempts to define our research discipline, and then examines world agrarian activities in relation to food and fibre production and the part that plant pathology plays. The complexities of our research activities and the host/pathogen systems we study are then considered, emphasising the increasing need for cross-discipline interactions and science collaboration to provide useful, practical solutions to the problems caused by plant diseases.

Plant pathology, our research discipline

Some definitions will help to focus on the science that underpins our discipline, and that which the Australasian Plant Pathology Society supports. The following are from the *New Oxford Dictionary of English* (Pearsall 1998):

> '**Pathology:** the science of the causes and effects of diseases.'
>
> '**Phytopathology (plant pathology):** the study of plant diseases.'
>
> '**Disease:** disorder of structure or function, . . . especially one that produces specific signs or symptoms or that affects a specific location and is not a direct result of physical injury.'
>
> '**Medicine:** the science or practice of the diagnosis, treatment and prevention of disease.'

Plant pathology is an ever-expanding conglomerate of increasingly specialised research, retaining an overall focus on plant disease. Furthermore, because plant diseases can have severe effects on plant populations, many plant pathologists focus on disease diagnosis and treatment (management, control), which is an integral part of modern plant pathology. While plant pathology is strictly (by definition) the science of causes and effects of plant diseases, our discipline also includes plant medicine. An excellent example of this concept has been developed at the University of Florida, where advanced education is offered in plant medicine (see McGovern 2004).

To summarise the activities of members of the Australasian Plant Pathology Society is difficult. A broad categorisation could be: developing understanding of the causes of plant diseases (identity and biology of plant pathogens); obtaining knowledge of the interactions between pathogens, their hosts and the environment; understanding factors affecting development of disease epidemics; determining effects (including economic) of diseases on the productivity of plant communities; and developing strategies for effective disease management. Biosecurity, where we aim to limit the human-assisted movement of plant pathogens, is an increasingly important focus for our discipline, spanning these categories of activity. We work in plant pathology and plant medicine.

Our research discipline originated from the need to control production-limiting plant diseases. A good example is the work of Woronin (1875) on 'Kohlpflanzen-Hernie' (cabbage hernia, clubroot of brassicas). This disease had, in some years, destroyed approximately half of the cabbage crop around the city of St Petersburg, causing severe economic losses and destruction of important food crops. Woronin's pioneering research first established and characterised *Plasmodiophora brassicae* as the cause of the disease. Then (in translation), 'After I was sure of the pathogen, it was not difficult to turn to control measures, which, though not completely eliminating the disease, might appreciably decrease its development.'

Today, while many branches of plant pathology expand basic knowledge on the interactions between pathogens, host

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plants and the environment, the ultimate direct or indirect aim of our activities must be to alleviate the problems caused by plant diseases. Reducing the harmful human nutritional, social, heritage and/or economic effects resulting from plant diseases is the goal of our science. Despite the many insights into basic biology that plant pathology continues to provide, our discipline is a science with 'applied' practical end points. Effective and appropriate control of plant diseases remains the objective of our research.

Plant pathology and global food security

World population trends

Some facts on global population (see Obaid 2004) are presented as a background to consideration of the place of plant pathology. The current world population is ~6.5 billion, and numbers of people are increasing at the rate of 76 million per year. The world's population is projected to be close to 9 billion by 2050. Population growth rates are slowing in developed countries, but continue to increase in countries where populations are young and poor.

World population has grown exponentially for most of human history, and particularly over the last 2000 years. Wright (2004) illustrated this well; the world's population was '~200 million at Rome's height (200 A.D.) . . .; ~400 million by 1500, when Europe reached the Americas, one billion people by 1825, at the start of the Coal Age; 2 billion by 1925, when the Oil Age gets underway; and 6 billion by the year 2000.' Recent actual and projected figures (Obaid 2004) indicate that the trend is continuing, with the world's population at 2.5 billion in 1950, 4.1 billion in 1975, 6.1 billion in 2000, and to be 7.9 billion in 2025 and 9 billion in 2050. 'Adding 200 million (to world population) after Rome took thirteen centuries; adding the last 200 million took only three years.' (Wright 2004).

World food production

Pinstrup-Andersen (2000) presented a detailed assessment of the 'outlook for global food security'. He pointed out that demand for food is influenced by several factors, including population growth, income levels, urbanisation, lifestyles and preferences. His organisation (the International Food Policy Research Institute) has estimated that global demand for food types, between 1993 and 2020, will increase by 41% for cereals, 63% for meats (requiring plant products for production), and 40% for roots and tubers. Over longer timeframes, demand will continue to increase beyond these levels if population predictions are accurate. Increases in food demand will be greatest in developing countries, where growth of population and incomes will be greatest. Food production in developing countries will not keep pace with demand, so an increasing proportion of their food will need to be imported from developed countries. Increased food production will be mostly from increased crop yields because there will be only small increases in land area available for cultivation.

Total world food production is currently adequate to provide energy and protein for all humans, and continues to increase annually (Pinstrup-Andersen 2000). Nevertheless, 800 million people remain chronically malnourished, and 2 billion (~30% of the world population) lack food security (Obaid 2004). Food quality is also important, with vitamin and mineral deficiencies affecting possibly 2 billion people, severely undermining physical and mental health, and hampering economic development (Adamson 2004).

Thus, while world food and fibre production is adequate to fulfil current human requirements, regional, cultural, economic and preference constraints, along with continuing population growth particularly in developing countries, pose very considerable problems. Production of food and fibre crops will remain a key requirement for continued human development.

'Developed' and 'developing' countries

World population growth and food production will differ in countries with differing levels of economic development. In developing countries, population growth rates will remain high (Obaid 2004) and increasing demands for food will be greatest. Local food production in these countries will need to expand to fulfil local demands. At the same time, requirements for food imports into these countries will expand, so developed regions will be required to produce more food for export (Pinstrup-Andersen 2000). This means that demands for increased crop production from increasing demand for food and fibre will be felt in all crop production areas of the world.

Effects of plant pathogens

Oerke *et al*. (1994) and Oerke and Dehne (2004) quantified the effects of plant pathogens (fungi, bacteria and viruses), animal pests (including nematodes) and weeds on crop production for the world's major food and fibre crops. They determined loss potential due to these agents (losses without crop protection intervention). The loss potential due to plant pathogens (not including nematodes) for eight crops, together occupying 47% of the world's crop-growing area, was greatest for potato (30% losses) and least for cotton and soybean (11–12% losses). The overall average loss potential due to these pathogens across the eight crops was calculated to be 18%.

Oerke and Dehne (2004) also estimated the efficacy of applied plant disease control measures for the eight crops (from 1996–1998), determined as the proportion of the loss potential prevented by control measures. For fungal and bacterial plant pathogens, control efficiency was 32%, and for plant viruses only 13%. This suggests that there is very considerable scope for improvement in the efficacy of plant disease control methods, a challenge for plant pathologists and practitioners of plant medicine.

Losses of product during and after harvest are not included in these figures. Postharvest losses well above 50% are possible and, overall, these have been estimated to be between 10 and 30% for all crops. Plant pathogens are likely to be the cause of a considerable proportion of this loss, particularly in grains and high-value fruit and vegetable products, and in tropical climates.

The economic value of crop and product losses due to plant pathogens is very difficult to determine. Oerke *et al*. (1994) estimated the loss of attainable production due to pathogens for the eight crops they considered was about $USA77 billion (thousand million) (1990 values). Extrapolation of their estimates, and allowing for inflationary influences, suggests that across all food crops, the value of yield losses due to plant pathogens could now be about $USA135 billion. These estimates do not include those due to postharvest losses. Nevertheless, the economic value of crop and product losses due to plant pathogens is undoubtedly very great.

The plant pathology contribution

Plant pathology and plant medicine will be integral parts of the continued drive towards providing food and fibre for the world's expanding population, and maintaining the heritage and aesthetic values of natural and urban environments. Our science has an excellent record in providing methods for management of plant diseases and reducing their deleterious effects.

Input from plant pathology to support increased crop productivity will be required in both 'developing' and 'developed' economies. Developing countries will need plant disease management to maintain/increase crop production for local consumption. Developed countries will require similar outcomes to provide local food supply and fulfil increased demand for exports. Already, members of the Australasian Plant Pathology Society are making excellent contributions to plant disease management in developing countries (particularly in South-East Asia, Papua-New Guinea and the Pacific), with numerous examples of specific projects where our members have had, and are having, very productive input. Plant pathologists are also working to maintain and improve food crop production in Australia and New Zealand, contributions that benefit local food production and food exports.

Biosecurity

Plant pathogens also pose threats to biosecurity. Burgess (2003, as President of this Society) addressed this question, emphasising the importance of plant pathology for biosecurity, as institutional frameworks are developed within countries to prevent incursion of harmful plant pathogens. These are developing in a climate of greatly increasing inter- and intra-national movement of trade goods (biological and industrial) and transportation accessories (road vehicles, ships and ballast, containers, packaging materials). The potential for incursions of new plant pathogens is increasing dramatically, and the economic value of these threats, while difficult to predict, is very likely to be large, particularly where the threats are to important economic crops and natural plant communities.

Burgess (2003) did not consider the threats of plant pathogens as potential bioterrorism weapons, an aspect currently exercising the minds of those considering international and national 'strategy' (i.e. the art of war). The potential importance of plant pathogens as weapons is obviously great, and the principles alluded to by Burgess apply equally to deliberately introduced biosecurity incursions; plant pathology and plant pathologists have important roles to play in preventing biosecurity threats to agrarian production and natural plant communities.

Integrated disease management

It has long been accepted that integrated systems are important for sustainable management of the problems caused by plant pathogens, pests and weeds for crop production, and for maintenance of natural plant ecosystems. Ehrler and Bottrell (2000) summarise the move towards integrated pest management (IPM) for crops in the USA, a system which was articulated for insect management in the 1950s, which became national policy in 1972, and which now includes animal pests, pathogens and weeds. IPM has been widely advocated as a sustainable approach to management of pest organisms. For example, the Consultative Group for International Agricultural Research (CGIAR) has strongly advocated IPM methods (see World Bank 1997). The CGIAR has a vision that will, 'through research and related activities, . . . contribute to sustainable improvements in the productivity of agriculture, forestry and fisheries in developing countries in ways that enhance nutrition and well being, especially of low-income people.' Pursuing this mission, the CGIAR recognises the key role of IPM in agricultural development, affirming that IPM principles should guide all pest control efforts.

Integrated pest management has been defined (World Bank 1997) as: 'ecologically-based pest management that promotes the health of crops and animals, and makes full use of natural and cultural control processes and methods, including host resistance and biological control. It uses chemical pesticides only where and when the above measures fail to keep pests below damaging levels. All interventions are need-based and are applied in ways that minimise undesirable side-effects.'

Effective management of plant diseases increasingly involves application of several different individual control methods. Development of effective chemical, biological and genetic (host resistance) disease controls usually requires direct input from plant pathology. Increasingly, however, interactions between plant pathology and other research disciplines are required to develop these methods. An example is development of disease-resistant cultivars. This requires identification of resistant germplasm using appropriate disease screening methods, and, increasingly, assistance from molecular technologies for identification of host resistance genes (marker-assisted selection). Plant pathology expertise is also important for characterisation of pathogens, determining pathotype variability, and developing appropriate disease assessment methods. Plant breeding is an essential component for determining the genetics of host resistance and introducing resistance characters into new cultivars, which must also have other characters required by consumers. Agronomic evaluation, and cultivar propagation, distribution and marketing skills are required to incorporate the new cultivars into crop production systems.

Collaboration: intra- and inter-disciplinary research for integrated disease management

The pesticide revolution of the second half of the 20th Century has dramatically improved the efficiency of plant disease control, as the specificity of activity of pesticide compounds has increased. This has required appropriate pesticide resistance management strategies, which have been increasingly adopted. Chemical methods for plant disease control now often involve multiple chemical compounds applied in mixtures or in rotations (see Delp 1988).

The widespread use of synthetic chemicals for control of plant pests, including diseases, has increasingly come under threat, with concern about the potential, perceived and actual deleterious effects of the introduction of these compounds into agricultural and natural ecosystems. Modern products for control of plant diseases caused by fungi generally have very low mammalian toxicities, although they may have deleterious effects on beneficial organisms in ecosystems. Other pesticides (particularly insecticides, nematicides and soil fumigants) are likely to have more directly dangerous effects on human and environmental health. These problems, coupled with wider social, environmental and economic factors, have hastened the move towards methods for managing plant diseases that take more comprehensive (integrated) approaches.

Effective integrated management of a particular plant disease requires an understanding of whole crop systems. While crop production has moved towards monocultures, there is increasing recognition that crop rotations are important for maintaining plant health, so management of a particular plant disease must consider effects that apply at temporally divergent stages as well as within the crop in question. Crop cultivars vary in susceptibility to diseases, so cultivar or variety choice must be a component of disease management. Disease intensity/crop loss models must be applied to determine the thresholds for application of particular control methods. Information from disease epidemiology can help predict the likelihood of a disease occurring, and direct and targeted pesticide control methods can then be applied if necessary.

Effective integrated disease management is a goal sought, but difficult to achieve. The complexities of factors involved mean that simple solutions are unlikely. This applies across all plant disease systems, but is particularly the case for soilborne diseases. We are increasingly coming to the conclusion that integrated approaches are essential for management of soilborne diseases because individual disease control methods usually do not completely eliminate the effects of the pathogens involved. Many of these diseases have posed intractable problems for growers, increasing in importance as crop production systems have intensified. A multiplicity of disease control methods, applied before and throughout individual crop growth cycles, is the only means by which reasonable levels of control can be achieved. An exception is with soil sterilisation using economically and environmentally acceptable methods – the possible solution in highly intensive crop production systems where land areas are small and environmental control is complete.

Some Australasian examples illustrate this well. Recent work (Donald *et al*. 2004) has made excellent progress with management of clubroot, a disease that has long been a problem for growers of vegetable brassicas. Appropriate control methods include crop rotation strategies, sensitive pathogen detection to identify levels of disease risk, possibly resistant plant cultivars, disease-free planting material, application of appropriate crop hygiene methods and targeted application of effective pesticides. Similarly, management of powdery scab of potato (Falloon 2006), a disease of increasing importance as potato production has intensified, now involves a range of control methods (crop rotation and field differentiation, pathogen detection, manipulation of the abiotic (chemical) soil environment, healthy propagation material, host resistance, pesticides, crop management). Recent work on take-all of wheat (Cromey *et al*. 2004), long a severe problem for growers, is using molecular technology for pathogen detection and assessment of disease risk, and identifying crop rotation practices likely to minimise occurrence of the disease. As well, chemical and biological methods are being investigated for take-all control. Effective management of Allium white rot (Stewart and McLean 2004) is likely to involve chemical, biological and cultural control methods, with considerable progress being made to integrate biological controls (fungal antagonists) with chemical pathogen stimulants, fungicides and crop fertilisation strategies to optimise control of this important disease.

Multi-disciplinary approaches are essential to understand the multiplicity of factors involved across integrated disease management systems. Again, soilborne diseases are good examples. Many biotic and abiotic factors are involved in the survival of inoculum of soilborne pathogens during non-host periods (crop rotations), and elucidation of these is likely to involve pedology (particularly soil chemistry), soil biology, aspects of agronomy and the broader plant sciences. Plant breeding and genetics will assist application of host resistance as a control strategy, and understanding of practical, modern crop production methods is essential for effective implementation of integrated disease management.

Appropriate disease management must also take full cognizance of the most important human dimension in crop production, the growers. Implementation is likely to be complex, requiring expertise across the spectrum of crop production. For example, effective methods for detection of soilborne pathogens (bioassays, immuno-absorbance methods, DNA technologies) require high levels of expertise for development, and probably for effective implementation and interpretation. Grower education, appropriate knowledge transfer to growers, and grower assistance from experts, are all essential components of effective integrated disease management.

A tempering viewpoint

Ehrler and Bottrell (2000) have presented a tempering viewpoint on IPM. They point out, for the United States, that true IPM has been implemented for only 4–8% of the crop area, suggesting several reasons for the lack of adoption of true IPM. These include high levels of sophistication and cost of the systems, high levels of complexity in agro-ecosystems, pest monitoring that is too simplistic for rational decision-making, very long research timeframes to determine dynamic pest thresholds, and that economic thresholds may not hold for some pests (particularly those with prolific and difficult-to-detect seed progeny or inoculum). It is very likely that integrated systems will be even more difficult to apply in agrarian systems less sophisticated than the USA, such as those in many developing countries.

Conclusions

Plant diseases will continue to pose problems for production of food crops, other agrarian activities, and in natural environments. Factors affecting our research discipline include increasing human population pressures with expanding global requirements for food and fibre, escalating demands for high-quality food products from environmentally sustainable production systems, and increasing requirements for environmental stewardship, both within and across international, political and regional boundaries.

Plant pathology will continue to provide knowledge advances in the basic biology of the interactions between host plants, their pathogens and the environments in which they grow. Our science will also be a key component in the development of economically and environmentally sustainable crop production systems, for preservation of plants to enhance social environments, and to maintain the heritage values of natural ecosystems. Collaborative, multi-disciplinary approaches, both within and outside the traditional boundaries of plant pathology, are essential for alleviation of the problems caused by plant diseases.

Sustainable use of the world's resources is becoming increasingly regarded as essential for continuation of human civilisation. Full sustainability will obviously be achieved only with progress across all human activities that demand use of the world's natural resources. Plant pathology, through sustainable strategies for management of plant diseases, will continue to play a significant role in support of sustainable human development.

The continuing expansion of human population and cultural development is having grave effects on the ecosystems of the world, and globalisation is making the world a single ecosystem for our species. There is a growing perception that *Homo sapiens* is on the verge of self-destruction, with the climaxing of the population of our species, and our global civilisation. Wright (2004) encapsulated this view: 'As we domesticated plants, the plants domesticated us. Without us, they die; without them, so do we. There is no escape from agriculture except into mass starvation. … Most people, throughout most of time, have lived on the edge of hunger – and much of the world still does.'

Our discipline will be able to assist only by taking holistic approaches, developing disease management systems that take consideration of all aspects of sustainable plant protection and crop production. Furthermore, we must take international collaborative approaches, and place our findings amongst those beyond the plant sciences, to develop holistic methods for management of plant diseases. Possibly above all, for these essential collaborative approaches to be fruitful, we must include growers and consumers of food and fibre products in the integration and collaboration continuum. This will help ensure that plant pathology continues to assist in the quest for economically and environmentally sustainable food and fibre production, to help sustain and advance the social structures and physical environments of our civilisation.

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