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Dispersal and population simulation model of spider mites and a phytoseiid predator in the corn plant microenvironment

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DISPERSAL AND POPULATION SIMULATION MODEL OF SPIDER MITES AND A PHYTOSEIID PREDATOR IN THE CORN PLANT MICROENVIRONMENT

by

James S. Berry

A DISSERTATION

Presented to the Faculty of
The Graduate College in the University of Nebraska
In Partial Fulfillment of Requirements
For the Degree of Doctor of Philosophy

Major: Entomology

Under the Supervision of Professors Thomas O. Holtzer
and John M. Norman

Lincoln, Nebraska

May, 1988

DISPERSAL AND POPULATION SIMULATION MODEL OF SPIDER MITES AND A PHYTOSEIID PREDATOR IN THE CORN PLANT MICROENVIRONMENT

James S. Berry, Ph.D.
University of Nebraska, 1988

Advisors: Thomas O. Holtzer and John M. Norman

Within plant dispersal of Banks grass mite (BGM), Oligonychus pratensis (Banks), and twospotted spider mite (TSM), Tetranychus urticae Koch, was evaluated through field experiments. Mites were introduced onto host plants at three levels in the canopy: flag leaf, ear leaf and third lowest leaf. Mites introduced onto the flag leaf survived poorly and moved to the lower parts of the plants. Both BGM and TSM did the best on the middle and lower leaves. TSM was more likely to disperse both upwards and downwards from the infested leaf than BGM.

Dispersal behavior of the predatory mite (NEO), Neoseiulus fallacis (Garman), was evaluated by simulating walking patterns for various prey and temperature combinations. The results were that NEO exhibited a random walk type of search more frequently at moderate to high prey densities (search for prey within a prey patch) and a very non-random, directional search more frequently at low prey densities (search for new prey patches). The non-random search allows the mite to closely follow leaf edges and quickly travel substantial distances in search of new prey patches.

A simulation model of the mite predator/prey system consisting of BGM and NEO was developed and validated. This model included the effects of temperature, humidity and predation and was coupled to a detailed plant canopy model. Results demonstrated the importance of using leaf surface conditions instead of weather station conditions to simulate the mite system on corn in Nebraska. Also, humidity was determined to be critically important (in addition to temperature) in NEO/BGM population dynamics. The temperature and humidity at the leaf surface of moderately drought stressed corn (compared to well watered corn) resulted in higher populations of BGM. Simulation studies also showed that colonization of a corn field by less than 1 adult female BGM/plant in June can result in crop destruction by August.

TITLE

Dispersal & Population Simulation Model of Spider Mites & a

Phytoseiid Predator in the Corn Plant Microenvironment

BY

James S. Berry

APPROVED	DATE
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General Introduction

Introduction

In Nebraska corn, spider mites and their phytoseiid mite predators are affected by microenvironment, the corn plant, disease and predatory insects. Microenvironmental variables (especially temperature and humidity) have been shown to be of fundamental importance. Temperature and humidity effects on developmental rate, fecundity, and longevity of Banks grass mite (BGM), Oligonychus pratensis (Banks), were evaluated under laboratory conditions by Perring et al. (1984a,b). Also, Perring et al. (1986) experimentally examined the effects of microenvironment in the field. They showed that drought stressed corn had higher leaf temperatures and greater populations of spider mites than non-stressed corn (Perring et al. 1986). In addition, computer simulation was used to further evaluate the effects of temperature, but not humidity, on BGM under field conditions (Toole et al. 1984). These studies represent a substantial gain in understanding the effects of microenvironment on the population dynamics of spider mites in Nebraska corn fields. However, several questions have arisen from the results of these studies.

Additional factors may influence spider mite populations. The nutritional value of the plant may be important. For example, drought stressed corn may have higher concentrations of certain nutrients or fewer allelochemicals. Although Perring et al. (1983) were unable to show a definitive relationship between spider mite populations and plant chemicals, additional investigation should be pursued. Microenvironmental variables also may have important indirect effects on the spider mites through effects

on predatory mites. Finally, predators and diseases may fluctuate for reasons unrelated to microenvironment and cause major changes in both the spider mite and phytoseiid mite populations.

The objective of this study was to further evaluate microenvironmental factors as they affect mite (both spider mites and phytoseiids) population dynamics in Nebraska corn fields. Some microenvironmental variables may directly influence spider mite and phytoseiid population growth rates. For example, mite developmental (Perring et al. 1984b, J.C. Heintz personal communication) and phytoseiid consumption (J.C. Heintz personal communication) rates are temperature dependent. In addition, oviposition rates and longevity are mediated by both temperature and humidity (Perring et al. 1984a, J.C. Heintz personal communication). Microenvironment also can affect population dynamics by affecting spider mite behavior (Mori 1961). Dispersal behavior is important for spider mite management because control recommendations are based in part on the location of the spider mites on the plant. In Nebraska, economic thresholds for mites are defined in terms of vertical distribution of spider mites and plant damage through the canopy (Peters et al. 1986). Dispersal also can affect the potential for biological control of spider mites by phytoseiid mites (Nachman 1987). Movement of both the spider mites and their phytoseiid predators can influence the spatial coincidence of the two species and thus help or hinder the phytoseiid mites search for and reduce the prey.

Chapter 1 presents the results of studies designed to evaluate the effects of microenvironmental variables on spider mite dispersal in the field. In Chapter 2, phytoseiid mite dispersal behavior is examined as a function of temperature and prey

density. A detailed simulation model of the spider mite/phytoseiid mite system, which includes the effects of temperature and humidity, was developed and coupled to a plant canopy model. With this model, mite population dynamics can be simulated using the microenvironmental conditions at the leaf surface, where the mites are found. A description of the mite model and its validation are presented in Chapter 3. In Chapter 4, the model was used to examine the importance of microenvironment on field populations of spider mites and phytoseiid mites. Implications of these simulations to mite management and ecology are also discussed in Chapter 4.

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Chapter 1

Vertical Dispersal of Twospotted Spider Mite and Banks Grass Mite in Relation to Environmental Conditions in the Field

Introduction

Many animals must travel from one location to another to satisfy their physical needs. In some species large scale migrations serve to move entire populations to more favorable and distant locations (see Stinner et al. 1983 for a review). Another type of movement is dispersal over short distances by individuals within a general habitat. The purpose of this study was to investigate the effects of environmental factors on short distance mite dispersal of two species of spider mites, Banks grass mite (BGM), Oligonychus pratensis (Banks) and twospotted spider mite (TSM), Tetranychus urticae Koch.

Considerable laboratory work has been carried out that relates environmental factors to mite locomotion and aerial dispersal. For example, light quality and quantity (Mori 1961, 1962a,b, Hussy and Parr 1963, Suski and Naegele 1963, McEnroe and Dronka 1971), humidity (Hussy and Parr 1963, McEnroe and Dronka 1971, Margolies 1987) and temperature (Mori 1961, 1962a, Penman and Chapman 1980) have been shown to affect spider mite dispersal. However, no studies have related environmental conditions to mite dispersal under field conditions.

BGM (Logan et al. 1983) and TSM (Peters et al. 1986) are generally found on the lower leaves of corn plants. As populations build on lower leaves, mites begin to move upward and colonize the rest of the plant (Peters et al. 1986). These observations raise the question: do spider mites select or prefer lower leaves (as opposed to upper leaves) or do they merely infest lower leaves first and then move up as the leaf