Crop Protection 64 (2014) 88–92

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Biorational versus conventional insecticides – Comparative field study for managing red spider mite and fruit borer on tomato

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ARTICLE INFO

Article history:
Received 22 April 2014
Received in revised form
12 June 2014
Accepted 13 June 2014
Available online

Keywords:
Pest management
Tetranychus marianae
Helicoverpa armigera
Tomato

ABSTRACT

Tomato, *Lycopersicum esculentum* L. (Solanaceae), is an important crop worldwide that is grown both outdoors and under protected structures, for fresh market consumption and for processing. In the Mariana Islands, tomato is grown as an outdoor crop throughout the year. Tomatoes are attacked by a variety of pests, including the tomato fruitworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae), and, in Pacific islands, the red spider mite *Tetranychus marianae* McGregor. These pests cause scarring, tissue damage, and aberrations in fruit shape or color, making the tomatoes undesirable for fresh market. Also, insect bodies, excretia or parts in fruits reduce their market suitability. Field trials aimed at improving management of these pests were undertaken at two locations in Guam (Yigo and Inarajan), USA in 2012 and 2013, assessing the efficacy of different biorational and conventional insecticides against *T. marianae* and *H. armigera* on tomato. At both locations, the mean percentage of mite-infested leaves and the population density of *T. marianae* were higher in control than in treated plots. An integrated pest management (IPM) program comprising sprays of selective insecticides (Petroleum spray oil, *Beauveria bassiana*, azadirachtin, and *Bacillus thuringiensis*), evaluated at 15, 30, 45 and 60 days after transplantation of tomato seedlings, significantly reduced the number of *T. marianae*-infested leaves and the density of *T. marianae* over plots treated with carbaryl, malathion, six applications of *B. bassiana* or *B. thuringiensis* and over both controls at both locations. Similarly, significantly lower fruit damage by *H. armigera* was recorded in the plots treated with the IPM program than in plots treated with carbaryl, malathion, or the control treatments at both locations. Marketable tomato yields from the plots which received with the IPM program were significantly greater at both locations than were those in the other treatments.

1. Introduction

Our recent survey on the Mariana Islands found *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae) and the red spider mite *Tetranychus marianae* McGregor (Acari: Tetranychidae) to be the most serious pests on tomato (*Solanum lycopersicum* L.) (Reddy et al., 2011; Reddy and Tangtrakulwanich, 2013). Rates of tomato damage caused by these pests are typically 60%, and sometimes reach 88% in severely infested fields in Guam. Infestations on tomato plants on farms in the Commonwealth of the Northern Mariana Islands (CNMI) by these pests can reach 100%. While other pests such as cutworms or armyworms (e.g. *Spodoptera litura* [F.]) (Lepidoptera: Noctuidae) can be found causing damage to tomatoes at the later stage of the crop, *H. armigera* was by far the most common species observed in the field, requiring careful monitoring and control to avoid high (40–50%) yield losses (Reddy and Tangtrakulwanich, 2013).

Processing and fresh market tomato acreage has been progressively increasing in the Mariana Islands during the preceding few years. Tomato has been widely grown in Guam as a new crop which regularly means dealing with a diverse pest complex. At present, *S. litura* is not damaging enough to require control. In addition, both adults and larvae of the Philippine lady beetle, *Epilachna viginsexpunctata* (Boisduval) (Coleoptera: Coccinellidae) feed on the leaves of tomato, leaving distinctive parallel brown scrape marks on the leaves. However, a parasitic wasp, *Pediobius foveolatus* (Crawford) (Hymenoptera: Eulophidae) has been introduced to Guam and the Commonwealth of the Northern Mariana Islands (CNMI) that attacks the pupal stage of the beetle efficiently, so that it is rarely damaging in these areas (Vargo and Schreiner, 2000). Another minor pest of tomato in the region is the silverleaf white fly (*Bemisia tabaci* strain B Bellows & Perring (Hemiptera:

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http://dx.doi.org/10.1016/j.cropro.2014.06.011

Aleyrodidae), which has been frequently found on tomato, eggplant, cucumber, and other vegetables, at times heavily infesting leaves. However, natural enemies often maintain this whitefly below damaging levels if key parasitoids are not killed by use of pesticides. Other direct pests of tomato such as thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) and stink bugs, *Euschistus variolarius* (Palisot de Beauvois) (Hemiptera: Pentatomidae) are not generally a problem in this region.

Many tomato growers in Guam and other Pacific Islands buy and spray conventional chemical pesticides without consultation or guidance. The majority of growers in the region use carbaryl or malathion to control *T. marianae* and *H. armigera* on tomato (Reddy and Tangtrakulwanich, 2013, 2014). As many as 13–15 applications may be applied to each tomato crop, which can greatly increases costs and exposure to pesticide residues. Also, carbaryl is known to make mite problems worse (by destruction of predatory mites) and resistance to the miticide Dicofol: 1, 1-bis (chlorophenyl)-2,2,2-trichloroethanol) (dicofol 4E®) can develop rapidly. Consequently, the current pest management program used by growers in the region for spider mites on tomato is unsatisfactory (Goyal, 1982; Reddy et al., 2013). In particular, carbaryl induces mite problems physiologically (Martinez-Rocha et al., 2008; Reddy and Bautista, 2012) and malathion, while somewhat effective against caterpillars, provides little control of mites. Many farmers in Guam often resort to repeated applications because of the ineffectiveness of these chemicals and resultant increases in mite and fruitworm populations (Reddy, 2001; Reddy and Tangtrakulwanich, 2013).

Recently, farmers have been encouraged to increase vegetable production, including tomato, to reduce the importation of vegetables to the region. Production of cherry tomatoes has expanded on commercial farms and in home gardens (Schulub and Yudin, 2002), but have been extensively damaged by *T. marianae* and *H. armigera*. The rationale in selecting some of the control measures to these pests are based on earliest tests were carried out in farmer's tomato fields, in which *Beauveria bassiana*, azadirachtin, *Bacillus thuringiensis* were used. The biorational chemicals was applied (as a spray) up to 6 times during the cropping period. The insect damage in the plot treated with *B. bassiana*, azadirachtin, *B. thuringiensis* was low compared with that in fields treated with traditional insecticides such as carbaryl and malathion, and a 35% higher yield of marketable tomatoes was obtained there.

The objective of the current study was to compare the efficacies of different management approaches of biorational and conventional-based pest management programs for these pests on tomato to replace conventional chemical pesticides used by growers.

2. Materials and methods

2.1. Seedling production and plot design

Seeds of the cherry tomato variety ‘Season Red’ were sown in trays (40 × 30 cm) and seedlings were grown for 40 days in a nursery in a shade house (30–32 °C, 60–80% RH, and 14:10 h L:D photoperiod) using the standard agronomic practices of the area (Schulub and Yudin, 2002).

Experiments were conducted at the University of Guam Agricultural Experiment Station at Yigo (N 13° 31.930' E 144° 52.351') in northern Guam and at the Inarajan Experiment Station (N 13° 61.963′ E 144° 45.353′) in southern Guam. Treatment plots (8 × 8 m) were arranged in a randomized block design and separated from other plots by 1.0 m buffer zones to prevent contamination from pesticide drift. Identical trials were conducted from June–September 2012 at Yigo and August–November 2013 at Inarajan. Thirty five tomato seedlings per plot that were 40 days old were transplanted with 75 cm spacing between rows and an average of 91.4 cm between plants within rows. Three replicates of each of the 11 treatments resulted in a total of 33 plots for each experiment. Each plot consisted of 5 rows of 12 tomato plants, for a total of 60 plants per plot. The total area of the experimental tomato field was 480 m^2 at each site. Fertilizer applications followed those of Schulub and Yudin (2002).

2.2. Treatment procedures

Nine chemical application treatments consisting of single products or combinations of products, a water spray control and a no spray control were applied to plots (Table 1). Carbaryl and malathion applications were made at the set time intervals normally practiced by Guam farmers (Table 2). The amount of spray solution per application was 95 L/ha for small plants (up to 45 days after transplanting/DAT) and 190.0 L/ha for larger ones (45 DAT until harvest). All the chemicals were applied with motorized backpack sprayers (Solo Brand; Forestry Suppliers, Jackson, Mississippi) equipped with an adjustable, flat spray, hollow cone, jet stream nozzle, with pressure (45 psi = 310 kPa) calibrated to deliver desired quantity of spray per hectare.

2.3. Arthropod sampling and tomato yields

To determine *T. marianae* population levels, 10 plants were selected randomly per plot and for each plant, three leaves were checked, one from the top, middle and bottom of the plant (Reddy et al., 2013). On the underside of each leaf, mites were counted using a magnifying lens. Leaf counts were repeated weekly, and in addition the number of leaves (mite-infested leaves) infested by *T. marianae* of the 30 leaves examined per plot was also recorded. The term “mite-infested leaves” means a leaf is characterized as “infested” when one or more mite individuals of any developmental stage was recorded on the underside. In practice such a leaf (with only 1-2 mites) may not be regarded as “infested” by tomato growers.

Larval infestation levels were estimated by randomly examining 60 unripe fruit per plot (one fruit per plant) and recording the

Table 1
Biological and conventional insecticides used in the present study.

Treatment	Active ingredient	Dose	Source
Aza-Direct® spray	1.2% Azadirachtin and other ingredients 98.8%	10 ml/1 L of water	Azadirachtin, Gowan Company, Yuma, AZ
Volck oil spray®	Petroleum Oil 97%, other ingredients 3%	20 ml/1 L of water	The Ortho Group, Marysville, OH
BotaniGard® 22WP	*Beauveria bassiana* Strain GHA 22%, inert ingredients 78%	2.4 g/1 L of water	Laverlam International Corporation, Butte, MT
DiPel® DF	*Bacillus thuringiensis*, subsp. *kurstaki*, strain ABTS-351, fermentation solids, spores, and insectidial toxins 54%; Other ingredients 46%	15 g/1 L of water	Valent USA, Libertyville, IL
Carbaryl 50 WP	1-Naphthyl N-methylcarbamate 50%, Inert Ingredients 50%	43 g/l L of water	AllPro, St. Joseph, MO
Malathion (Prentox®)	Malathion 0,0-dimethyl phosphorodithioate of diethyl mercaptosuccinate 57%, other ingredients 43%	5 ml/1 L of water	Prentiss Incorporated, Floral Park, NY