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DAMPING-OFF AS A CONSTRAINT TO INCREASED GREENHOUSE PRODUCTION IN OMAN

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Abstract

Pythium species are the main biotic constraint to increased production in the greenhouses of Oman. *Pythium aphanidermatum* predominates as the cause of damping-off although *P. spinosum* and *P. splendens* are also common causes of the disease. Severities of damping-off are exacerbated by continued monocropping of cucumber as growers produce 3 or even 4 crops per season. The disease is most severe during the warmer seasons – a reflection of the temperature requirements of the dominant pathogen. All cucumber varieties are susceptible to the disease and local growers use excessive amounts of fungicide, especially metalaxyl to try to limit losses. Epidemics are usually short lived but severe with as many as 20% of seedlings killed within 2 weeks of transplanting. Analysis of the spatio-temporal dynamics of the disease suggests that the epidemic begins at isolated infected individuals. With time, disease foci expand to include neighbouring plants within each row. Expansion of local foci is probably a result of plant to plant infections, local differences in pathogen density in the soil, and environmental factors, especially poor distribution of fungicide around individual plants. Rapid biodegradation of metalaxyl in the soil as well as poor application methods contribute to poor management of the problem. On a regional basis, damping-off is more severe in greenhouses which also have high irrigation water salinities. *Pythium aphanidermatum* has the ability to grow and reproduce at EC levels beyond the upper tolerance limit of cucumber, suggesting synergism between water quality and pathogen activity.

Key words: Greenhouse, cucumber, damping-off, *Pythium*, epidemic analysis

INTRODUCTION

The growth of the greenhouse crop production sector in Oman over the last decade has been dramatic. In the last 5 years alone the number of farms with greenhouses and the total number of greenhouses has increased several folds. To some extent this has been stimulated by financial subsidy from the Ministry of Agriculture and Fisheries, nonetheless considerable private investment has taken place. Greenhouses are clustered along the coastal highway that runs from the capital, Muscat, to the larger towns and onward to Dubai. The greatest increase in greenhouse number has occurred in the agricultural areas closest to Muscat.

Greenhouses are cooled using fans drawing air across water-soaked pads, and are generally 30 m long and 9 m wide. Almost all greenhouses are used to grow cucumbers. Most farmers utilise three seasons per year; relatively few include a fourth summer season when outside temperatures reduce profit margins because of excessive electricity consumption for cooling. For convenience, the seasons can be labelled according to planting date as: Season 1 (August, September, and October), Season 2 (November, December, and January), Season 3 (February, March, April) and Season 4 (May, June, July). Yields are highest in Season 2 and generally reduce as the temperature rises. Overall yields range between 2000-8000 kg per greenhouse per season. With each greenhouse containing between 700 and 960 plants in it, usually 6 double rows, this equates to 3.0-11.0 kg per plant. The principal constraints to production are salinity and disease (Kiyoomi et al., 2007). Salinity is rising along coastal northern Oman. This is primarily because of excessive groundwater pumping to satisfy the needs of an expanding agricultural sector. Seawater intrusion has raised salinity levels, especially where agriculture is most intensive. The principal disease constraints are fungal, primarily damping-off disease (*Pythium aphanidermatum*), downy mildew (*Pseudoperonospora cubense*) and flower and fruit rot (*Fusarium*, *Alternaria*, *Botrytis* and others, (Deadman et al., 2007).

CURRENT FARMER PRACTICE

As part of a detailed, multi-level survey of farmer practice over 60 farms in the northern region were visited and information collected on disease and pest prevalence, pesticide use, yields, irrigation, fertilizer use and other cultivation techniques. The results showed that damping-off disease is most intense during the warmer seasons. The relationship between disease intensity and temperature reflects the higher temperature optimum for growth in *P. aphanidermatum* relative to other species of *Pythium* and other damping-off pathogens, such as *Rhizoctonia*. It is most likely that yields actually reflect the level of crop management expertise, and farms with lower husbandry skills available get lower yields in part because of poor disease management. In response to disease, growers use excessive amounts of fungicide; over 45 applications per season (about 90 days). The active ingredients applied most commonly include metalaxyl (usually with mancozeb), tolclofos methyl, propamocarb and hymexazol. However, many other active ingredients are applied, often without knowledge of target organism, dose, frequency or harvest interval. Instances of misdiagnoses are common and consequently incorrect product application is frequent. Disease problems are exacerbated by cucumber monocropping.

Many farmers also over irrigate and over apply fertilizers. In both cases, an increase in disease intensity is likely. Over irrigation is often rationalised as necessary to reduce salinity. In other cases farmers replace the greenhouse soil, perhaps as frequently as every 3 years. This involves excessive expenditure and is of dubious sustainability. Farmers also replace the soil when pathogen population levels become too high. Some farmers solarise their soil, especially when no crop is planted in the summer. However, solarisation usually only involves allowing the soil to remain fallow during the hottest part of the year. Other growers use soil fumigants, including formaldehyde. Prior to planting, many farmers ridge the soil, planting the crop on raised beds in an attempt to improve drainage and reduce disease levels.

In view of the seriousness of damping-off and the level of irrational pesticide use, a detailed study of the epidemiology of the disease is currently being undertaken. The purpose is to analytically examine farmer practice with a view to identifying best practice in relation to disease management.

ANALYSIS OF DAMPIN G-OFF EPIDEMICS

Within greenhouses damping-off is usually observed spatially as a two stage process. Isolated individual plants become disease and represent foci of infection. The probability of an individual becoming a disease focus depends on the density of pathogen inoculum in the soil, the random distribution of this pathogen, the application of any pesticides prior to planting and to some extent the position of the plant in the greenhouse. Following focus establishment, disease spatially proceeds along the rows. The speed and extent of this secondary spread depends on factors such as temperature, irrigation and soil wetness. Conceptually of course this two phase process is the equivalent of the van der Plank (1963) model for compound interest-like increase in disease where $X = X_o e^{rt}$, with X_o in this case representing the amount of primary foci and r representing some measure of the extent of secondary spread. In practice growers are faced with gaps in the rows of cucumber plants the size of which vary from season to season, vary with location, and a whole host of other factors.

The extent of the secondary spread within the greenhouse can be quantified by the calculation of a simple Singles Index (SI) where the number of isolated infected plants is divided by the total number of infections. Clearly, as disease intensity increases, the SI value would be expected to fall, even if disease remained randomly distributed in the greenhouse. In reality and in the majority of greenhouses the observed SI is significantly lower than expected, were disease to be spatially random.

Temporally, disease increases in a non-linear pattern. Initial rates of increase are very high and quenching is rapid in most epidemics with few new diseased individuals appearing after 30 or so days. In some cases new disease continues to appear throughout the season. In modeling disease progress using purpose-written PVWave code, the progress of primary and secondary disease can be analyzed by separately accumulating isolated disease individuals and disease occurring in plants next to locations already “occupied” by disease. Series of non-linear functions can then be used to estimate regression parameters. This results in rate curves and cumulative curves for primary and secondary disease. Subsequent examination provides biologically relevant and quantifiable information on epidemic characteristics including time to first primary disease and maximum primary disease, the time lag to secondary disease initiation and maximum secondary disease, and the final level of primary and secondary disease. Epidemic quenching can be visualized by the extent to which the rate curves are skewed. Temporal and spatial dynamics can be visually combined to provide a graphical surface that represents the change in cluster size over the course of the epidemic.

Data from over 25 naturally occurring damping-off epidemics has been collected to date. This data indicates an average loss of 6.7% of plants. The average time between planting and the first appearance of disease is 9 days, although it was a little as 2 days in some greenhouses. On average new disease continued to appear over a 30 day period. Maximum disease level, areas under disease progress curves and non-linear function parameters for asymptotic disease levels were all correlated with the average temperature during the growing period. Disease levels were lower where growers used raised beds to cultivate the crop.

The epidemics could be classified as fast or slow, early or late and stepped or smooth. Epidemics with low SI values, i.e. those with highest levels of non-randomness were those with the most marked step-shaped progress curve. This would appear to confirm the two phase process in disease progress, with primary and secondary spread both contributing to overall disease increase. Clumpiness in the epidemics, however, as quantified by the SI values did not appear to be related to season of production, temperature or variety. However, ongoing studies will determine whether SI or the ratio between primary and secondary disease is affected by cropping history.

CONCLUSIONS

Damping-off disease is the most important biological constraint to greenhouse cucumber production in Oman. Average losses of over 6% of seedlings are common, with much higher losses occurring on many farms, especially where crop management practices are poor. In response many farmers use excessive levels of fungicides, usually without heed to appropriateness for the particular problem, dose, frequency or harvest interval. In order better to understand how disease increases in greenhouse cucumbers, data on natural epidemics has been collected and is currently being analyzed to determine the effect of farmer practice on disease dynamics. Models of disease progress are able to distinguish between the temporal progress of primary and secondary disease. Spatial progress can be quantified and combined with temporal progress. This will provide valuable quantifiable information on the effectiveness of disease management practices.

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