# Biological Performance of Potato Tuber Moth on Leaves of Tomatoes

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## Abstract

Lower population buildup of potato tuber moth (PTM) in tomatoes, when compared with potato, during vegetative growth period was observed. The present study was made to investigate on whether the lower PTM buildup in tomatoes was due to poor performance of PTM larvae on tomato leaves. Leaf feeding bioassays were carried out on three tomato cultivars in comparison with potato. Potato and tomato leaves were taken at preblossom and blossom plant stages and assayed under fully controlled condition. According to the results, the survival of PTM larvae reared on leaves taken at the preblossom stage was higher on cherry (87.5%) than other tomatoes and potato. Whereas, the survival on leaves taken at the blossom stage was higher on potato than tomatoes. Moreover, larval and larva–adult development times were significantly shorter on potato than tomatoes leaves at both plant stages. Therefore, the higher level of survival and significantly shortened larval and larva-adult development times on potato than the tomato leaves showed that tomato leaves were poor quality food source to the PTM compared with potato. Thus, the in-situ lower PTM population buildup on tomato leaves was attributed to poor performance of its larvae. Hence, any attempt to control the PTM on tomatoes should use this opportunity and focus on the post-flowering period.

Key words: potato tuber moth, performance, potato, tomato, feeding bioassay

## Introduction

Although tomato leaf serves as one of the feeding sites for potato tuber moth (PTM) larvae, it is mainly before tomato plants set fruits and the borne fruits start to mature that PTM larvae live on tomato leaves by blotch mining (Bayeh 2003). Nevertheless, the buildup of PTM on tomato leaves has been too slow in comparison with potato leaves and resulted in small population increase over the vegetative growth period of tomatoes (Bayeh 2003). Instead, PTM larvae population in tomatoes peaked during the fruiting period (Bayeh 2003). This contrasting effect of leaves and fruits of tomatoes on PTM entails that tomato leaves might provide less quality food for larvae of the PTM than the fruits. Besides this larvae feeding in tomato fruits get a protected feeding niche (Coll and Bayeh 2003, Bayeh and Betre 2004, and Bayeh et al., 2004) than those feeding in the leaves. These imply that consuming tomato leaves might affect the biological performance of PTM larvae more than the fruits do. Therefore, considering the increasing importance of PTM on tomatoes, its biological performance on tomatoes needs to be well understood.

Performance is a composite term for survival, growth, development, reproduction and longevity (Thompson 1988). The biological performance of the PTM in fruits of tomatoes was confirmed to be influenced by the size, maturity and α-tomatine content of the fruits. Tomato cultivar with big fruits and trace amount of α-tomatine provided the best feeding niche, which was found to be particularly the case in the ripening fruits (Bayeh et al. 2006). The present study was made to investigate on the biological performance of PTM larvae in tomato leaves through leaf feeding bioassays.

## Materials and Methods

Fully expanded young leaves from three tomato cultivars: a cherry (cv. Series), processing (cv. Serio) and fresh market (cv. Marglobe) types and the preferred host potato were collected randomly from plots planted for the purpose. An excised leaf was placed in separate plastic box and stored in icebox on ice cubes until use.

Assays were performed in sterilized Petri dishes (Ø 9cm) lined with moistened Whatman filter papers. A leaflet was transferred into each Petri dish and its cut end was immediately covered with water soaked cotton ball. The assays were carried out on leaves taken from plants at preblossom and blossom stages. One neonate larva, less than 24 hr old, was then placed on the leaflet.

Eighty larvae were initially used per cultivar at each growth stage of the tomatoes. The test larvae were taken from the culture established in the laboratory. All Petri dishes were transferred to a climate chamber set at 26°C, a photoperiod of 12L: 12D and 70% RH. The arrangement in the chamber was completely randomized. The Petri dishes were checked at 14x magnification 24 hr later, in order to determine whether the introduced larvae had settled and started to feed. Thereafter, all Petri dishes were examined daily for larval activity, and the cut ends of the leaflets were watered daily. This was continued until the developing larva in each leaflet died or stopped feeding and displayed typical pre-pupation wandering behavior. Body weights of wandering larvae were measured, and the larvae were afterwards transferred individually into gelatin capsules to allow pupation. Capsules were examined twice a day and pupation time was recorded. Pupae were removed from the gelatin capsules several hours later, after their cuticle had hardened, and their body weight was measured. They were then transferred into individual glass vials and placed in the climate chamber to complete pupal development.

During the course of the study, the following data were collected on each test larva: survival in the different stages of development until adult emerged, development time of each larval instar and of the pupal stage, body weight of wandering larvae, and weight of pupae. Larval survival rate on each cultivar was determined based on the initial 80 larvae. The follow up was continued until the last adult moth emerged from the last viable pupa. Larval instar was determined based on head capsule size and, when possible, by locating the molted head capsules from between the leaf sheathes.

### *Oviposition preference*

Free oviposition choice trial was conducted among the three tomato cultivars and potato in laboratory cages using excised leaves. Fully expanded young leaves were collected from field-grown tomato plants from plants of each tomato cultivar and potato. They were placed in the four corners of Plexiglas cages (0.6 m X 0.6 m X 0.6 m) by dipping each of their rachis in tap water filled plastic bottle. A pair of newly emerged PTM adults was introduced into each cage and provided sugar solution as source of food and water. The adults were removed from the cages after three days and the number of oviposited eggs and their location were recorded. There were a total of 30 repetitions made using leaves from each cultivar.

### *Statistical analysis*

Rior to the conduct of analysis of variance, the collected data were tested for normality. Then after, on data obtained from the leaf feeding assays, two-way ANOVA were run on the effect of cultivar and plant phenology on both the development and growth performance data. The survival dataare

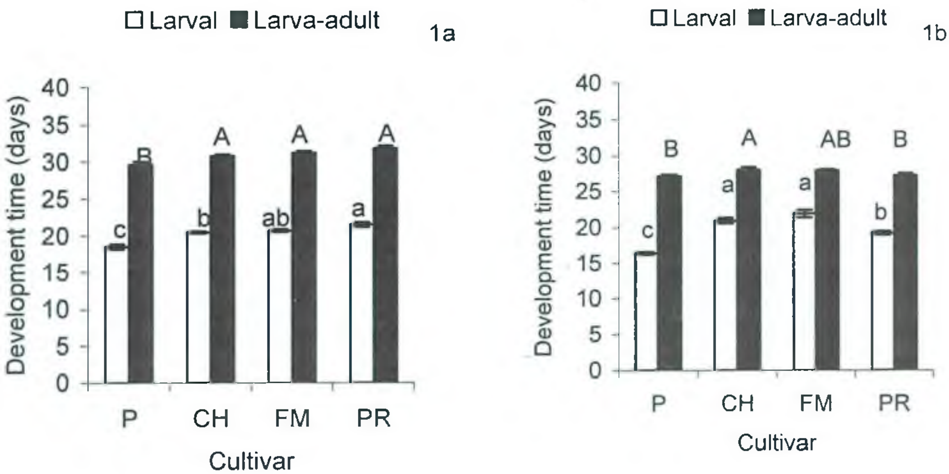


Figure 1. Mean ± SE larval and larva-to-adult development time of PTM on leaves of the cherry (CH), processing (PR), fresh market (FM) tomatoes and the potato (P) at preblossom (1a) and blossom (1b) stages.

Table 1. F-ratios and P-values on within cultivar comparisons of larval performance, on leaves of tomatoes and potato, between preblossom and blossom stages

| | Leaf source cultivars | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Cherry | | Processing | | Fr. Market | | Potato | |
| Fitness parameters | F | P | F | P | F | P | F | P |
| Development time (L) | NS | NS | 45.6 | 0.0001 | 6.2 | 0.01 | 33.2 | 0.0001 |
| Body weight (L) (mg) | 24.5 | 0.0001 | 17.4 | 0.0001 | 75 | 0.0001 | 9.6 | 0.002 |
| Body weight (P) (mg) | 4.9 | 0.0001 | 4.6 | 0.03 | 31 | 0.0001 | 4.3 | 0.04 |
| Development time (L-A) | 31.3 | 0.0001 | 84.3 | 0.0001 | 73 | 0.0001 | 27.8 | 0.0001 |

L = larva, P = pupa and A = adult, F = F-ratio and P = probability values, Fr = fresh

reported as mean percentage values per cultivar and plant stage. On the oviposition data, one-way ANOVA was done. Mean values for development, growth and oviposition were compared for differences between cultivars using Tukey-Kramer honest significance difference test ($P < 0.05$). Moreover, correlation analysis was done between oviposition and the three performance measurement variables for the respective tomato cultivars and the potato (JMP In Statistical Software, version 5.1).

## Results

### *Survival of PTM larvae*

At preblossom stage, 87.5% of the larvae reared on the cherry leaves survived to reach the adult stage. Whereas on the processing and fresh market tomatoes leaves, 67.5% of the larvae survived, while on potato only 65% survived and reached the adult stage. At the blossom stage, the highest survival was on the potato leaves (78.75%). Whereas, on the tomatoes, 53.75%, 51.25% and 38.25% survived to reach the adult stage on the cherry, processing and fresh market tomatoes, respectively.

### *Development time for PTM larvae*

There were significant interactions between the crop cultivars and the two plant phenologies (preblossom and blossom) in affecting total development times (DT) ($F_{3,400}$ = 4.92, P < 0.0002) i.e. from neonate larvae to adult moths. Total larval DT at the preblossom stage was significantly shorter on potato and longer on the processing followed by the fresh market, in which it did not differ from the cherry tomato ($F_{3,236}$ = 30.5, P < 0.0001) (Figure 1a). At the blossom stage, total larval DT was significantly longer on the cherry and fresh market cultivars and shorter on the potato ($F_{3,200}$ = 62, P < 0.0001) (Figure 1b).

Pupal DT was not significantly different between the tomato cultivars and potato at preblossom stage ($F_{3,227}$ = 2.26, P < 0.08); but it was significantly longer in potato at blossom stage ($F_{3,174}$ = 82.5, P < 0.0001).

Larva-to-adult DT at preblossom stage was significantly shorter on potato than the tomatoes ($F_{3,226}$ = 7.24, P < 0.0001) (Figure 1a). At the blossom stage, it was longer on the cherry and shorter on the potato and the processing tomato ($F_{3,174}$ = 4.14, P < 0.002) (Figure 1b).

### *Growth of PTM larvae*

There were significant interactions between the plant phenological stages and the crop cultivars in affecting body weights of larvae

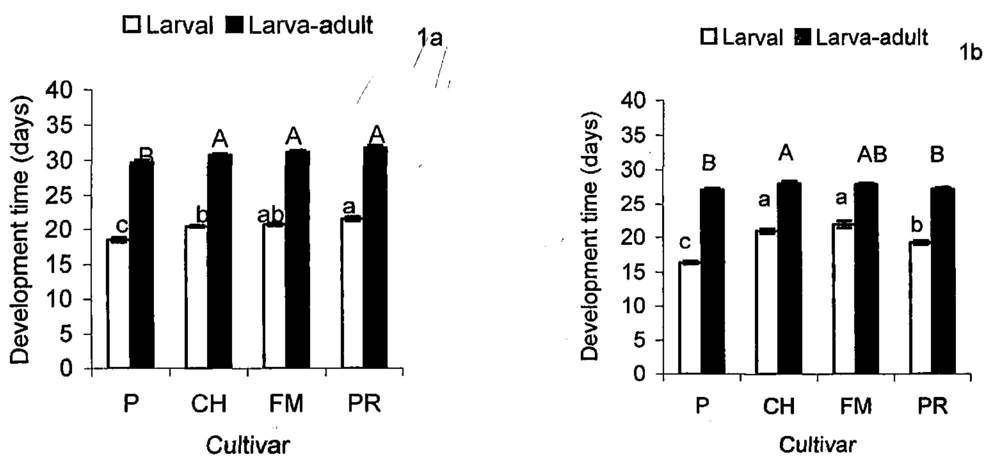


Figure 1. Mean ± SE larval and larva-to-adult development time of PTM on leaves of the cherry (CH), process (PR), and fresh market (FM) tomatoes and the potato (P) at preblossom (1a) and blossom (1b) stages.

Table 2. Pair wise correlations between oviposition preference of the potato tuber moth and different biological performance measuring parameters

| Crop varieties | Eggs/ leaf branch | DT (days) | LBW (g) | PBW (g) | Survival (%) |
|---|---|---|---|---|---|
| Cherry tomato | 7.1 | 28.94 | 10.84 | 7.69 | 53.56 |
| Processing tomato | 4.3 | 27.34 | 10.03 | 7.25 | 51.25 |
| Fresh market tomato | 5.1 | 28.55 | 10.63 | 7.45 | 38.75 |
| Potato | 21.33 | 27.39 | 11.09 | 7.93 | 78.75 |
| Correlations of oviposition with | | 0.74 | -0.43 | 0.87 | 0.93 |
| (P-value) | | (0.26) | (0.57) | (0.13) | (0.06) |

DT = development time, LBW = larval body weight and PBW = pupal body weight, Sur.= Survival

($F_{3,446}$ = 6.00 and P < 0.001) and pupae ($F_{3,431}$ = 4.53 P < 0.003). The highest body weight ($F_{3,240}$ = 6.42, P < 0.003) was recoded for larvae reared at the preblossom stage on the fresh market tomato followed by the cherry, on which larval weight was not different from the potato and the processing tomato. In contrast, there was no significant difference in body weight of larvae reared on all the tomato cultivars and potato at blossom stage ($F_{3,206}$ = 1.84 P < 0.14).

Pupal weight was significantly higher ($F_{3,234}$ = 5.942, P < 0.0006) on the fresh market, followed by the potato on which it was not significantly different from the cherry and processing tomatoes at the preblossom stage (Figure 2a). The differences were not significant ($F_{3,197}$ = 1.74, P < 0.15) at the blossom stage (Figure 2b).

The within cultivar comparisons, between the two plant phenologies, of larval performance were in general significantly higher for larvae reared on leaves at the preblossom stage (Table 1).

### *Oviposition preference*

Significantly more eggs were deposited on potato leaves than the three tomato cultivars ($F_{3,115}$=22.3, P<0.0001). There was no significant difference among the three tomato cultivars in the number of eggs deposited on them ($F_{2,87}$=0.06, P<0.93). More than 95% of the eggs were laid on the lower surfaces of the leaves of all the cultivars. On this surface, most of the eggs were laid in the cervices of the leaflets midribs' and close to the major veins radiating from the midribs. On the upper surfaces, eggs were found only in grooves located at the posterior ends of the midribs of leaflets. Nevertheless, the correlations between the number of eggs deposited on the leaves of each cultivars and the corresponding values for the different biological performance measuring parameters taken at the blossom stage were not statistically significant (Table 2).

## Discussion

Both larval and larva–adult development time on potato was significantly shorter than on the tomatoes, which agrees with Lopes et al. (2001) who reported that feeding on tomato leaves increases PTM larval development time when compared with potato leaves.

On the other hand, the prolonged development time of PTM larvae on the fresh market tomato cultivar leaves, taken at the preblossom stage, was accompanied with significant body weight gain, although the total number of larvae survived feeding on the leaves of this cultivar was very low. On the other hand, in the foliages of the cherry cultivar, although their development time was prolonged, more larvae survived to reach the adult stage. However, the body weight they were able to attain was significantly lower than on the fresh market tomato foliage, but was comparable with the processing tomato and the potato cultivars. Therefore, shortened development time is probably one of the important parameters that has made potato a preferred host by the PTM. Because, when development time is shortened due to availability of suitable host plant and is accompanied with significant survival, the number of possible generations per year is more, resulting in higher population buildup on potato. Whereas, the effect is otherwise when development time is prolonged and survival is low.

A host plant that may prolong larval development time has other consequences. It may expose herbivorous insects to their natural enemies for longer period (Price 1986). But for the PTM on tomatoes, although its development time was prolonged, it was confirmed that these same tomato cultivars provided the PTM with natural enemy free space (Bayeh et al. 2004). Hence, supporting the possibility, as stated by Thomas and Waage (1996), of the adverse effect a host plant might have both on herbivore insect and its natural enemies.

There was significant temporal difference in the suitability of the leaves of the tomato cultivars to the PTM where relatively better larval performance was recorded at the preblossom than the blossom stage. The increased mortality of PTM larvae on the cherry leaves at the blossom stage might be due to loss of nutritional quality of its foliage, probably due to the increasing shift of the sink to the reproductive structures which might have rendered the cherry tomato leaves to be poor quality food to the PTM. On the other hand, in the fresh market and processing tomato cultivars, it seems that there are a number of factors inplanta besides the loss of nutritional quality that affected PTM larval performance, particularly larval survival and development time.

Although the oviposition difference between the tomato cultivars, in the free choice trial conducted using excised leaves in laboratory cage, was not significant, more eggs were laid on the leaves of the cherry cultivar. Besides, in another free choice trial, performed in an exclusion field cage on actively growing tomato plants, significantly higher leaf infestation was sustained by the cherry cultivar (Bayeh Mulatu 2003). These give indications that PTM prefers the foliages of the cherry cultivar to the others, which is supported by the observed better larval performance on the cherry cultivar leaves at preblossom stage in the current study. Thompson (1988) stated that for a herbivorous insect, relationships between oviposition preference and various components of performance of offspring on different plant species range from good to poor correspondence. However, the relationships between preference and performance are still incompletely known (Thompson 1988). In this particular study, the lack of significant correspondence between oviposition preference and PTM progenies performance contributed to the unknown.

Based on the results discussed above, it seems two distinct life history strategies that PTM, on the three tomato cultivars, which showed differential suitability, uses to insure its survival in tomatoes: (i) in the poor quality leaves of the fresh market tomato, prolonging development time yet gaining significant body weight by the few survived larvae and (ii) in the relatively good quality leaves of the cherry cultivar, at the preblossom stage, increasing survival of larvae by compromising body weight gain to survival.

In general, from the results of the leaf feeding bioassays, it could be concluded that the leaves of the tomatoes are suboptimal hosts and are poorly preferred by the PTM. Thus, the in-situ lower PTM population buildup in tomato leaves is the result of poor performance of its larvae. Thus during vegetative growth period tomato growers should focus only on monitoring for PTM presence in their tomato fields. No control measures should be taken before flowering period. On the other hand, during the flowering and fruit development period, application of insecticides could provide effective control of the pest. This will help tomato growers in places where PTM is a serious problem to reduce the use of insecticides, hence contributing both to the farmers economic gain and the environment.

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