Inoculum Dose, Diversity, Dispersal, and Damage: Simulating Optimal Economic Control of an Aerially-Dispersed Plant Pathogen at the Regional Scale

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Abstract

Plant pathogens that disperse by airborne propagules may cause damage that extends beyond the borders of individual fields. Developing sound management strategies therefore requires consideration of heterogeneity in pathogen transmission, the effectiveness of control measures, host susceptibility and pathogen virulence, and the resulting economic outcomes that scale up at regional or landscape level. We use hop powdery mildew as a motivating pathosystem to develop a coupled epidemiological-economic model to enable simulation of the impact of epidemic conditions and management interventions on profitability. This pathosystem is a well-suited case study because disease development may be limited by primary inoculum and fungicide applications, yet the pathogen can spread via long-distance dispersal between fields and rapidly damage both crop yield and quality. We parameterized the model using data collected from a census sample of commercial hop yards in Oregon during 2014 to 2017, including the monthly incidence of plants with powdery mildew, fungicides applied by growers, and estimated revenue depending on how the incidence of diseased hop cones affects yield and the likelihood of crop devaluation. We show that conditions in the early stages of epidemics related to primary inoculum

dose, pathogen diversity, and early season management intervention interact and determine the optimal regional control strategy. As the likelihood of primary infection increases, due to either the dose of primary inoculum or virulence of the pathogen population, mean profitability decreases. Occurrence of primary inoculum in yards more central in the network had a smaller but detectable effect on profitability. Whereas there is a not a single optimal control strategy when primary inoculum is rare, as primary inoculum increases, fungicide applications made in the early stages of epidemics display a bimodal effect on profitability and increasingly intensive control measures become warranted to limit crop damage. Under an assumption of increasingly stringent quality standards under low market demand, we demonstrate that the economic optimal control strategy is to increase fungicide applications to reduce the likelihood of crop devaluation or rejection. Our research allows for new insights into optimal control to inform disease management strategies.

Keywords: plant disease, pathogens, epidemiology, economic impacts, disease management, landscape-scale