Sources of Resistance in Tomato Against Fruitworms

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Abstract

Screening of tomato germplasm for resistance against fruitworms (*Phthorimaea operculella* and *Helicoverpa armigera*) was carried out under natural infestation in the field for three crop seasons starting in 1992 at the Melkassa site of Nazareth Research Centre, Ethiopia. Out of 87 genotypes evaluated in succession, four were identified to be resistant. These were: 'Pusa Early Dwarf', 'Pusa Ruby', 'Seedathing', and 'Serio'. 'RV-44' and the commercial variety 'Money Maker' were moderately resistant whereas 'Marglobe' was susceptible. 'Serio' was also the highest yielder, with marketable yield advantage of nearly 36 and 132 percent over the commercial varieties 'Money Maker' and 'Marglobe', respectively. There were strong positive correlations between damage caused by fruitworms and fruit size. Significant correlations between fruit damage and number of larvae per 100 fruit were also observed during the three seasons; however, it is suggested that percent fruit damage is a more reliable and practical measure of resistance than number of larvae.

Introduction

Tomato is one of the most important vegetable crops grown as a supplement to cereal diets by the smallholder farmers and as an important source of raw material for the processing industry in the commercial sector, particularly in the rift valley region of Ethiopia. Current production is estimated at 4 000 ha with the national average yield of about 7 to 10 metric tonnes per ha. Approximately 70% of the total production is in the hands of smallholders (Heussler & Ayele 1987). Although Ethiopia has an immense potential for developing intensive tomato production in the smallholder agriculture as well as on a commercial scale, the current hectarage is small and productivity is low (Herath & Lemma 1994). Damage inflicted by insect pests is among the major constraints of tomato production in this country.

More than 23 species of arthropod pests attack tomato in Ethiopia (Abate 1988). Of these, the potato tuber moth (PTM), *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae), and the African bollworm (ABW), *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae), collectively known as fruitworms, are the most important pests that can cause up to 100% crop loss in susceptible tomato varieties (Gashawbeza & Abate 1993).

Although some degree of natural biological control is provided by locally occurring natural enemies of both insects (Abate 1991) it has not been sufficient to prevent economic loss. Control using insecticides is not sustainable. An integrated pest management (IPM) approach based on the use of resistant varieties, coupled with cultural practices and natural biological control, offers a good opportunity for controlling fruitworms on tomato, especially under smallholder production.

Although information exists on host plant resistance in tomato to other fruitworms, such as *Heliothis zea* (Boddie) (Ferry & Cuthbert 1975; Isman & Duffey 1982, Dimock & Kennedy 1983, Farrar & Kennedy 1987), no such information is available regarding PTM or ABW on tomato.

An investigation to identify resistant varieties to fruitworms on tomato, as part of an IPM programme, was carried out during three seasons between 1992/93 and 1994/95 under natural infestations in the field. Results of this work are reported herein.

Materials and Methods

Preliminary Nursery

Four sets of tomato germplasm consisting of 84 genotypes that were introduced for screening for fresh market and processing purposes were evaluated for their resistance to fruitworms during the 1992/93 crop season at the Melkassa site of Nazareth Research Centre of the Institute of Agricultural Research (IAR). In addition, three commercial varieties ('Roma VF', 'Marglobe' and 'Money Maker') were included as standard checks. Seedlings were raised in seedbeds from seeds sown in mid November and transplanted in late December. Each genotype was planted in a single row of 5.1 m and seedlings within each row were 30 cm apart.

Plots were kept weed-free by hand weeding and irrigated as needed. Plots were not fertilized and the plants were not staked. Ripened fruit from all plants in the plot was picked weekly; during each picking the number and weight of undamaged and insect damaged fruit was recorded. Damaged fruit was also dissected to determine the number of larvae per fruit.

To categorise the genotypes into "highly resistant" (HR), "resistant" (R), "moderately resistant" (MR), "moderately susceptible" (MS), "susceptible" (S), and "highly susceptible" (HS) the following formula, adapted from Chiang and Talekar (1980), was used

Magnitude	Rating
$x < G - 2SD$	HR
$G - 2SD \leq x \leq G - 1SD$	R
$G - 1SD \leq x \leq G$	MR
$G \leq x \leq G + 1SD$	MS
$G + 1SD \leq x \leq G + 2SD$	S
$x > G + 2SD$	HS

where $\times$=genotype mean and G=grand mean (based on percentage fruit damage). In other words, all genotypes whose mean percentage insect damage is less than the grand mean minus two standard deviations are rated as highly resistant, those with means between grand mean minus two standard deviation and grand mean minus one standard deviation are rated resistant, and so forth.

Advanced Nursery

Eighteen top-performing genotypes were advanced from the preliminary nursery and were evaluated along with the three commercial varieties mentioned above as standard checks, in a randomized complete block design (RCBD) in three replications during the 1993/94 season. Although the genotypes 'L 97' and 'CL 1131-0-0-38-4' were highly resistant in the preliminary nursery, they were not included in the advanced nursery because of poor germination and establishment. Seeds were sown on 17 November 1993 and transplanted on 24 December 1993. Plots consisted of two rows of 5.1 m length. Yield data were also taken from both rows in each plot. Other details were the same as in the previous season described above.

Reconfirmation Nursery

Six genotypes that showed high levels of resistance to fruitworms and one susceptible test entry ('Piline') were advanced from the 1993/94 season advanced nursery and were evaluated in a replicated reconfirmation trial during the 1994/95 season ('RV-41' showed poor germination and was not included). The commercial varieties 'Money Maker" and 'Marglobe' were included as standard checks. Seeds were sown on 28 November 1994 and transplanted on 13 January 1995. The experiment was laid out in a RCBD factorial with split plots; main plots were insecticide (cypermethrin 75 g ai/ha) and no insecticide; subplot treatments were genotypes. Plots consisted of four rows of 5.1 m. Subplots, main plots and replications were separated by an alley of 1, 2.5 m and 3 m, respectively. Yield data (that included marketable and total yields) were taken from the central two rows. Other details are similar to the previous seasons.

Results

Preliminary Nursery

High levels of infestation were observed and variability among tomato genotypes in their performance against fruitworm damage was evident in the preliminary nursery. Average fruitworm damage ranged between 19.3 and 90 percent (mean $\pm$se=57.96 $\pm$1.7) among the 87 genotypes evaluated. Likewise, the number of larvae per 100 damaged fruit ranged between 3.5 and 81.3 (mean=29.3 $\pm$1.8).

Figure 1 shows the frequency distribution of the various categories of resistance for the 87 tomato genotypes tested in the 1992 nursery. It can be seen that the genotypes were evenly distributed with 55 (63.2%) of them falling within the categories of moderately resistant (MR) or moderately susceptible (MS), and 32

(36.8%) evenly split between highly susceptible (HS) or highly resistant (HR) categories.

The genotypes 'L 97' and 'CL 1131-0-0-38-4' were rated HR; examples of genotypes that were rated resistant (R) included 'Pusa Early Dwarf', 'Pusa Ruby', 'Seedathing', 'Red Pear', and 'RV-41'. By contrast, the hybrid 'PT 4110' was rated HS. The commercial varieties 'Roma VF', 'Money Maker', and 'Marglobe' that were included as the standard checks, were rated R, MR, and MS, respectively.

Advanced Nursery

Highly significant differences were observed in terms of percent damaged fruit, larvae per 100 damaged fruit, and marketable yield among the 21 tomato genotypes tested in the advanced nursery, as presented in Table 1. PTM and ABW accounted for about 80 and 15 percent of the total fruit damage, respectively, with the remaining 5 percent attributed to damage by a combination of both species.

Percent fruit damage was lowest in 'Pusa Early Dwarf' and 'Pusa Ruby', followed by 'Seedathing', 'RV-44', 'RV-41', 'Red Pear', 'CL-900-1-3-0', and 'Money Maker' (one of the commercial varieties). By contrast, the highest percent damage was recorded on 'Solar Set (hybrid), followed by 'BL-439', 'Floradade', 'Red Ball', and 'ACE 55 VF7' as shown in Table 1.

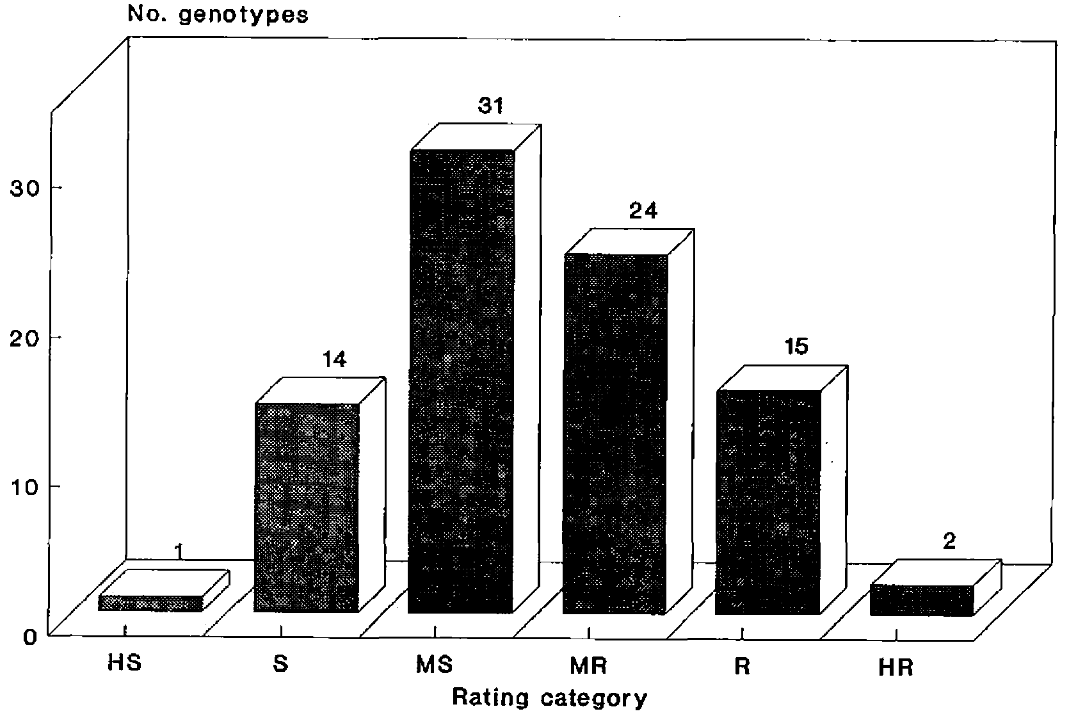

Fig. 1 Frequency distribution of resistance ratings for 87 tomato genotypes against fruitworms at Melkassa, 1992/93

As regards larvae per 100 damaged fruit, the least number was recorded on 'Seedathing', followed by 'Pusa Early Dwarf', 'RV-44', 'Mexico', 'Rubia', 'CL-900-1-3-0', 'UC 204 A', and 'Roma VF'. The genotypes 'VFN 138 (L-4028)', 'ACE 55 VF7', 'Marglobe', and 'Solar Set', on the other hand, sustained the highest number of larvae per 100 damaged fruit (Table 1).

The highest yield was obtained from 'Pusa Early Dwarf', followed by 'Pusa Red', 'RV-41', and 'Serio'. Some of the lowest yielding genotypes were 'ACE 55 VF7', 'UC 204 A', 'Solar Set', 'Floradade', 'Red Ball', and 'Marglobe'. The commercial varieties 'Roma VF' and 'Money Maker' yielded significantly higher than the lowest and lower than the highest yielding genotypes (Table 1). In general, 'Pusa Early Dwarf' was least damaged by fruitworms, sustained the smallest number of larvae per 100 damaged fruit and gave the highest yield.

Table 1. Percent damaged fruit, fruitworm larvae per 100 damaged fruit, and marketable fruit yield (t ha-[1]) in 21 tomato genotypes at Melkassa, 1993/94*

Genotype	Damage	Larvae	Yield
Pusa Early Dwarf	12.5 a	28.2 ab	24.8 a
Pusa Ruby	22.9 ab	37.2 b-f	18.1 b
Seedathing	27.1 bc	22.0 a	4.9 ij
RV-44	28.0 bc	30.4 ab	10.1 d-i
RV-41	29.4 bc	32.0 a-d	17.4 bc
Red Pear	29.9 bc	33.2 a-d	13.1 b-f
CL-900-1-3-0	30.8 bc	26.7 ab	13.2 b-e
Serio	34.5 bcd	34.3 b-e	14.6 bcd
Piline	39.2 c-f	31.8 a-d	11.1 d-h
Mexico	44.9 d-g	30.7 ab	7.8 f-j
Rubia	45.7 d-g	29.8 ab	8.9 e-j
UC-204 A	47.0 cde	29.0 ab	4.0 j
VFN 138 (L-4028)	48.6 fgh	49.1 g	7.3 g-j
ACE 55 VF7	55.1 gh	48.5 fg	3.5 j
Floradade	56.5 gh	35.7 b-e	4.2 ij
Red Ball	54.8 gh	42.8 c-g	4.7 ij
BL-439	59.6 hi	35.3 b-e	6.6 hij
Solar Set (hybrid)	68.3 i	43.6 d-g	4.0 j
Roma VF**	35.6 cde	28.9 ab	13.2 b-f
Money Maker**	28.1 bc	31.1 abc	12.3 c-g
Marglobe**	50.0 fgh	45.7 efg	5.1 ij
Mean	40.4	34.6	10.0
CV (%)	16.4	18.0	29.0

*Means within a column followed by the same letter are not significantly different from each other (P<0.05) using Duncan's Multiple Range Test (DMRT); **standard checks.*

Reconfirmation Nursery

Insecticide treatment had significant effects on fruit damage and on larvae per 100 damaged fruit although it did not significantly affect yields. On the other hand, varietal differences for all the parameters were highly significant (Tables 2 & 3). In addition, interaction effects were highly significant for percent fruit damage and larvae per 100 damaged fruit, but nonsignificant for yields.

Table 2 summarizes the mean percent fruit damage by fruitworms and number of larvae per 100 damaged fruit in eight tomato genotypes grown with and without insecticide protection during the 1994/95 season. Percent fruit damage in untreated plots was significantly less on 'Pusa Early Dwarf', 'Pusa Ruby', and 'Seedathing', than the rest of the genotypes; these were followed by 'Serio' and 'RV-44'. 'Piline' and 'Marglobe' suffered significantly greater fruit damage than all other genotypes;

Table 2. Mean percent fruit damage by fruitworms and number of larvae per 100 damaged fruit in eight tomato genotypes grown with and without insecticide protection at Melkassa, 1994/95*

Genotype	Fruit damage		No. larvae	
	Untreated	Treated	Untreated	Treated
Pusa Early Dwarf	4.8 a	2.0 a	7.3 a	3.6 a
Pusa Ruby	4.3 a	0.6 a	17.2 ab	8.3 a
Seedathing	4.7 a	0.3 a	13.4 ab	0.0 a
RV-44	8.9 b	1.6 a	13.0 ab	0.8 a
Serio	6.7 ab	1.7 a	16.8 ab	1.0 a
Piline	21.3 d	7.6 b	22.5 b	3.7 a
Money Maker	13.5 c	2.0 a	13.1 ab	3.7 a
Marglobe	19.8 d	7.9 b	43.5 c	8.9 a
Mean	10.5	3.0	18.4	3.8
CV (%)	21.0	70.8	49.0	166.8

**Means within a column followed by the same letter are not significantly different from each other (P<0.05) (DMRT).*

'Money Maker' was intermediate between the most and least damaged genotypes. Percent fruit damage in treated plots was significantly greater in 'Piline' and 'Marglobe' than the rest of the genotypes (Table 2).

Mean number of larvae per 100 damaged fruit in untreated plots was significantly fewer in 'Pusa Early Dwarf' and greater in 'Marglobe' than all the genotypes tested in the reconfirmation nursery. 'Piline' supported significantly greater number of fruitworms than 'Pusa Early Dwarf' but fewer than 'Marglobe'; the rest of the genotypes were intermediate between these two genotypes (Table 2). No significant differences were observed among genotypes in treated plots regarding larvae per 100 damaged fruit.

Data for damage caused by factors othern than fruitworms and fruit yields in the eight tomato genotypes tested in the reconfirmation nursery are shown in Table 3. It can be seen from the table that 'Serio' suffered the least damage due to factors other than fruitworms; this was followed by 'Pusa Early Dwarf'. 'Pusa Ruby', followed by 'RV-44' and 'Marglobe' was the most damaged whereas 'Money Maker', 'Piline' and 'Seedathing' were intermediate (Table 3).

'Serio' and 'Marglobe' gave significantly higher and lower marketable yields, respectively, than the rest of the genotypes. The next highest yielders were 'Pusa Early Dwarf', 'Pusa Ruby', 'Seedathing', and 'Money Maker', with no significant difference among them; 'RV-44' was intermediate between the highest and lowest yielders. Total yields also followed a similar trend (Table 3).

Discussion

Our experiments have confirmed that the genotypes 'Pusa Early Dwarf', 'Pusa Ruby', 'Seedathing', and 'Serio' are resistant to fruitworms; 'RV-44' and the commercial variety 'Money Maker' are moderately resistant. The other commercial variety, 'Marglobe' is susceptible. It is interesting to note that 'Serio' was not only one of the resistant genotypes to fruitworms but also the highest yielder (with nearly 33 tonnes per ha) and suffered the least damage due to factors other than fruitworms such as rotting, sun scorch, and bird damage. Similarly, although its yield was not as high as 'Serio', 'Pusa Ruby' also showed equally good performance against fruit damage due to other factors.

Table 3. Percent fruit damage due to factors other than insects, and yield of eight tomato genotypes at Melkassa, 1994/95.

Genotype	Damage	Yield ($t\ ha^{-1}$)	
		Total	Marketable
Pusa Early Dwarf	19.8 ab	36.4 abc	21.2 b
Pusa Ruby	39.7 c	30.5 cd	24.4 b
Seedathing	30.0 abc	27.2 d	18.8 bc
RV-44	34.7 bc	32.7 bcd	20.5 b
Serio	16.9 a	40.9 a	32.9 a
Piline	30.5 abc	37.5 abc	22.0 b
Money Maker	29.8 abc	38.6 ab	24.3 b
Marglobe	34.9 bc	27.5 d	14.2 c
Mean	29.5	33.9	22.3
CV (%)	22.2	17.8	22.8

Means within a column followed by the same letter are not significantly different from each other (P<0.05) (DNMRT).

In these experiments we examined relationships between various parameters as shown in Table 4. It can be seen that percent fruit damage and number of larvae per 100 damaged fruit are positively correlated during the three seasons, suggesting that either one of the two parameters can be used as a criterion for measuring resistance to fruitworms in tomato.

However, we consider percent fruit damage to be more reliable (compare the coefficient of variability [CV] values in Tables 1 and 2) because it is not always easy to find all the worms in the fruit, particularly in the case of *Helicoverpa armigera*, which does not stay in the fruit but leaves the characteristic clear feeding holes (Ofuya 1991) on the fruit. Moreover, it is easier and more economical to count damaged fruit than dissecting them to check for the worms inside.

There were also positive correlations between larvae per 100 damaged fruit and fruit size (Table 4) indicating that tomato genotypes with large sized fruit are more susceptible than those with smaller fruit.

Percent fruit damage and marketable yield showed highly significant negative correlations during the 1993/94 season but these relations were nonsignificant during the reconfirmation nursery in the 1994/95 season. In other words, differences in percent fruitworm damage by fruitworms explained nearly 68 percent of the variability among the 21 tomato genotypes tested in 1993/94 whereas only 26 percent of the variability among the eight tomato genotypes was explained by fruitworm damage in the 1994/95 season. On the other hand, we observed that damage caused by factors other than fruitworm damage during the latter season accounted for more than 65 percent ($r=-0.807$; $P<0.05$) of the difference in marketable yield among genotypes.

This lack of consistent relationship between percent fruit damage caused by fruitworms and fruit yields indicates that tomato yields under the Melkassa conditions are influenced not only by fruitworm damage but also by other factors mentioned earlier. These findings suggest that great attention should be given to resistance to fruitworms as well as varietal characteristics of tomatoes and cultural practices such as staking that minimize damage caused by factors other than fruitworms.

Although ABW is a well known pest of tomato in Ethiopia and elsewhere in the tropics and subtropics (Abate 1988, Ogunwolu 1989, Ofuya 1991, Srinivasan et al. 1994) PTM has not been considered important on tomato in this country until the late 1980s. For example, laboratory and field experiments by Adhanom and Tessema (1984) suggest that tomato is among the least preferred host plants of PTM in Ethiopia; it is the major pest of potato worldwide. By contrast, Abate and Gashawbeza (1992) and Gashawbeza and Abate (1993) reported that PTM damage accounts for more than 95 percent of tomato fruit in the rift valley zone of Ethiopia. The underlying reason for the shift in the pest status of PTM on tomato is unclear.

Table 4. Correlations among various factors relating to fruitworms on tomato at Melkassa[1]

Correlations between	Correlation coefficient (r) in		
	1992/93	1993/94	1994/95
Damage & no. larvae	0.682***	0.621**	0.763*
No. larvae & fruit size	0.485***	0.842***	0.694*
Damage & yield	-	-0.823***	-0.503NS

1 *, **, ***=significant at 5, 1, and 0.1 percent, respectively; NS=nonsignificant.*

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References

Abate T. 1988. Insect and mite pests of horticultural and miscellaneous plants in Ethiopia. IAR Handbook No. 1. IAR: Addis Ababa. 115 pp.

Abate T. 1991. Entomophagous arthropods of Ethiopia: a catalog. Technical Manual No.4. IAR: Addis Ababa 50 pp.

Abate T, Gashawbeza Ayalew. 1992. Progress in vegetable pest management research, 1985-1992. pp. 187-193. In Herath E, Dessalegne L (eds.), Horticultural Research and Development in Ethiopia. IAR: Addis Ababa.

Adhanom Negasi, Tessema Megenasa. 1984. Host preference study of potato tuber moth *Phthorimaea operculella* (Zeller) under field and controlled conditions. Ethiopian Journal of Agricultural Sciences 6:51-56.

Chiang HS, Talekar NS. 1980. Identification of sources of resistance to the bean fly and two other agromyzid flies in soybean and mungbean. Journal of Economic Entomology 73(2):197-199.

Dimock MB, Kennedy GG. 1983. The role of glandular trichomes in the resistance of *Lycopersiconhirsutum* f. *glabratum* to *Heliothis zea*. Entomologia Experimentalis et Applicata. 33:263-268.

Farrar RR, Kennedy GG. 1987. 2-Undecanone, a constituent of the glandular trichomes of *Lycopersicon hirsutum* f. *glabratum*: effects on *Heliothis zea* and *Manduca sexta* growth and survival. Entomologia Experimentalis et Applicata. 43:17-23.

Ferry RL, Cuthbert FP. 1975. Antibiosis in *Lycopersicon* to the tomato fruitworm (*Heliothiszea*). Journal of the American Society for Horticultural Science 100:276-278.

Gashawbeza Ayalew, Abate T. 1993. Management of fruitworms in tomato. Presented at the 1st Conference of the Crop Protection Society of Ethiopia. 14-15 April 1993. Addis Ababa.

Herath E, Lemma Dessalegne. 1994 (eds.). Horticultural Research and Development in Ethiopia. Proceedings of the Second National Horticultural Workshop. 1-3 December 1992. IAR: Addis Ababa. 353 pp.

Heussler P, Ayele Onke. 1987. Development of potato production in Ethiopia. pp. 147-152. In Godfrey-Sam-Aggrey W, Tuku BT (eds.), Proceedings of the First Ethiopian Horticultural Workshop. IAR: Addis Ababa.

Isman MB, Duffey SS. 1982. Phenolic compounds in the ecology of commercial tomato cultivars as growth inhibitors to the fruitworm *Heliothiszea*. Journal of the American Society for Horticultural Science 107:167-170.

Ofuya TI. 1991. Observations on insect infestation and damage in cowpea (*Vigna unguiculata*) intercropped with tomato (*Lycopersicon esculentum*) in a rainforest area of Nigeria. Experimental Agriculture 27:407-412.

Ogunwolu EO. 1989. Effects and insecticidal suppression of damage caused by *Heliothis armigera* (Hbn.) on rainfed tomato in Nigeria. Tropical Pest Management 35:406-409.

Srinivasan K, Krishna Moorthy PN, Raviprasad TN. 1994. African marigold as a trap crop for the management of the fruitborer *Helicoverpaarmigera* on tomato. International Pest Management 40:56-63.