2. A REVIEW OF THE USE OF INTERCROPPING IN DISEASE CONTROL

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INTRODUCTION

Intercropping, that is, the growing of two or more crops simultaneously on the same area of land, is widely practised by small farmers in tropical countries. This system, at one time regarded as primitive, is now perceived to have significant advantages. Of these, better use of available land and reduced risk of losses from diseases, pests and weeds are of particular importance (11).

It is not surprising that diseases tend to be less severe in intercrop systems (Table 1). It is a part of the conventional wisdom of plant pathologists that large scale cultivation of genetically uniform crop plants favours the development of disease epidemics. By the same token it is to be expected that mixed cropping or intercropping should reduce the risks of epidemic disease.

The question must be asked, however, whether the reduction in disease achieved by intercropping is sufficient to preclude the need for other control measures. The answer to this question may well vary for different locations, different intercrop components and for different diseases. A subsidiary question but one of great importance is whether the benefits of intercropping can be improved by detailed modification of the system eg by choice of more suitable crop cultivars or by modification of the planting pattern.

Answers to these questions are urgently needed. They may enable better agronomic practices to be introduced and also enable attention to be focussed on specific diseases which require the introduction of additional control practices.

Research into disease development in intercrop systems is not likely to be easy but it need not be an entirely "hit or miss" affair. In the past two decades there has been intensive research into the interaction between pathogens and heterogeneous plant populations. These studies provide important clues concerning the mechanisms whereby epidemics are diminished in severity and indicate how intercrop systems may be modified to improve disease control.

MULTILINES AND MIXTURES

In Europe and North America the major small grain cereals (wheat, barley, oats) are inbreeders and cultivated varieties are genetically highly homogeneous. Moreover, individual varieties are planted on a vast scale offering the maximum opportunity for epidemic development of pathogens. Control of foliar pathogens, particularly rusts and powdery mildew, by means of resistant varieties has been bedevilled by pathogen mutation. As fast as the plant breeder introduces genes for resistance so does the pathogen produce mutant forms capable of overcoming them. To deal with this dilemma, plant breeders and plant pathologists have attempted to develop new strategies of exploiting host resistance. Broadly speaking these fall into two groups: (i) increasing diversity within the crop and (ii) increasing diversity between crops. The first has a relevance for intercropping: the latter does not.

To increase diversity within crops, two approaches have been attempted. The first is to use multilines, i.e. mixtures of near-isogenic lines differing only in specific resistance genes. This approach was advocated by Jensen (16) and Borlaug (2). Browning & Frey (4) developed the first multiline in oats to combat crown rust (*Puccinia coronata*). The benefits in terms of reduced disease development and increased yield were clearly demonstrated. Nevertheless multilines have not been widely adopted, largely because of the time required for their development. For this reason Wolfe (28) who was particularly concerned with powdery mildew of barley (*Erysiphe graminis* f. sp. *hordei*) chose to use mixtures of existing cultivars containing different resistance genes in an attempt to reduce its severity. In the present context the work of Wolfe and his colleagues is of particular importance because, in addition to showing that disease progress was reduced in cultivar mixtures they also attempted to elucidate and quantify the mechanisms involved (8).

Before these studies were undertaken a number of mechanisms had been proposed to account for the reduction in disease in multilines and mixtures. Some (19,4) considered interception of spores by resistant plants was of major importance whilst others (5,6) placed emphasis on reduction in density of susceptible plants. A further mechanism suggested was induced resistance or cross protection (3,17). From their studies Chin & Wolfe (8) were able to conclude that all three mechanisms operated in cultivar mixtures designed to control powdery mildew of barley. Their relative importance, however, varied depending on the stage of crop and epidemic development, and on the host and pathogen genotypes.

Although most of the studies on pathogen development in heterogeneous plant populations have been concerned with race-specialised pathogens it is important to note that mixture benefits also occur with non-race specialised pathogens as shown by Jeger *et al* (14) for the interaction between *Septoria nodorum* and cultivar mixtures of wheat. In this situation cross protection probably does not play a significant role; barrier and density effects are presumed to be the principal mechanisms involved.

In mixtures of crop species it is to be expected that all three mechanisms identified by Chin & Wolfe (8) (and possibly others so far unidentified) may play a part in reducing disease severity.

Table 1: Published reports of effects of intercropping or mixed cropping on disease severity, 1981-1986. (Source: Review of Plant Pathology).

Crops	Diseases increased (I) or decreased (R)	Reference
Beans/maize	Pseudomonas phaseolicola(R) Collectotrichum lindemuthianum(R) Xanthomonas phaseoli(R) Elsinoe phaseoli(R) Phoma exigua var diversispora(R) Erysiphe polygoni(R)	Rheenan et al. (1981)
Potatoes/lupins Potatoes/beans	Potato diseases significantly reduced when intercropped(R)	Steiner, (1982)
Maize/legume	Ustilago maydis increased by 50% in mixed crop(I)	Hegewald (1984)
Cocoyams/plantain	Sclerotium rolfsii on cocoyam(R)	Igbokwe et al. (1984)
Pigeon pea/sorghum	Pigeon pea sterility mosaic virus (I)	Bhatnagar et al. (1984)
Okra/pumpkin	Yellow vein mosaic virus in Okra(I)	Khan & Mukhopadhyay, (1985)
Cocoa/coconut Cocoa/Leucaena	Pests and diseases less with coconut as shade trees than with Leucaena leucocephala(R)	Smith (1985)
Vigna mungo/V.radiata	Yellow mosaic virus on both V.mungo and V.radiata(R)	Dasgupta & Chowdhury, (1985)
Cotton/Vigna radiata Cotton/Vigna mungo	Stenosis in cotton(R)	Padaganur et al, 1985
Oat/barley/wheat	Puccinia coronata(oats)(R) Erysiphe graminis(wheat)(R) Helminthosporium teres(barley)(R)	Dzietror, 1985
Beans/maize	Web blight of beans(R) Espinosa (1986)	Rosada May & Gracia
Chickpea/linseed	Wilt of chickpea (Fusarium oxysporum f.sp. ciceri)(R)	Chattopadhyay & Bagchi (1986)

PLANTING PATTERNS

In multilines and cultivar mixtures of cereals, individual genotypes are randomly distributed but this is not normally the case with intercropping. Variation in planting pattern may be considerable, and it is important to enquire whether different patterns significantly influence disease development. Recent studies using both computer simulation and field experimentation offer some clues. Computer simulation of situations in which the distribution of susceptible and non-susceptible individuals is varied (20, 21) have indicated that clustering of susceptible individuals, even though they comprise the same proportion of the population, decrease the benefits of the mixture effect. Support for this conclusion has been provided by field studies using intraspecific mixtures of beans and maize (22).

These results have obvious implications for intercropping systems and indicate that investigation of planting patterns is likely to be rewarding.

CONCLUSIONS

Evidence from many studies on diverse intercrops indicates that in general disease is likely to be less severe than in pure stands. Experimental data from multilines and cultivar mixtures of small grains (wheat, barley, oats) of maize and of beans all show that genetic diversity depresses the rate of epidemic development of pathogens. Because the basic mechanisms contributing to the mixture benefit are becoming better understood, the effects of mixtures on disease development can now be analysed in these systems by computer simulation.

It may well be that the situations presented by intercropping are more complex than in multilines and cultivar mixtures but as understanding of intercropping effects increases there seems no reason why it should not be possible to provide computer models which will enable refinements to be made.

At the present time two specific recommendations can be made which should enhance the benefits of intercropping in terms of disease reduction. First, intercropping should minimise clustering of individual components as far as possible: second intercrop components should, if possible, be genetically diverse.

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