Biological and Cultural Factors Contributing to the Importance of Potato Tuber Moth on Tomatoes in Ethiopia

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Abstract

Tomato has not been in the list of the major solanaceous hosts of the potato tuber moth (PTM). But, lately it has become one in some countries such as Ethiopia. A number of factors might have contributed for this. The current study was therefore conducted to determine whether or not: (1) PTM races specifically adapted to tomatoes have evolved, (2) potato-proximate tomato supports high PTM populations even in the presence of potato, and (3) growing tomatoes non-staked increases PTM pressure. According to the study, there was no significant difference in the total larval development time on tomato leaves between the PTM larvae from tomato and potato populations. PTM inflicted significantly lower damage on tomato planted in proximate with potato than on the potato. PTM pressure was significantly lower on staked than on non-staked tomatoes. The absence of tomato-adapted PTM race evolved, the common practice of growing tomatoes non-staked, and the absence of crop diversification involving the more attractive host plants (potato and/or tobacco) are the important biological and cultural factors that might have contributed to the establishment of PTM as a major pest of tomatoes in Ethiopia.

Key words: Potato tuber moth, allopatric populations, tomato, plant stalking

Introduction

The potato tuber moth (PTM), *Phthorimaea operculella* (Zeller) is present in almost all tropical and subtropical regions of the world where potato is grown (Kroschel and koch 1996). The history of the interaction of PTM with tomato ranges from avoidance (Traynier 1975) to the use of soil surrounding tomato plant for oviposition (Varela and Bernyas 1988). Lately, it has become a major pest of open-field-grown tomatoes in a number of countries including Israel (Yathom 1986), Turkey (Bozkurt and Genc 1994), Ethiopia (Abate & Ayalew 1994), and Italy (Luciano et al. 1996).

In Ethiopia, major potato and tomato production areas are often separated. Even when both crops are grown in same location, they are largely separated spatio-temporally (Bayeh Mulatu unpubl. Data 2000). It was reported that when tomatoes are grown alone, up to 100% of the fruits might be infested in susceptible cultivars to tomato fruitworms that include mainly PTM (Tsedeke and Gashawbeza 1997). Elsewhere, processing tomatoes, planted in summer after spring potatoes, were reported to sustain economic damage from PTM attack (Gilboa and Podoler 1994 and Luciano et al. 1996). Berlinger and Mordechi (1997) identified planting tomato without staking as a cultural factor that favors the multiplication of PTM in tomato crops. Although it is not known how common growing tomato in proximity to potato is in Ethiopia, this is practiced by subsistent farmers in some places (Bayeh Mulatu personal observation, Arsi negele 2000). The contribution such a practice might have for the build-up of PTM.

population on tomatoes has never been assessed

Following the spatio-temporal separation of the production of the two crops, a genetic difference between PTM populations may develop. These populations would differ in their ability to use tomato and potato as hosts. The formation of host races may contribute to the establishment of PTM on tomatoes. Traynier (1975) suggested that local races of PTM that have adapted to feed on tomatoes might have evolved. This, however, has not been established for PTM populations present on tomatoes in Ethiopia. The current authors sought that comparing the biological performance of two allopatric PTM populations, one collected from tomato and the other from potato, on tomato could suggest whether two host races had evolved in Ethiopia.

In Ethiopia, tomatoes are planted both as staked and non-staked (Bayeh Mulatu personal observation Upper Awash and Ziway, 2000) crop. It is not known, however, which one is more commonly practiced and how this practice influences PTM population build-up on tomatoes. Moreover, as indicated earlier, the build-up of PTM population on tomatoes has never been quantified when tomato is planted in proximity with potato. The present study, therefore, was conducted with the objectives to determine whether or not (1) PTM races specifically adapted to tomatoes have evolved, (2) growing tomatoes, non-staked increases PTM pressure and (3) potato-proximate tomato supports high PTM populations even in the presence of potato.

Materials and Methods

Evolution of PTM race adapted to tomato

The presence of PTM race genetically adapted to tomatoes was investigated by comparing larval stage specific cohort parameters. These include: settling response, development time variability and survival by instar levels of larvae from two allopatric PTM populations (Zangerl and Berenbaum 1993). Samples were collected from two geographically isolated PTM populations: larvae in tomato fruits from Melkassa (39°21'E 8°26'N) and pupae in potato seed store and Holetta (38°31'E 9°03'N). The sample locations are separated by about 160 km.

Healthy plants of a processing tomato cultivar (cv. Serio) were raised in pots of Ø25 cm filled with garden soil with a mix of manure, sand and soil at a ratio of 1:1:3 and placed in a lath-house free from pesticides. When the seedlings reached nine-true-leaf stage, fully expanded young leaves were detached and used to run the feeding assays. Healthy leaflets were cut from the sampled leaves and provided to the test larvae in petri dishes.

One hundred and sixty sterile petri dishes were lined with Whatman filter paper (Ø9 cm) and wetted with sterilized tap water. One tomato leaflet was introduced into each petri dish and their cut ends were immediately covered with cotton balls soaked in sterilized water. Finally, one neonate larva from either population was transferred to each test leaflet. All the Petri dishes were put in a growth chamber at a temperature of 26°C, a photoperiod of 12L:12D and 70% RH. Soaking the cotton balls regularly watered the leaflets. Test leaflets showing signs of deterioration were replaced. The follow-up continued until the developing larva in each leaflet died or abandoned the leaflet and displayed a typical wandering behavior. Each wandering larva was transferred into a gelatin capsule to allow it to pupate and the length of total larval development time was determined.

Data were collected on the number of neonate larvae that settled after the first 24 hours, larvae that survived through the different larval development stages and the time taken to complete each.

Developmental time was determined by daily monitoring the molting of larvae. Molting was confirmed by examining the changes in the head capsule size of the larvae viz. their body morphology, which is always at par in width with the rest of the body right after an insect is molted.

Effects of proximate potato on PTM population build-up in tomatoes

A tomato and potato cultivars each planted on 280 m^2 plots were found adjacent to one another in the Debub University research site at Awassa (7°05'N 38°29'E). The tomato was planted before the potato by about one month. During the sampling period, the plants in the adjacent potato plots were forming tubers and the tomato plants were fruiting. Each plot was subdivided into seven sub-plots, which were considered as replicates. Every two weeks, 15 plants were sampled randomly per plot and all the larvae present on each plant were recorded for three times. Besides, five pairs of proximate tomato and potato fields owned by small farmers were also assessed on-farm, in the Central Rift Valley of Ethiopia. Similarly, 15 plants were sampled at random per field and PTM larvae present per plant were recorded. This was recorded only one time per field.

Effect of staked and non-staked tomatoes on PTM

Tomato fruit infestation by the PTM in smallholders' production fields in the Central Rift Valley of Ethiopia was determined both in staked and non-staked fields. Because the farmers plant tomatoes along perennial riverbanks, in patches and one field per patch was randomly sampled. Totally 22 non-staked and 13-staked fields were examined. The size of the fields ranged between 250–1000 m^2. Fifteen plants were randomly picked per 250 m^2 area and all the fruits present on the sampled plants were examined for damage by PTM larvae. Fruit damage is typified by a tunnel holed along the center of the locule of a tomato fruit. The numbers of larvae recovered in fruits per plant were recorded.

Data analysis

Percentage values were computed for neonate larvae from the two populations that settled on the tomato leaves, after the first 24 hours and also for the larvae that survived through the different instar levels to pupate. One-way ANOVA were run to compare the development time of the different instar levels, between the two populations; the infestation levels between proximate tomato and potato plots and staked and non-staked tomato plots. Two-way ANOVA was run to see host plant by sampling day on the infestation levels on proximate potato and tomato plots. The statistical software used was JMPIN 4.0.3 (1989-2000 SAS Institute Inc).

Results

Evolution PTM race adapted to tomato

Ninty-seven per cent (n = 80) and 90% (n = 80) of the larvae of the PTM populations collected from tomato and potato, respectively, settled after the first 24 hours. The survival on the tomato foliage of the settled larvae to pupation was 70% and 86% for tomato and potato populations, respectively (Figure 1). The first, third and fourth instars of larvae from the potato populations had significantly shorter development time on tomato foliage than their counterparts from the tomato populations. These differences, however, did not lead to a significant difference in total development time of larvae from the two allopatric populations (Table 1).

Effect of proximate potato on PTM in tomatoes

More than 90% of the larvae that were recovered from the tomato plants were found in the borne fruits, whereas on the potato 100% of the larvae were recovered in the leaf mines. The number of PTM larvae recovered per plant was found to be significantly dependent on the interaction of host plant by sampling day ($F_{2,36} = 5.4$, $P < 0.009$). The infestation difference was not significant on the first sampling day, but was significantly higher on potato on the last two sampling days (2nd sampling: $F_{1,12} = 9.2$, $P < 0.01$ and 3rd sampling: $F_{1,12} = 30$, $P < 0.0001$) (Figure 2). The overall mean number of larvae per plant, too, was significantly ($F_{1,40} = 18.4$, $P < 0.0001$) higher on the potato (2.78 ± 0.31) than the tomato (1.25 ± 0.18). In small farmers' fields too, significantly higher mean number of PTM larvae per plant was recorded in potato (2.80 ± 0.0.52) than in the proximate tomato (1.30 ± 0.23) plots ($F_{1,16} = 8$, $P<0.01$).

Table 1. Mean ± SE development time taken by PTM larvae, from potato (Holetta region) and tomato adapted populations (Melkassa region), to complete the subsequent larval stadia on tomato leaves

Development	Mean ± SE development time in days			
stage	Tomato-adapted	Potato-adapted	F-ratio	P-value
I-II	6.29 ± 0.097 (n = 69)	5.83 ± 0.095 (n = 72)	11.3	0.001
II-III	5.13 ± 0.19 (n = 63)	5.50 ± 0.17 (n = 70)	1.61	0.20
III-IV	5.50 ± 0.29 (n = 56)	4.83 ± 0.13 (n = 70)	4.64	0.03
IV-Pupa	4.20 ± 0.18 (n = 55)	5.00 ± 0.19 (n = 68)	9.55	0.002
I-Pupa	21.09 ± 0.21 (n = 55)	21.08 ± 0.16 (n = 68)	0.0001	0.99

Effect of staked and non-staked tomatoes on PTM

Fresh-market and processing tomato cultivars were the crops of choice by smallholders. Among the fields surveyed, 62% were covered with non-staked tomatoes whereas the rest were staked. Almost all the staked tomato fields were planted with fresh market cultivars, mainly cv. Marglobe. Most of the non-staked fields were planted to the processing cultivar cv. Serio (Melkasalsa). The PTM pressure was found to be associated differently with the two practices. The damage sustained by the tomato fruits in non-staked fields (1.25 ± 0.22) was found to be significantly higher ($F_{1,44} = 7.6$, $p < 0.009$) than in staked fields (0.49 ± 0.09).

Discussion

Larvae from the potato-adapted population were expected to perform poorly on tomato foliage. This is because PTM populations in this area are well established on potato, the most abundant host crop, and are rarely exposed to tomato. Moreover, the two PTM source locations are separated by about 160 km; hence the PTM, being a poor flier, (Fenemore 1988 and Coll et al. 1997) has lower chance of moving between them. But, it was shown in current study that PTM larvae, with progenitors collected from potato system, performed equally well on tomato leaves with larvae whose

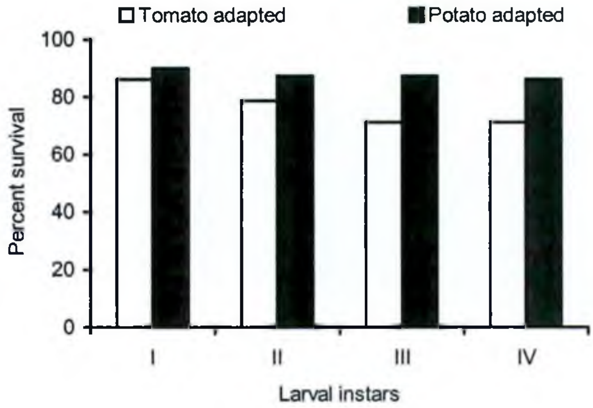

Figure 1. Survival on tomato leaves of PTM larvae by instars levels of two populations from major tomato (Melkassa) and potato (Holetta) production regions in Ethiopia

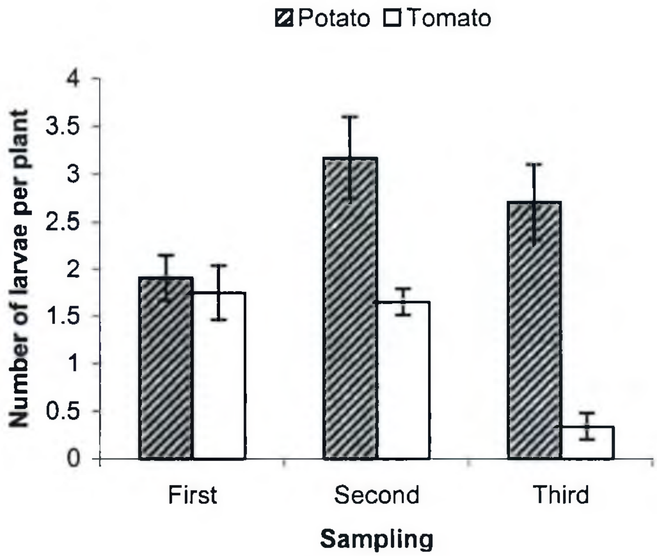

Figure 2. Mean±SE number of PTM larvae recovered per plant on adjacent tomato and potato plots sampled fortnightly at Debub University farm

progenitors have long well established on tomatoes. The lack of difference suggests that PTM populations, which are established on tomatoes, have not evolved into specific race(s) that are adapted to feed on tomatoes. Instead, it is highly likely that there is no significant genetic difference between the two populations in their ability to utilize tomato as a host plant. Gilboa (1994) also reported the absence of genetic difference between tomato and potato populations of the PTM in Israel.

These indicate the presence of host plant use elasticity acquired by PTM, which might be due to its genetic background that is enabling the insect to live on different solanaceous hosts when one or the other is the sole host plant available. Availability of one or another solanaceous host was reported to influence the host plant use strategy of the PTM (Goldson and Emberson 1985, Gilboa and Podoler 1994, 1995, Luciano et al. 1996).

The results have evidently shown that the build-up of PTM population on tomatoes grown in proximity with potato is much lower than in the adjacently planted potato, indicating that potato is the more preferred host. On the other hand, the significantly higher fruit infestation level sustained by non-staked than staked tomato plants showed the importance of the cultural practice to reduce PTM population pressure on tomatoes. Thus, supporting the earlier report by Berlinger and Mordechi (1997).

The absence of tomato-adapted PTM race evolved, the common practice of growing tomatoes non-staked and the absence of crop diversification involving the more attractive host plants (potato and/or tobacco) are important biological and cultural factors that might have been contributing for the PTM in becoming a major pest of tomatoes in Ethiopia.

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