Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.7, No.16, 2017

Colorization of the Tomato Fruit due to Infestation with Helicoverpa Armigera Larvae

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Abstract
Helicoverpa armigera (Hub.) is one of the most serious and highly polyphagous species causing damage in vegetative and reproductive plant stages. The present experiment was performed on a tomato field in Mirtia, Ilia, Greece. The color of the fruits transformed from green to yellow within 7 days post infestation by *H. armigera* larvae and converted to black within 14 days. This work indicates conversion color linked to infestation from *H. armigera* larvae and in the degradation rate of tomato fruit
Keywords: *Helicoverpa armigera,* tomato cultivation*,* coloriztion

1. Introduction

Tomato (*Solanum lycopersicum* L., Solanaceae) is one of the most common and nutritious vegetable crops in Greece. The color of the fruits is among the most important attributes of fruit quality, though color definition is quite complex due to the fact that perception of primary (red, blue, yellow) and secondary (orange, green, purple, etc.) colors is a matter of subjective interpretation of the Human eye. The color complexity of tomato fruits is due to the presence of a diverse carotenoid pigment system with appearance conditioned by different pigment types and concentrations, and subject to both genetic and environmental factors (Kachanovsky et al. 2012). Red color is the result of chlorophyll degradation and synthesis of lycopene and other carotenoids, as chloroplasts convert into chromoplasts.

On the other hand, tomato is very susceptible to insect attack throughout its life cycle, from seedling to fruiting stage (Arah et al. 2015). This crop is attacked by several insect species in Greece, among which, the highly polyphagous tomato fruit borer, *Helicoverpa (=Heliothis) armigera* (Hübner) (Lepidoptera: Noctuidae) which is the most significant (Akbulut et al. 2003). Its larvae have been reported affecting more than 60 species of cultivated and wild plants belonging to ~67 host families (Pogue 2004). Furthermore, this herbivore insect can cause losses to various other economically important crops, such as cotton, sorghum, maize, tomato, and several leguminous, ornamental and tree plant species (Moral Garcia 2006). *H. armigera* is geographically widespread, being present in Europe, Asia, Africa and Oceania (Zalucki et al. 1994; Guo 1997; Akbulut et al. 2003). Its larvae feed on the leaves, stems, green color fruits, causing Post-harvest damage of tomato produce (Wang & Li 1984). The aim of this work was to determine the effect of *H. armigera* infestation to the color of tomato fruits.

2. Colorization experimental protocol

In this study, *H. armigera* individuals, initially collected from tomato fields in Mirtia, Hlia, Greece (37.702267, 21.359392), were reared on artificial substrate in laboratory conditions as reported by Nagarkatti and Satyaprakash, 1974 and Özgur et al. 2009. All stages were maintained in a room with constant temperature 25 ± 1°C, humidity 60 to 70% and photoperiod 16:8 hour light: dark. The larvae used in the bioassays were newly immerged L_2 instars. The experiment was performed on a tomato field in Mirtia, Ilia, Greece. *H. armigera* larvae were transferred on small, green, tomato fruits (Fig 1 b-c) after 45 minutes of starvation. The system "tomato fruit – larva" was covered with a plastic bag 10 × 30cm. Twenty *H. armigera* L_2 larvae were used per experiment (1 larva on 1 tomato fruit x 10 tomato fruit x 2 replications). Larvae were observed for 21 days. Fruits free from larval infestation were used as controls. The experiment was laid out in a Randomized Complete Block Design. Normal agronomic practices were conducted uniformly and no insect preventative measures were applied. Data on the following parameters were recorded: i) entry bore color: recorded as grey or black, ii) The color of the fruit: after infestation, recorded as green, yellow or black. Prior to Anova (Tukey Variance), data were tested for homogeneity of variances and normality, these values were arcsine transformed.

Figure 1. a) The tunnel of the *H. armigera* larvae after one day on the tomato fruit, b-c) Small green tomato fruit with the *H. armigera* larvae before the infestation after 45 minute of starvation. d) After 14d black color tomato fruit.

/The recorded parameters showed an interaction between the color of the tomato fruit and infestation by *H. armigera* larvae. The color of the fruit after infestation was altering from green to yellow and from yellow to black. The passing from green to yellow took place within 7 days post larval infestation and conversion to black within 14 days (Fig 1d). No color changing was found in control tomato fruit (Fig 2a-b). Anova results showed that the number of days had a significant effect on the change of the color ($F=67.276$, $df=2.97$, $P<0.000$).

Figure 2. a-b) Control green tomato fruit after 21d.

The color of the entry bore was made by *H. armigera* changed from grey to black rapidly within only 3 days (Fig 1a) and Anova showed that again the number of days had a significant effect on the change of the tunnel color (F=57.731, df =2.97, P<0.000). The last day of recording color changes for this experiment was the day when each larva *H. armigera* was turned to pupae stage in the black color tomato fruit.

3. Conclusion

The results of this work indicate that tomato fruit color conversion is linked to infestation from *H. armigera* larvae. We hypothesize that the nitrogenous wastes (Uric acid, Urea, Ammonia) in the larval feaces have a toxic effect that alters the color of the fruit from the green to black within a very short period of time. A follow-up study has been planned for the coming year that will more precisely explain the pathway and determine the factors of tomato fruit color conversion. Primary, we intended to measure oxidative stress markers (Lipid peroxidation) and antioxidant defense (Catalase activity) of the tomato plant. In another stage of the experiment we designed to evaluated the pigment substances of control and infested with larvae tomato fruit

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