Tritrophic level interactions in Ethiopian tomato systems: effects of plants on potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae) and its parasitoids

Thesis submitted for the degree of

Doctor of Philosophy

By

Bayeh Mulatu Aregay

Submitted to the Senate of the Hebrew University of Jerusalem

January 2003

ABSTRACT

The potato tuber moth (PTM) *Phthorimaea operculella* (Zeller) has become a major tomato fruitworm in warm and dry environments in Ethiopia. In susceptible cultivars it may cause up to 100% fruit loss. However, early reports indicate that the effects of tomatoes on PTM are often negative. What, then, are the possible causes for the increasing importance of PTM on tomatoes in Ethiopia? Both plant quality and natural enemies influence the population ecology of herbivores (review by Hunter et al., 1997). Perhaps tomato cultivars in Ethiopia are susceptible to PTM; while the latter's natural enemies are not effective. On the other hand, the tomato cultivars may be suboptimal hosts, and the PTM is protected from its natural enemies either directly by the tomatoes or indirectly through what it may acquire from them. Either of these conditions might have allowed the PTM to increase its population and cause economic damage. The overall objective of this study was therefore to assess the possible causes for the increased economic importance of the PTM on tomatoes in Ethiopia. The specific objectives were:

1. to determine the rates of field infestations by PTM on three tomato cultivars, in tomatoes grown alone and in the presence of a proximate potato crop;
2. to establish the importance of tomato leaf trichomes for oviposition preference and larval settling of PTM on the three tomato cultivars;
3. to study the effects of the three tomato cultivars on PTM survival, growth and development and relate them to the content of the tomato alkaloid α-tomatine in foliage and fruits;
4. to determine the role of natural enemies as mortality factors for PTM on tomatoes.

In all four objectives, three different tomato cultivars were compared: cherry (small fruit), processing (medium sized fruit) and fresh market (large fruit). First I studied the natural infestation rates of PTM on these cultivars, in the absence and presence of a proximate potato crop. The tomatoes were planted in plots alone in 1999-2000 and with proximate potatoes in 2000-2001. The activity of adult PTM was monitored daily using sex pheromone-baited traps, and leaf and fruit damage were recorded weekly by randomly sampling 25 plants at a time per plot. In the lone tomato plots, there were no significant differences in adult PTM activity on the three cultivars. However, the larval population buildup and associated leaf damage were significantly higher on the cherry than fresh market tomato. In the presence of proximate potato, neither the adult activity nor larval population buildup and associated leaf damage were significantly different among the tomato cultivars. In the lone tomato plots, there was significantly higher fruit infestation of the fresh market cultivar and a similar result was obtained in the presence of proximate potato. However, fruit infestation pressure was low until after the latter crop's harvest. Under both planting conditions, only natural infestations of fruits by the PTM were significantly correlated with the trap census. It was concluded that there is variation in the susceptibilities of the tomato cultivars to PTM, and that the presence of potato influences these responses.

The causes for these variations in susceptibility were then investigated. The importance of leaf trichomes in oviposition preference and larval settling of PTM were studied with the three tomato cultivars. The choice of host plant was studied in an exclusion cage by planting the tomatoes in a completely randomized design. Twenty-five

pairs of PTM pupae were introduced per locus at six equally spaced loci and weekly records of leaf infestation levels were made. The PTM showed significant preference for the cherry cultivar with the densest leaf trichomes, but in an oviposition cage where an ovipositing female was allowed to choose among the tomato cultivars and the potato, it oviposited significantly more eggs on the latter.

Leaf discs cut from fully expanded young, healthy leaves of the three tomato cultivars were used to determine the density of the type VI glandular head trichomes on the foliage of the three tomato cultivars. The settling responses of neonate larvae under the leaf sheaths of young, fully expanded, healthy leaves from the three cultivars, both before and after washing off the leaf trichomes, were also determined at the preblossom and blossom stages. Although the density of the type VI glandular head trichomes was significantly higher on the cherry cultivar leaves, there were no significant differences in the settling of neonate larvae among the tomatoes at either plant stage. It was concluded that leaf trichomes do not impart resistance to PTM and may in fact allow the PTM to successfully colonize the tomato cultivars.

The third objective was to determine through leaf- and fruit-feeding assays, the effects of the three tomato cultivars on the moth's survival, growth and development, and to relate these effects to the amounts of α-tomatine, the major allelochemical in tomatoes. Leaf-feeding assays were carried out in petri dishes with detached leaflets. One neonate larva was introduced into each petri dish and development followed until completion or death. The study was carried out using leaves from plants at preblossom and blossom stages. The assays were run in a growth chamber at 24°C, 12L:12H and 70% RH. Data were collected on larval survival, development time for each of the four larval instars,

body weight and length of wandering larvae, pupal weight and larva-adult development time. More larvae survived on the cherry cultivar at the preblossom stage. At the blossom stage, there was reduced larval survival on all tomato cultivars, which was most pronounced on the fresh market cultivar. Larval and larva-pupal development times were significantly shorter on potato. Among the tomato cultivars, at the preblossom stage, larval development time was significantly longer on the processing cultivar whereas at the blossom stage, it was significantly longer on the cherry and fresh market cultivar. Larval body weight was significantly higher on the fresh market tomato at the preblossom stage, but at the blossom stage, the differences in weight were not significant.

Foliage α-tomatine contents were determined using HPLC in order to resolve responses of the different PTM stages to the different developmental stages of the three cultivars. α-Tomatine content was found to be significantly dependent on plant stage and cultivar. The correlations of the performance parameters with α-tomatine contents in the foliages of the tomatoes were in general very variable at both phenologies. Despite the reduction in α-tomatine content in the cherry foliage at the blossom stage, larval development was significantly delayed and mortality increased. This implies that α-tomatine does not seem to be an important factor affecting PTM performance on the cherry foliage at this plant phenology. There was significant amount of α-tomatine in the processing cultivar foliage at the blossom stage and yet the development time for larvae was significantly shorter than on the other cultivars. It is highly likely that loss of nutritional quality is the cause for the low performance of PTM on the cherry cultivar. In the foliage of the other tomato cultivars, a complex of factors, rather than α-tomatine alone, might be affecting PTM performance.

The fruit-feeding assays were carried out on intact fruits by caging one bunch of fruits per plant with PTM neonate larvae at twice the number of fruits present on each bunch. The cages were left for 2 weeks and each bunch was harvested separately. Data were collected on percent-infested fruits, percent survival of larvae per plant, body weight and head capsule size of the recovered larvae. The work was done on immature green, maturing green and ripening fruits. Significantly higher infestation was observed on ripening fruits of the fresh market compared to the cherry and processing cultivars. However, survival of larvae was significantly and consistently higher on the fresh market cultivar at the three fruit stages. Larval body weight was significantly higher on the fruits of the fresh market cultivar than the others at the three fruit stages. The head capsule size of the larvae was also significantly larger on the fresh market cultivar than on the others. α-Tomatine contents in the fruit loculi of the three cultivars were determined following the same procedure used on leaves. The amounts of α-tomatine present in the fruit loculi were significantly different among the cultivars. In the fresh market cultivar, there were traceable amounts of α-tomatine only in the fruit loculi of immature green fruits, but not in fruits at the other fruit stages. The α-tomatine contents were significantly and negatively correlated with larvae head capsule size in maturing green and ripening fruits. Head capsule size was significantly lower on the cherry and processing cultivars than on the fresh market fruits, thus supporting the notion that α-tomatine may be delaying the development of PTM in fruit loculi of the cherry and processing cultivars fruits.

The fourth objective was to investigate the significance of natural enemies as a factor in PTM mortality on the tomato cultivars. The three tomato cultivars and potato were each planted in 300 m^2 plots and 10 pairs of plants were selected at random per

cultivar and checked thoroughly for predators and the presence of PTM. They were then removed, each plant was caged separately, and 25 neonate larvae were introduced. The cage cover was removed from one plant from each pair after 48 h. The larvae on each plant were allowed to feed for 9 days, and then cut down at the root-stem crown and taken for analysis. Larvae were recovered and transferred to potato tubers to complete their development. Data were taken on larval survival and parasitism. The trial was carried out at the preblossom and blossom stages. Mortality was significantly lower in caged, and higher on exposed potato plants. Predation was significantly higher on exposed potato plants at the preblossom stage and intermediate between the cherry cultivar and the other tomatoes at the blossom stage. There was no parasitism of larvae on the exposed tomato plants while there was a significant level of parasitism on the exposed potato plants. The three conditions hypothesized by Berdegue et al. (1996) for the presence of enemy-free space were tested using the larval survival data. The three conditions were supported by the data taken at the preblossom stage, whereas only the first two conditions were supported at the blossom stage. Moreover, no parasitism was found in tomato production fields while there was a significant level of parasitism in proximate potato fields. The direct and indirect effects of tomato on the parasitoids of PTM were determined using the PTM parasitoid, *Diadegma pulchiripes*. This parasitoid did not parasitize PTM larvae while they were feeding on tomato leaves but it did parasitize a higher number of larvae on potato leaves. In contrast, parasitism levels of larvae reared on tomato leaves were not significantly different from those reared on potato leaves when both groups were exposed to this same parasitoid after being removed

from the host plant. Therefore it appears that tomatoes provide enemy free space for PTM.

It is concluded that there is differential susceptibility of tomato cultivars to PTM and that natural enemies are not an important factor in PTM mortality on tomatoes in Ethiopia. The cherry cultivar is not widely accepted by Ethiopian farmers due to a preference for cultivars with larger fruits, whereas the fresh market and processing cultivars are widely grown. The fresh market cultivar's foliage provides a suboptimal feeding niche while its fruits are susceptible. It seems that the natural enemy-free refuge in its foliage and the protected and suitable feeding niche in its fruits may have allowed the PTM to perpetuate itself and cause economic damage to tomato crops in Ethiopia.