Effect of BAM-FX® in Developing a Management Program to Control Major Insect Pests of Tomato: Sweetpotato Whitefly (Hemiptera: Aleyrodidae), Thrips (Thysanoptera: Thripidae), and their Transmitted Viruses

Authors: Seal, Dakshina, Khan, Rafia, Vendrame, Wagnar, and Waddill, Christine

Source: Florida Entomologist, 102(3) : 596-606

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.102.0325

Effect of BAM-FX® in developing a management program to control major insect pests of tomato: sweetpotato whitefly (Hemiptera: Aleyrodidae), thrips (Thysanoptera: Thripidae), and their transmitted viruses

Dakshina Seal[1,], Rafia Khan[1], Wagnar Vendrame[1], and Christine Waddill[1]*

Abstract

BAM-FX® is a bioavailable mineral system that helps in moving necessary mineral ions to the site of deficiency in a plant system, resulting in increased vigor of plants. In the present study, this product was evaluated for its potential effect on improving management of sweetpotato whitefly (*Bemisia tabaci* [Gennadius]; Hemiptera: Aleyrodidae) (biotype B) and thrips (Thysanoptera: Thripidae) in tomato. Seven treatments were evaluated, 4 containing BAM-FX, without N-P-K fertilizer, applied either by soil drench or foliar application, with or without pesticide application. Two treatments included standard N-P-K fertilizer, without BAM-FX application, with or without pesticide application. An additional treatment included BAM-FX, N-P-K fertilizer, and pesticide application. The study was conducted in research plots at the Tropical Research and Education Center, University of Florida, Institute of Food and Agricultural Sciences, in Homestead, Florida, USA, during 2 vegetable growing seasons in 2014 and 2016. Plants treated with BAM-FX had significantly lower incidence of sweetpotato whitefly compared to the control plants without BAM-FX and pesticides. Mean numbers of sweetpotato whitefly eggs and nymphs also were lower significantly in plants treated with BAM-FX than the non-treated control. Mean numbers of melon thrips adults (*Thrips palmi* Karny; Thysanoptera: Thripidae) were consistently fewer in BAM-FX plus pesticide treated plots than the N-P-K treated plots. Mean numbers of common blossom thrips (*Frankliniella schultzei* Trybom; Thysanoptera: Thripidae) and western flowers thrips (*Frankliniella occidentalis* [Pergande]; Thysanoptera: Thripidae) in BAM-FX treated plants did not differ from the N-P-K treated plots. Tomato yellow leaf curl virus incidence was significantly lower in BAM-FX treated plots than the untreated control plots. Application of pesticides and BAM-FX in combination with N-P-K reduced tomato yellow leaf curl virus on a majority of the sampling dates. However, tomato chlorotic spot virus incidence was inconsistently lower in all BAM-FX and N-P-K treated plots compared to the untreated control. Plant height, width, and fruit numbers were significantly higher in N-P-K treated plants compared to BAM-FX treated plants. BAM-FX alone did not increase the mean numbers of fruits, but it increased fruit production when used in a program with N-P-K and effective pesticides. Nutrient levels in the leaves of treated plants were within the normal range. However, BAM-FX showed potential in reducing sweetpotato whitefly and melon thrips and their transmitted viruses, which should be explored to improve pest management programs in tomato and other vegetable and ornamental crops.

Key Words: tospovirus; management; tomato yellow leaf curl virus

Resumen

BAM-FX® es un sistema mineral biodisponible que ayuda a mover los iones minerales necesarios al sitio de deficiencia en un sistema de plantas, lo que resulta en un mayor vigor de las plantas. En el presente estudio, este producto fue evaluado por su efecto potencial en la mejora del manejo de plagas de insectos en el tomate. Se evaluaron siete tratamientos, cuatro que contenían BAM-FX, sin fertilizante N-P-K, aplicados por empapamiento del suelo o aplicación foliar, con o sin aplicación de pesticida. Dos tratamientos incluyeron fertilizante estándar N-P-K, sin aplicación de BAM-FX, con o sin aplicación de pesticida. Un tratamiento adicional incluyó BAM-FX, fertilizante N-P-K y aplicación de pesticida. El estudio se realizó en parcelas de investigación en el Centro de Investigación y Educación Tropical, University of Florida, Institute of Food and Agricultural Sciences, en Homestead, Florida, USA, durante dos temporadas de cultivo de hortalizas en 2014 y 2016. Las plantas tratadas con BAM-FX tuvieron una incidencia significativamente menor de batata, mosca blanca (*Bemisia tabaci* [Gennadius]; Hemiptera: Aleyrodidae) (biotipo B) en comparación con las plantas de control sin BAM-FX e pesticidas. La cantidad media de huevos y ninfas de mosca blanca de batata también fue significativamente menor en las plantas tratadas con BAM-FX que en el control no tratado. La cantidad promedio de adultos de melón (*Thrips palmi* Karny; Thysanoptera: Thripidae) fue consistentemente menor en las parcelas tratadas con pesticida BAM-FX más que en las parcelas tratadas con N-P-K. La cantidad media de trips de flores comunes (*Frankliniella schultzei* Trybom; Thysanoptera: Thripidae) y trips de flores occidentales (*Frankliniella occidentalis* [Pergande]; Thysanoptera: Thripidae) en plantas tratadas con BAM-FX no difirió de las parcelas tratadas con N-P-K. La incidencia del virus del rizo amarillo de la hoja del tomate fue significativamente menor en las parcelas tratadas con BAM-FX que en las parcelas de control sin tratar. La aplicación de pesticidas y BAM-FX en combinación con N-P-K redujo el virus del rizo amarillo de la hoja del tomate en la mayoría de las fechas de muestreo. Sin embargo, la incidencia del virus de la mancha clorótica del tomate fue inconsistentemente menor en todas las parcelas tratadas con BAM-FM y N-P-K en comparación con el control sin tratar. La altura, el ancho y el número de frutos de las plantas fueron significativamente mayores en las plantas tratadas con N-P-K en

[1]University of Florida-IFAS, Tropical Research and Education Center, 18905 SW 280th Street, Homestead, Florida 33031, USA; E-mail: dseal3@ufl.edu (D. S.), rkhan@ufl.edu (R. K.), vendrame@ufl.edu (W. V.), cwaddill@ufl.edu (C. W.)
*Corresponding author; E-mail: dseal3@ufl.edu

comparación con las plantas tratadas con BAM-FX. Los niveles de nutrientes en las hojas de las plantas tratadas estaban dentro del rango normal. Sin embargo, BAM-FX mostró potenciales en la reducción de batata, mosca blanca y melones y sus virus transmitidos, que deberían explorarse para mejorar los programas de manejo de plagas en tomate y otros cultivos vegetales y ornamentales.

Palabras Clave: tospovirus; manejo; tomate amarillo hoja curl virus

Tomato is grown globally in 144 countries on 3.7 million ha (FAOSTAT 2004). The USA ranks in the top 3 tomato producing nations in the world, producing 14.5 million tons (https://www.whichcountry.co/tomato-production/). Florida and California are the states producing the most fresh-market tomato in the nation. Florida generated $348 million in 2014 from fresh market tomato harvesting of 13,360 ha (Florida Tomato Committee 2014). Tomato is a high-value crop with an average production cost of $11.12 to 14.82 thousand per ha, where the cost of pesticides to control insect pests runs from $1,235 to $1,729 per ha. The cost of pest management may exceed far more than this amount where virus epidemic occurs. Tomato crop, as in other vegetables, suffers from various arthropod pest attacks, including whitefly, thrips, beet armyworm, fruit worm, leaf miner, aphids, mites, cucumber beetle, and cutworm, varying in time and the growth stages of tomato plants (Webb et al. 2001). Among these insect pests, sweetpotato whitefly (*Bemisia tabaci* [Gennadius]; Hemiptera: Aleyrodidae) (biotype B) and thrips (melon thrips, *Thrips palmi* Karny; Thysanoptera: Thripidae; common blossom thrips, *Frankliniella schultzei* Trybom; Thysanoptera: Thripidae; and western flower thrips, *Frankliniella occidentalis* [Pergande]; Thysanoptera: Thripidae) are the most important ones due to their ability to transmit viral diseases in tomatoes.

Both sweetpotato whitefly and thrips are polyphagous. Sweetpotato whitefly feeds on 600 species of plants (Brown et al. 1995; De Barro et al. 2011). With the increase of biotypes, 20 known already, host species number may exceed far more than 900. Sweetpotato whitefly transmits 100 plant viruses, including tomato yellow leaf curl virus and bean golden yellow mosaic virus. Major crop losses due to sweetpotato whitefly feeding and virus transmission occurs throughout the world.

Thrips belonging to different species are damaging pests of tomato worldwide. About 100 out of 6,151 known species are considered economic pests (Mound 1997; Thrips Wiki 2017). They are very small in size, slender, cryptic, and fast reproducing with a short generation time. Most of them are invasive and feed on a wide array of hosts (Marullo & De Grazia 2013). Thrips cause damage by their oviposition, feeding, and transmission of viral diseases (Riley et al. 2011). Eight out of 20 common species of thrips have been identified to transmit tospovirus (Rotenberg et al. 2015). Emergence of a tospovirus (tomato chlorotic spot virus) damaging to tomato was detected in south Florida in 2012 (Londono et al. 2012; Zhang et al. 2015). Common blossom thrips (*F. schultzei*) and western flower thrips (*F. occidentalis*) are known vectors of tospoviruses like tomato chlorotic spot virus, tomato spotted wilt virus and groundnut ring spot virus (Funderburk et al. 2011). In 2014 and 2015, tomato chlorotic spot virus caused about 30 to 50% damage to tomato plants, which increased to 70 to 90% at the end of the tomato season (D. Seal, personal observation). Some of the tomato fields were abandoned before harvesting because of the severe outbreak of tomato chlorotic spot virus. Crop losses due to tospoviruses around the world are estimated to be over $1.4 billion.

The use of effective pesticides is a primary consideration to commercial growers to combat the insect pests of tomato and other vegetables. This practice often results in development of resistance and other negative consequences. Various alternative management programs can be considered to reduce the sole dependence on chemical pesticides. Balance nutrients to increase plant vigor, varietal resistance, and cultural control methods can be integrated to reduce pest infestation and virus infection. The absence or inadequate amount of some of the major nutrients may cause plants to become vulnerable to insect pests and diseases. BAM-FX® (bioavailable minerals, formula X; BAM Agricultural Solutions, Boca Raton, Florida, USA) is a product that helps plants by providing required nutrients at the site of deficiency, and thereby increasing plant vigor and yield.

The composition of BAM-FX includes ionic copper and zinc in an ammonia ligand that contains 2.1% copper sulfate pentahydrate and 6.9% zinc sulfate, provided as active ingredients with the other 91% composed of inert carriers, such as 5% other sulfates and 86% water (Kennedy 2016). This is intended to provide a delivery system that helps to move necessary ions to deficiency sites within a plant, which may improve plant growth, yields, and potentially protect crops from insects and the viruses they transmit. Although the principle seems reasonable, the effectiveness of the product under variable environmental and soil conditions is still unknown and needs to be evaluated. We explored this idea to determine the potential of BAM-FX in affecting key pests of tomatoes including sweetpotato whitefly, and thrips (melon thrips, common blossom thrips, and western flower thrips) using the South Florida environmental and soil conditions. Our studies also investigated the effects of BAM-FX in reducing tomato yellow leaf curl virus and tomato chlorotic spot virus. Mineral and nutrient contents of tomato foliage from plants treated, or not, with BAM-FX were compared.

Materials and Methods

The study was conducted in research plots at the Tropical Research and Education Center, University of Florida, Institute of Food and Agricultural Sciences, located at 25.513055°N, 80.504722°W in Homestead, Florida, USA. The soil type is a Rockdale, which consists of about 33% soil and 67% limestone pebbles (> 2 mm) (Noble et al. 1996). The pH value of this calcareous soil ranges between 7.4 and 8.4. Raised beds, 0.15 m high and 0.71 m wide, were formed and covered with black-white plastic mulch (0.9 mil, Canslit Inc., Victoriaville, Quebec, Canada). Beds were provided with two drip tapes (Ro Drip, San Diego, California, USA) having emitter spaces 30 cm apart and placed 15 cm apart on each side parallel to the center of each bed to provide irrigation. The drip irrigation system delivered 1.51 L per min per 30.48 m. 'Sanibel' tomato seedlings were grown in the greenhouse for 6 wk and were set on beds 0.46 m apart within rows on 23 Dec 2013 and 16 Nov 2015. Plants were irrigated 1 h every d to provide enough water (28 m^2), which is considered 100% of field capacity.

The treatment plots, each 12.19 m long, were arranged in a randomized complete block design with 4 replications. BAM-FX was applied at 7.81 mL per L in 4 treatments varying in application methods (foliar spray or soil drench), times (drench once at planting or spray weekly 4 times), use of N-P-K fertilizer once at planting and pesticides (Table 1). The effect of BAM-FX treatments (all treatments receiving BAM-FX) were compared with 2 additional treatments (N-P-K treatments) differing by not having BAM-FX, but with N-P-K application. Finally, both BAM-FX treatments (T1–T4) and N-P-K treatments (T6, T7) were compared with a treatment (T5) by applying BAM-FX and N-P-K at

Table 1. BAM-FX in various combinations of application methods, application time, pesticides, and N-P-K granular fertilizer. Rate of BAM-FX application was 1 oz per gallon (7.81 mL per L) of water.

Treatment no.	Treatment component[1] BAM-FX – Pes – NPK	Method of application of treatment components in an order
T1	Fol – 0 – 0	Spray 4 times
T2	Soil – 0 – 0	Drench at planting
T3	Fol – Pes – 0	Spray 4 times; spray as needed
T4	Soil – Pes – 0	Drench at planting; spray as needed
T5	Soil – Pes – NPK	Drench at planting; spray as needed; once at planting
T6	0 – Pes– NPK	Spray as needed; once at planting
T7	0 – 0 – NPK	Once at planting

[1]Fol = foliar application of BAM-FX; Soil = soil application of BAM-FX; Pes = pesticide; NPK = N-P-K granular fertilizer. Component = a treatment consisted of 1 or all 3 of the components which include BAM-FX, pesticide, and N-P-K granular fertilizer; application method of the component is expressed using Fol or Soil; use of the component in any specific treatment is expressed by mentioning the abbreviated name of a component or '0' for not included in the treatment.

planting in soil. This treatment (T5) also received pesticides as needed basis. The total of 7 treatments are shown in Table 1. The granular fertilizer N-P-K (6:12:12) (Loveland Products Inc., Greeley, Colorado, USA) was applied once, before laying out plastic on the beds, using a rate of 1,069 kg per ha in 2 furrows, each 20 cm from and parallel to either side of the transplant row, and was incorporated within the top 15 cm of the soil.

USE OF PESTICIDES

Sweetpotato whitefly and thrips are the key pests of tomato, because the adults transmit viral diseases and feed on plant tissues. The immature stages of both groups cause damage by feeding on host materials. Infestation starts with adults, and continues through a secondary increase in population. Population abundance of both adults and immatures remained low throughout the study. Pesticides were used in treatments T3 to T6 to suppress adults and immatures simultaneously. The various pesticides used in these treatments included imidacloprid (Admire®, Bayer CropScience, IRAC # 4, Research Triangle Park, North Carolina, USA), cyantraniliprole (Exirel®, Dupont, IRAC # 28, Mississauga, Ontario, Canada), spinetoram (Radiant, Dow Agro Sciences, IRAC # 5, Indianapolis, Indiana, USA); tolfenpyrad (Torac®, Nichino America, IRAC # 21, Wilmington, Delaware, USA). Imidacloprid (1.75 L per ha) was applied as a soil drench at planting using 832.79 L per ha or 78 mL per plant as a preventive measure to reduce initial infestation of adult whitefly and thrips, and F1 immatures. Spinetoram (0.58 L per ha) was sprayed on foliage in a rotation with cyantraniliprole (1.17 L per ha) and tolfenpyrad (1.53 L per ha) at weekly intervals starting from the third wk after planting until the second wk of flowering to control sweetpotato whitefly and thrips. Pesticides were applied in the order of soil drench of imidacloprid at planting, followed by foliar application of spinetoram in the third wk, cyantraniliprole in the fourth wk, and tolfenpyrad in the fifth wk, and we continued using this order. Foliar application of all pesticides was accomplished by using a CO_2 backpack sprayer (R & D Sprayers, Bellspray, Inc., Opelousas, Louisiana, USA) with 2 flat fan nozzles (Tee Jet, Sprayer Depot, Orlando, Florida, USA) delivering 280.62 to 467.70 L per ha depending on the canopy volume. Dyne-Amic (Helena Chemical Co., Collierville, Tennessee, USA), a non-ionic surfactant, was included at 0.25% v/v to all foliar-applied pesticides. BAM-FX and pesticides were applied separately.

EFFECT OF BAM-FX ON SWEETPOTATO WHITEFLY IN TOMATO

The effectiveness of various BAM-FX treatments in managing sweetpotato whitefly was evaluated in 2014 and 2016 by counting the number of adults, eggs, and nymphs per leaf on 10 randomly selected leaves, 1 leaf per plant, in each treatment plot. We conducted sampling on 4 dates, 9, 15, 22, and 29 Jan during the first season (2014), and 6 dates, 14, 21, and 28 Dec, 4, 11, and 18 Jan during the second season (2015/2016). The number of adults was counted by gently turning over the selected leaves between 10:00 A.M. and 12:00 P.M. on the sampling dates. After counting the adults, the leaves were excised at the base of the petiole, and placed in a 0.95 L (1 qt) plastic cup marked with the date, block, and treatment. All samples were transported to the laboratory to record the number of eggs and nymphs on three 1-cm^2 sections on each leaf by using a Leica Wild M3Z dissecting microscope (Microoptics of Florida, Inc., Plantation, Florida, USA) at 10×. The biotype of whiteflies as sweetpotato whitefly or biotype B was confirmed by sending random samples to Cindy McKenzie (USDA, ARS, Fort Pierce, Florida, USA) for identification.

EFFECT OF BAM-FX ON THRIPS IN TOMATO

Melon thrips, common blossom thrips, and western flower thrips are the most common pests of tomato; common blossom thrips and western flower thrips have been confirmed to transmit tospoviruses. The role of melon thrips in transmission of tospoviruses has not yet been confirmed. The abundance of thrips was sampled on 6 dates in 2016 by collecting 10 tomato leaves from each treatment plot following the method discussed above for sweetpotato whitefly. All leaves were placed in a 0.95 L plastic container and marked with date, block, and treatment. Leaf samples were then transported to the vegetable IPM laboratory at Tropical Research and Education Center, Homestead, Florida, USA, where the leaves were washed with 70% ethanol to separate thrips from the leaves. The number of adults by species was recorded using a Leica Wild M 3Z dissecting microscope. Specimens were identified and separated based on their body color, size, and antennal segments. The antennal setae, post ocular setae, and comb on the ninth abdominal segment also were checked for identification. Due to the lack of adequate expertise in identifying larvae, we did not record larvae in this report.

EFFECT OF BAM-FX ON TOMATO YELLOW LEAF CURL VIRUS

Tomato yellow leaf curl virus is a DNA virus belonging to the genus *Begomovirus* in the Geminiviridae. It is the most destructive disease of tomato transmitted persistently by sweetpotato whitefly. Sweetpotato whitefly adults can acquire and inoculate this virus within 15 to 60 min and 10 to 30 min, respectively. Infected tomato plants are severely stunted, and their terminal and axillary shoots become deformed. Infected leaflets are reduced in size and abnormally shaped.

Leaves that develop soon after infection are cupped down. Infected plants are yellowish in color. In the present study, we evaluated the effect of BAM-FX on tomato yellow leaf curl virus incidence by checking tomato plants in various treatment plots for symptoms of this virus on the same dates of sampling sweetpotato whitefly adults in 2014 (4 dates) and 2015/2016 (6 dates). Plants showing signs of tomato yellow leaf curl virus were counted and recorded by plot and treatment. Recount of infected plants was prevented by marking plants with sampling dates.

EFFECT OF BAM-FX ON TOMATO CHLOROTIC SPOT VIRUS

Tomato chlorotic spot virus is a tospovirus known to infect pepper and tomato, and is transmitted by the common blossom thrips and western flower thrips. Only the immature stages of these thrips acquire this virus during feeding on the infected hosts. Infected plants develop necrotic and chlorotic spots, resulting in bronze leaves with inward rolling. Necrotic ring spots appear on stems, leaves, petioles, flowers, and fruits. We evaluated the BAM-FX effect on the incidence of tomato chlorotic spot virus in tomato plants in various treatment plots, and marked them to prevent recount on the next sampling date. The number of infected plants shown in the results are specific for each sampling date. Target plants were tested using immunoassay strips.

EFFECT OF BAM-FX ON PLANT GROWTH

Assessment of plant growth was made by noting plant height, width, and nutrient levels in tomato leaves. Plant height and width were determined 85 days after planting using a ruler to measure the height and width of 5 plants per plot. Width (cm) was measured at the widest level of each plant foliage, and length (cm) was measured by placing the ruler on the ground level at the base of the plant and extending it to the tip of a leaf at the highest level of a plant canopy.

EFFECT OF BAM-FX ON LEAF NUTRIENT LEVEL

From each treatment plot, 400 g of mature tomato leaves, 100 leaves per replication, were collected, placed into a plastic bag, and brought to the laboratory, where they were maintained at 24 ± 1.5 °C, 60 ± 10% RH. Leaves were rinsed with deionized water for 2 min followed by placement on a sieve for 5 min to remove excess water. A soap solution was prepared by mixing 30 mL of Liquinox detergent (Alconox, Inc., White Plains, New York, USA) with 2.5 L of deionized water, and an acid solution was made by mixing 30 mL of 12N HCl with 2.5 L of deionized water. The leaves were submerged for 2 min in the soap solution, then removed and rinsed with deionized water to wash off the soap residue. For the following 1 to 2 min, the leaves were immersed in acid solution in a plastic container, then removed and given a final rinse with deionized water for 3 to 5 min, then dried on a paper towel. Leaves from each plot were then placed into a 3.8 L labelled paper bag, and all the bags containing leaves were dried in an oven at 75 °C for about 5 to 7 d. Proper drying was confirmed when 2 subsequent weights (1 d apart) did not show variation per sample. Dried, labelled leaf samples were then sent for nutrient analysis to the A & L Analytical Laboratories, Memphis, Tennessee, USA. The total amount of nitrogen in plant tissue was determined by the combustion method (Campbell 1992). All other elements were determined simultaneously by using emission spectroscopy (Isaac and Johnson 1992).

EFFECT OF BAM-FX ON FRUIT YIELD

For each yr of study, all fruits from 5 randomly selected plants per treatment plot were harvested when plants stopped producing fruits. All fruits of different sizes and quality were counted and recorded per plant.

STATISTICAL ANALYSIS

Data on sweetpotato whitefly (adults, eggs, and nymphs), thrips (melon thrips, common blossom thrips, and western flower thrips) and viral diseases (tomato yellow leaf curl virus and tomato chlorotic spot virus) were subjected to square root (x + 0.25) transformation to normalize error variances. Statistical analysis was performed using a 2-way analysis of variance (ANOVA). Transformed data were analyzed using the SAS Statistical Package (SAS Institute 2013). The Waller-Duncan k-ratio t-test was used to separate treatment means where significant ($P < 0.05$) differences occurred (Waller & Duncan 1969). Linear regression was conducted using the REG procedure, SAS, to examine the relationship (R^2) between the independent variables, melon thrips, common blossom thrips, and western flower thrips per plot, and the dependent variable, incidence of tomato chlorotic spot virus ratings. The Pearson product-moment correlation coefficient (r) was calculated to determine the strength of a linear association between the incidence of tomato chlorotic spot virus and tomato yellow leaf curl virus with sampling time.

Results

EFFECT OF BAM-FX ON THE POPULATION ABUNDANCE OF SWEETPOTATO WHITEFLY ADULTS ON TOMATO

On the first sample date (9 Jan 2014) mean numbers of sweetpotato whitefly on tomato plants under the BAM-FX program was significantly lower than the plants in the untreated control plots (T7) under the standard N-P-K program without pesticide ($F = 6.97$; df = 6,132; $P =$

Table 2. Mean number of silverleaf whitefly adults per tomato leaf treated with various treatments of BAM-FX and N-P-K granular fertilizer in 2014 and 2016.

		2014				2016					
Treatments	BAM[1] – Pes – NPK*	9 Jan	15 Jan	22 Jan	29 Jan	14 Dec	21 Dec	28 Dec	4 Jan	11 Jan	18 Jan
T1	Fol – 0 – 0	0.25 c	0.35 b	1.53 cd	2.25 b	0.17 c	0.25 b	0.67 bc	0.50 c	0.67 b	0.90 bc
T2	Soil – 0 – 0	0.10	0.80 b	2.15 bc	2.30 b	0.17 c	0.17 b	0.50 c	0.58 c	0.17 c	1.00 b
T3	Fol – Pes – 0	0.15 c	0.65 b	1.15 d	1.50 c	0 c	0.25 b	0.25 c	0.33 c	0.09 c	0.50 cd
T4	Soil – Pes – 0	0.20 c	0.60 b	1.20 d	1.70 c	0.25 c	0.50 b	0.33 c	0.42 c	0.08 c	0.40 d
T5	Soil – Pes – NPK	0.65 bc	1.15 ab	1.25 c	1.55 b	0.58 b	0.83 b	0.92 bc	1.17 b	0.92 b	0.85 bc
T6	0 – Pes – NPK (Standard)	0.75 b	1.90 a	2.55 b	3.95 a	0.91 b	1.92 a	1.17 b	1.17 b	1.00 b	1.30 b
T7	0 – 0 – NPK (Untreated control)	1.55 a	1.95 a	3.80 a	4.75 a	1.42 a	2.42 a	2.17 a	2.16 a	2.33 a	2.75 a

[1]Fol = Foliar application; Soil = Soil application. *BAM = BAM-FX at 1 oz per acre (foliar application or soil application); Pes = pesticide; NPK = N-P-K at standard rate. Means within a column followed by the same letters do not differ significantly ($P > 0.05$; Waller-Duncan K-ratio t Test).

0.001) (Table 2). On the second, third, and fourth (15 Jan, 22 Jan, 29 Jan 2014) sampling dates, mean numbers of sweetpotato whitefly adults increased in each treatment plot, but the number was still significantly higher on the untreated control plants under the standard N-P-K program (T7) than on other treatment plants (15 Jan: F = 4.90; df = 6,132; P = 0.001; 22 Jan: F = 10.99; df = 6,132; P = 0.001; 29 Jan: F = 25.53; df = 6,132; P = 0.001). The application method of BAM-FX did not affect the abundance of sweetpotato whitefly adults. In 2016, a similar pattern of significantly lower abundance of sweetpotato whitefly adults was observed on all treated plants (T1–T6) than on the untreated control plants (T7) that received N-P-K fertilizer and no pesticide application (14 Dec: F = 12.41; df = 6,77; P = 0.001; 21 Dec: F = 23.35; df = 6,77; P = 0.001; 28 Dec: F = 9.41; df = 6,77; P = 0.001; 4 Jan: F = 9.51; df = 6.77; P = 0.001; 11 Jan: F = 10.10; df = 6,77; P = 0.001; 18 Jan: F = 12.54; df = 6,77; P = 0.001) (Table 2). The treatments, including BAM-FX alone (T1, T2), BAM-FX plus pesticides (T3, T4), BAM-FX plus N-P-K plus pesticides (T5) and N-P-K plus pesticides (T6), significantly reduced sweetpotato whitefly adults on almost all sampling dates in 2014 and 2015 compared to the nontreated control (T7).

SWEETPOTATO WHITEFLY EGGS

In the 2014 study, mean numbers of sweetpotato whitefly eggs per leaf were significantly lower in plants treated with BAM-FX (T1, T2), BAM-FX plus pesticides (T3, T4), and BAM-FX plus N-P-K plus pesticides (T5) than in plants receiving N-P-K plus pesticides (T6), and N-P-K fertilizer alone (T7, untreated control), a trend observed on all sampling dates in 2014 (9 Jan: F = 4.73; df = 6,132; P = 0.001; 15 Jan: F = 4.11; df = 6,132; P = 0.001; 22 Jan: F = 8.49; df = 6,132; P = 0.001; 29 Jan: F = 23.0; df = 6,132; P = 0.001 (Table 3). A similar pattern of reduction in the number of sweetpotato whitefly eggs in BAM-FX treated plants (T1–T5) also was recorded in the 2016 study (14 Dec: F = 8.93; df = 6,77; P = 0.001; 21 Dec: F = 5.33; df = 6,77; P = 0.001; 28 Dec: F = 20.14; df = 6,77; P = 0.001; 4 Jan: F = 23.80; df = 6,77; P = 0.001; 11 Jan: F = 34.26; df = 6,77; P = 0.001; 18 Jan: F = 19.98; df = 6,77; P = 0.001 (Table 3). In this study, plants receiving N-P-K fertilizer routinely with pesticides (T6) also had significantly fewer eggs than the control plants without pesticide application (T7).

SWEETPOTATO WHITEFLY NYMPHS

In the 2014 study, all plants treated with BAM-FX (T1, T2), and BAM-FX plus pesticides (T3, T4) had significantly fewer nymphs than the untreated control plant (T7) on the first sampling date (F = 2.83; df = 6,132; P = 0.01) (Table 4). Other treatment plants (T5, T6) receiving N-P-K and pesticides had lower numbers of nymphs than the untreated control (T7), but these numbers were not significantly different from the control. On the second sampling date, BAM-FX treated plants (T1–T4) did not show any reduction in the number of sweetpotato whitefly nymphs, irrespective of the presence or absence of pesticides, and these treatments did not differ statistically from plants receiving N-P-K (T5–T7). On the third (F = 4.05; df = 6,132; P = 0.001) and fourth (F = 12.55; df = 6,132; P = 0.001) sampling date, BAM-FX treatments (T1–T4) and N-P-K plus BAM-FX plus pesticide treatment (T5) consistently showed significant reduction in the numbers of sweetpotato whitefly nymphs compared to the untreated control (T7).

In 2016, all treatments receiving BAM-FX and pesticides, irrespective of N-P-K application (T1–T6), had significantly fewer nymphs than the untreated control plants (T7) receiving N-P-K on all sampling dates (14 Dec: F = 6.79; df = 6,77; P = 0.001; 21 Dec: F = 14.98; df = 6,77; P = 0.001; 28 Dec: F = 19.62; df = 6,77; P = 0.001; 4 Jan: F = 9.51; df = 6,77; P = 0.001; 11 Jan: F = 56.10; df = 6,77; P = 0.001; 18 Jan: F = 28.04; df = 6,77; P = 0.001) (Table 4). On all sampling dates of 2014 and 2015 plantings, the untreated control (T7) had a higher number of nymphs than the other treatments (T1–T6).

EFFECT OF BAM-FX ON THRIPS PESTS OF TOMATO

Melon Thrips

In 2016, mean numbers of melon thrips among treatments did not differ significantly on the first sample date (14 Dec: F = 1.62; df = 6,105; P = 0.001 (Fig. 1). On the remaining sampling dates (21 Dec: F = 4.78; df = 6,104; P = 0.001; 28 Dec: F = 5.44; df = 6,104; P = 0.001; 4 Jan: F = 5.69; df = 6,104; P = 0.001; 11 Jan: F = 8.48; df = 6,104; P = 0.001; 18 Jan: F = 4.88; df = 6,104; P = 0.001) mean numbers of melon thrips in BAM-FX treated plants (T1, T4), irrespective of pesticide application, were significantly lower than the untreated control (T7). Treatment T5 receiving N-P-K plus BAM-FX plus pesticides also had mean numbers of melon thrips adults significantly lower than the non BAM-FX treatments (T6, T7) on the last 2 sampling dates. In the present study, melon thrips abundance showed a significant relationship with tomato chlorotic spot virus incidence (R^2 = 0.24, Coeff Var = 74.73).

Common Blossom Thrips

Common blossom thrips population was low during this study in 2016 (Fig. 2). Common blossom thrips were recorded on all sampling dates in all treatment plots. However, the common blossom thrips number did not differ significantly among treatments on any sampling dates (14 Dec: F = 0.54; df = 6,104; P = 0.7741; 21 Dec: F = 2.07; df = 6,104; P = 0.0631; 28 Dec: F = 2.23; df = 6,104; P = 0.457; 4 Jan: F = 2.84; df = 6,104; P = 0.0132; 11 Jan: F = 1.86; df = 6,104; P = 0.0954; 18 Jan: F = 1.06; df = 6,104; P = 0.3898). Common blossom thrips showed a higher relationship with the incidence of tomato chlorotic spot virus (R^2 = 0.18; Coeff Var = 62.31).

Table 3. Mean number of silverleaf whitefly eggs per tomato leaf treated with various treatments of BAM-FX and N-P-K granular fertilizer in 2014 and 2016.

		2014				2016					
Treatments	BAM[1] – Pes – NPK*	9 Jan	15 Jan	22 Jan	29 Jan	14 Dec	21 Dec	28 Dec	4 Jan	11 Jan	18 Jan
T1	Soil – 0 – 0	0.20 c	0.40 c	0.79 b	1.25 cd	0.08 b	1.00 b	2.08 c	2.08 c	2.08 c	2.05 bc
T2	Fol – Pes – 0	0.25 bc	0.60 bc	0.80 b	1.85 c	0.25 b	0.83 b	1.58 cd	1.58 cd	1.25 d	2.65 b
T3	Soil – Pes – 0	0.10 c	0.35 c	0.50 b	1.00 c	0.17 b	0.50 b	0.92 e	0.92 e	1.00 de	0.40 d
T4	Soil – Pes – NPK	0.20 c	0.40 c	0.35 b	1.10 c	0.17 b	0.58 b	1.00 de	1.00 de	0.58 e	0.55 d
T5	0 – Pes – NPK	0.40 bc	0.30 c	0.35 b	0.95 c	0.50 bc	0.92 bc	1.75 c	2.50 c	2.50 c	1.95 bc
T6	0 – Pes – NPK (Standard)	0.65 ab	1.05 ab	1.90 a	3.30 b	1.00 a	1.92 b	3.50 b	3.50 b	3.92 b	1.80 c
T7	0 – 0 – NPK (Untreated control)	1.10 a	1.35 a	2.45 a	4.75 a	1.42 a	2.83 a	4.67 a	4.67 a	6.33 a	3.95 a

[1]Fol = Foliar application; Soil = Soil application. *BAM = BAM-FX at 1 oz per acre (foliar application or soil application); Pes = pesticide; NPK = N-P-K at standard rate. Means within a column followed by the same letters do not differ significantly (P > 0.05; Waller-Duncan K-ratio t Test).

Table 4. Mean number of silverleaf whitefly nymphs per tomato leaf treated with various treatments of BAM-FX and N-P-K granular fertilizer in 2014 and 2016.

		2014				2016					
Treatments	BAM[1] – Pes – NPK*	9 Jan	15 Jan	22 Jan	29 Jan	14 Dec	21 Dec	28 Dec	4 Jan	11 Jan	18 Jan
T1	Soil – 0 – 0	0.10 b	0.15 abb	0.37 b	0.70 bc	0.25 c	0.58 b	0.42 cd	0.42 c	0.83 c	0.65 b
T2	Fol – Pes – 0	0.15 b	0.20 ab	0.45 b	1.10 b	0.08 c	0.25 b	0.33 cd	0.33 c	0.42 de	0.75 b
T3	Soil – Pes – 0	0 b	0.25 ab	0.25 b	0.40 c	0.17 c	0.25 b	0.33 cd	0.33 c	0.17 ef	0.00 c
T4	Soil – Pes – NPK	0.15 b	0.05 b	020 b	0.55 c	0.08 c	0.25 b	0.08 cd	0.08 c	0.0 f	0.10 c
T5	0 – Pes – NPK	0.25 ab	0.20 ab	0.25 b	0.70 bc	0.42 bc	0.50 b	0.67 c	1.67 b	0.67 cd	0.45 b
T6	0 – Pes – NPK (Standard)	0.25 ab	0.55 a	0.90 b	2.00 a	0.83 ab	2.00 a	1.83 b	1.33 b	2.17 ab	0.85 b
T7	0 – 0 – NPK (Untreated control)	0.55 a	0.55 a	7.65 a	2.70 a	1.33 a	2.08 a	3.00 a	3.00 a	4.50 a	2.65 a

[1]Fol = Foliar application; Soil = Soil application. *BAM = BAM-FX at 1 oz per acre (foliar application or soil application); Pes = pesticide; NPK = N-P-K at standard rate. Means within a column followed by the same letters do not differ significantly ($P > 0.05$; Waller-Duncan K-ratio t Test).

Western Flower Thrips

Similar to common blossom thrips population, western flower thrips population abundance was low in all treatment plots in 2016 (Fig. 3). Mean numbers of thrips in all treatments increased with the incremental sampling dates, although the numbers did not differ significantly from the untreated control (T7) on any sampling date (14 Dec: $F = 1.95$; df = 6,104; $P = 0.0966$; 21 Dec: $F = 1.73$; df = 6,104; $P = 0.1205$; 28 Dec: $F = 3.03$; df = 6,104; $P = 0.0089$; 4 Jan: $F = 3.24$; df = 6,104; $P = 0.0058$; 11 Jan: $F = 1.41$; df = 6,104; $P = 0.2178$; 18 Jan: $F = 1.62$; df = 6,104; $P = 0.1488$). In this study, western flower thrips showed a weak relationship with the incidence of tomato chlorotic spot virus ($R^2 = 0.093$, Coeff Var = 76.95).

Effect of BAM-FX on Tomato Yellow Leaf Curl Virus

BAM-FX treatments (T1–T4) provided significant suppression of tomato yellow leaf curl virus, irrespective of receiving pesticides (T3, T4) or no pesticides (T1, T2), compared to the non BAM-FX treatments (T6, T7) in 2014 (Table 5). In treatment T5, addition of BAM-FX to N-P-K plus pesticides did not affect tomato yellow leaf curl virus incidence compared to the untreated control (T7). On the first sampling date (9 Jan 2014), there were no tomato yellow leaf curl virus infected plants in the BAM-FX treated plots, irrespective of rates, method of application, or pesticides. In contrast, tomato plants under standard N-P-K program (T5, T6, T7) had few tomato yellow leaf curl virus infected plants, which differed significantly from the BAM-FX treatments (T1–T4) ($F = 6.21$; df = 6,21; $P = 0.001$). On the second sampling date (15 Jan 2014), BAM-FX provided significant suppression of tomato yellow leaf curl virus when plants under the N-P-K program (T5–T7) had 1.00 to 1.50 tomato yellow leaf curl virus infected plants, as in the previous sampling date ($F = 6.21$; df = 6,21; $P = 0.001$). On the third ($F = 28.01$; df = 6,21; $P = 0.001$) and fourth ($F = 19.53$; df = 6,21; $P = 0.001$) sampling dates, tomato yellow leaf curl virus incidence was recorded on all

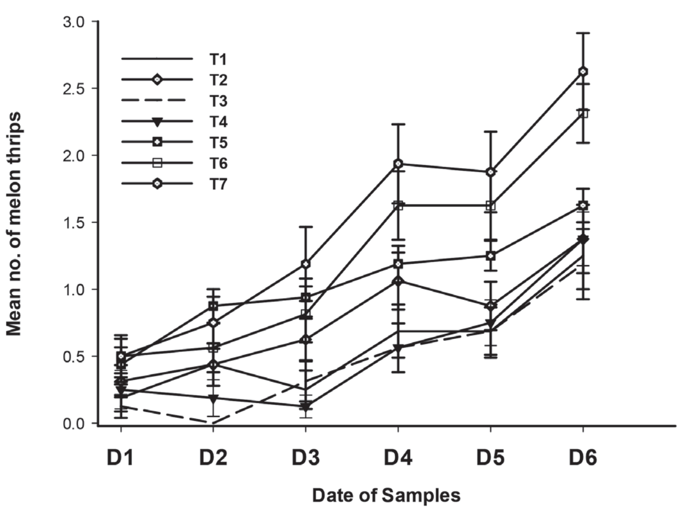

Fig. 1. Mean number of melon thrips (*Thrips palmi*) per 5 leaf sample of tomato treated with various treatments of BAM-FX and N-P-K granular fertilizer in 2016. Bars represent standard error of the means. T1 = BAM-FX applied on soil, no pesticide, no N-P-K fertilizer; T2 = BAM-FX applied on foliage, no pesticide, no N-P-K fertilizer; T3 = BAM-FX applied on soil, pesticide, no N-P-K fertilizer; T4 = BAM-FX applied on foliage, pesticide, no N-P-K fertilizer; T5 = BAM-FX applied on foliage, pesticide, N-P-K fertilizer; T6 = no BAM-FX, pesticide, N-P-K fertilizer; T7 = no BAM-FX, no pesticide, N-P-K fertilizer; D1 = first sampling date (14 Dec); D2 = second sampling date (21 Dec); D3 = third sampling date (21 Dec); D4 = fourth sampling date (28 Dec); D5 = fifth sampling date (4 Jan); D6 = sixth sampling date (11 Jan).

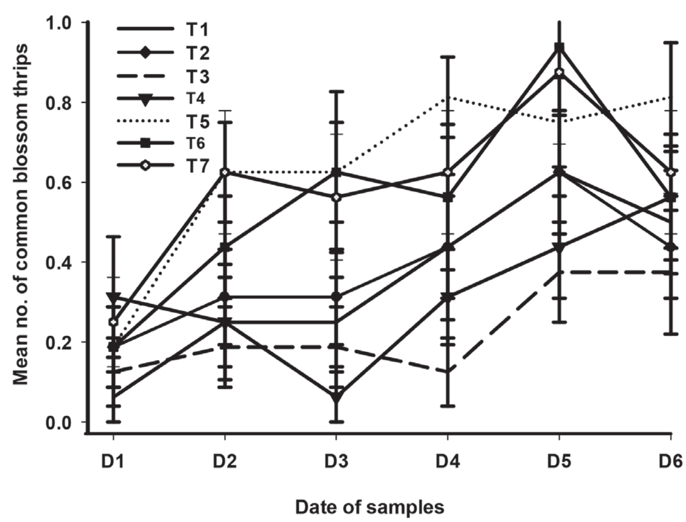

Fig. 2. Mean number of common blossom thrips (*Frankliniella schultzei*) per 5 leaf sample of tomato treated with various treatments of BAM-FX and N-P-K granular fertilizer in 2016. Bars represent standard error of the means. T1 = BAM-FX applied on soil, no pesticide, no N-P-K fertilizer; T2 = BAM-FX applied on foliage, no pesticide, no N-P-K fertilizer; T3 = BAM-FX applied on soil, pesticide, no N-P-K fertilizer; T4 = BAM-FX applied on foliage, pesticide, no N-P-K fertilizer; T5 = BAM-FX applied on foliage, pesticide, N-P-K fertilizer; T6 = no BAM-FX, pesticide, N-P-K fertilizer; T7 = no BAM-FX, no pesticide, N-P-K fertilizer; D1 = first sampling date (14 Dec); D2 = second sampling date (21 Dec); D3 = third sampling date (21 Dec); D4 = fourth sampling date (28 Dec); D5 = fifth sampling date (4 Jan); D6 = 6th sampling date (11 Jan).

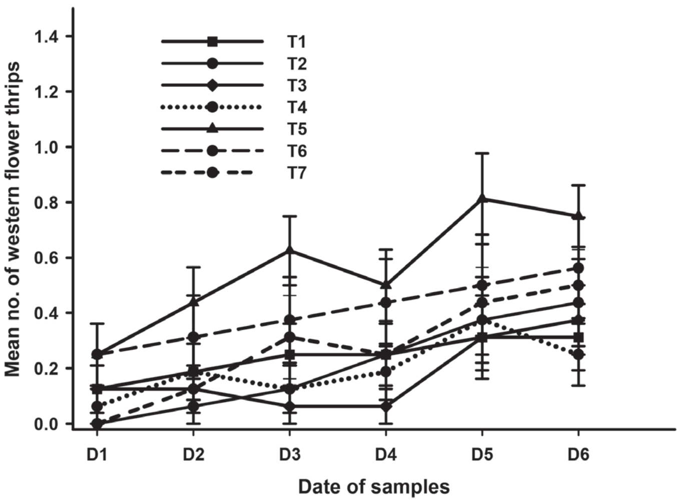

Fig. 3. Mean number of western flower thrips (*Frankliniella occidentalis*) per 5 leaf sample of tomato treated with various treatments of BAM-FX and N-P-K granular fertilizer in 2016. Bars represent standard error of the means. T1 = BAM-FX applied on soil, no pesticide, no N-P-K fertilizer; T2 = BAM-FX applied on foliage, no pesticide, no N-P-K fertilizer; T3 = BAM-FX applied on soil, pesticide, no N-P-K fertilizer; T4 = BAM-FX applied on foliage, pesticide, no N-P-K fertilizer; T5 = BAM-FX applied on foliage, pesticide, N-P-K fertilizer; T6 = no BAM-FX, pesticide, N-P-K fertilizer; T7 = no BAM-FX, no pesticide, N-P-K fertilizer; D1 = first sampling date (14 Dec); D2 = second sampling date (21 Dec); D3 = third sampling date (21 Dec); D4 = fourth sampling date (28 Dec); D5 = fifth sampling date (4 Jan); D6 = sixth sampling date (11 Jan).

treatment plots with significantly higher number in the N-P-K plots (T5–T7). In this study, addition of BAM-FX to N-P-K plus pesticides (T5) did not provide suppression of tomato yellow leaf curl virus compared to the untreated control (T7).

In 2016, tomato yellow leaf curl virus infected plants were significantly higher in the plots receiving N-P-K (T5, T6) than the BAM-FX treated plots (T1–T4) on almost all sampling dates (14 Dec: $F = 4.99$; df = 6,21; $P = 0.002$; 21 Dec: $F = 6.21$; df = 6,21; $P = 0.001$; 28 Dec: $F = 6.07$; df = 6,21; $P = 0.001$; 4 Jan: $F = 13.69$; df = 6,21; $P = 0.001$; 11 Jan: $F = 5.00$; df = 6,21; $P = 0.001$; 18 Jan: $F = 7.48$; df = 6,21; $P = 0.001$) (Table 5). Overall, the increased pattern of tomato yellow leaf curl virus incidence in tomato plants on different sampling dates is strongly correlated with the increment in sampling dates ($r = 0.78$, $P < 0.0001$). Various treatments showed very weak correlation on the increase in incidence of tomato yellow leaf curl virus ($r = 0.17$; $P = 0.002$).

Effect of BAM-FX on Tomato Chlorotic Spot Virus

On the first sampling date (9 Jan), there were no tomato chlorotic spot virus symptomatic tomato plants in any of the plots, irrespective of the BAM-FX program and the N-P-K program (Table 6). On the second sampling date (15 Jan), BAM-FX treated plots did not have any tomato chlorotic spot virus infected plants, whereas the N-P-K treated plots (T5–T7) had fewer tomato chlorotic spot virus infected plants, although not significantly different from the BAM-FX treated plots. On the third sampling date (22 Jan), all plots, irrespective of any management program (BAM-FX and standard N-P-K), had tomato chlorotic spot virus infected plants, which did not differ significantly among treatments. On the fourth sampling date (29 Jan), mean numbers of tomato chlorotic spot virus infected plants increased in each treatment plot, although the number of infected plants were significantly lower in BAM-FX treated plants (T1–T4) than the N-P-K treated plants (T5–T7) ($F = 8.41$; df = 6,21; $P = 0.001$). Addition of BAM-FX to N-P-K plus pesticides (T5) did not reduce tomato chlorotic spot virus compared to the untreated control (T7).

In 2016, mean numbers of tomato chlorotic spot virus infected plants, irrespective of treatments, were inconsistent across the sampling dates (Table 6). Plants receiving BAM-FX treatments (T1–T4) significantly reduced tomato chlorotic spot virus incidence on the first ($F = 2.45$; df = 6,21; $P = 0.05$), fourth ($F = 2.49$; df = 6,21; $P = 0.05$; and sixth ($F = 54.63$; df = 6,21; $P = 0.001$) sampling dates. Addition of BAM-FX to N-P-K plus pesticides in treatment T5 significantly reduced tomato chlorotic spot virus incidence on the last 4 sampling dates (28 Dec: $F = 3.14$; df = 6,21; $P = 0.05$; 4 Jun: $F = 2.49$; df = 6,21; $P = 0.05$; 11 Jun: $F = 2.25$; df = 6,21; $P = 0.07$; 18 Jun: $F = 54.63$; df = 6,21; $P = 0.001$) compared to the untreated control (T7). Use of pesticides with the BAM-FX program (T3, T5) or N-P-K program (T6) did not impact the incidence of tomato chlorotic spot virus when compared with the BAM-FX treatments (T1, T2) and N-P-K treatment (T7).

Effect of BAM-FX on Plant Growth

Among the treatments, there were significant differences in plant height, plant width, root width, and root length (Table 7). Plants receiving BAM-FX (T1–T4) had significantly shorter height than plants (T6, T7) under the N-P-K program. However, the highest plant height was recorded when plants (T5) received BAM-FX in addition to N-P-K plus pesticides ($F = 77.15$; df = 6,133; $P = 0.001$). BAM-FX applied on foliage (T1, T3) had better response on plant height than when applied on soil (T2, T4). Addition of pesticides to BAM-FX (T3, T4) did not cause any significant difference in plant

Table 5. Mean number of tomato yellow leaf curl virus infected tomato plants treated with various treatments of BAM-FX and N-P-K granular fertilizer in 2014 and 2016.

		2014				2016					
Treatments	BAM[1] – Pes – NPK*	9 Jan	15 Jan	22 Jan	29 Jan	14 Dec	21 Dec	28 Dec	4 Jan	11 Jan	18 Jan
T1	Soil – 0 – 0	0 b	0.25 bc	0.75 b	2.00 b	0.25 b	1.00 a	1.75 bc	3.25 bc	2.50 bd	1.75 bc
T2	Fol – Pes – 0	0 b	0 c	0.25 b	1.75 b	0.25 b	1.25 a	1.75 bc	3.00 bc	2.75 bd	2.00 bc
T3	Soil – Pes – 0	0 b	0 c	0.25 b	1.50 b	0 b	1.00 a	1.00 c	1.50 d	2.25 c	1.25 cd
T4	Soil – Pes – NPK	0 b	0 c	0.25 b	1.00 b	0 b	0.75 a	1.50 c	2.25 cd	2.25 c	0.75 d
T5	0 – Pes – NPK	1.25 a	1.50 a	7.00 a	7.00 a	0.25 b	0.50 a	1.00 c	2.33 c	3.50 ab	1.50 c
T6	0 – Pes – NPK (Standard)	1.00 a	1.00 ab	7.75 a	9.25 a	0.75 b	1.00 a	2.75 ab	4.00 b	4.50 a	3.00 ab
T7	0 – 0 – NPK (Untreated control)	1.00 a	1.25 a	6.00 a	8.50 a	1.75 a	1.25 a	4.00 a	6.00 a	3.25 bc	4.00 a

[1]Fol = Foliar application; Soil = Soil application. *BAM = BAM-FX at 1 oz per acre (foliar application or soil application); Pes = pesticide; NPK = N-P-K at standard rate. Means within a column followed by the same letters do not differ significantly ($P > 0.05$; Waller-Duncan K-ratio t Test).

Table 6. Mean number of tomato chlorotic spot virus infected tomato plants treated with various treatments of BAM-FX and N-P-K granular fertilizer in 2014 and 2016.

		2014				2016					
Treatments	BAM[1] – Pes – NPK*	9 Jan	15 Jan	22 Jan	29 Jan	14 Dec	21 Dec	28 Dec	4 Jan	11 Jan	18 Jan
T1	Soil – 0 – 0	0	0 a	0.25 a	2.00 b	0.25 ab	0.50 a	1.00 ab	2.25 ab	3.00 a	0.00 d
T2	Fol – Pes – 0	0	0 a	0.25a	2.25 b	0 b	0.50 a	0.75 b	1.75 b	2.00 ab	0.00 d
T3	Soil – Pes – 0	0	0 a	0.25 a	3.25 b	0 b	0.50 a	1.50 ab	2.00 b	2.25 ab	1.50 c
T4	Soil – Pes – NPK	0	0 a	0.25 a	3.00 b	0 b	0.50 a	1.25 ab	1.75 b	2.00 ab	2.50 b
T5	0 – Pes – NPK	0	0.25 a	1.00 a	7.50 a	0.50 ab	0.25 a	0.75 b	1.67 b	1.50 b	2.25 b
T6	0 – Pes – NPK (Standard)	0	0.50 a	0.75 a	7.75 a	0.50 ab	0.50 a	2.25 a	2.50 ab	2.25 ab	3.00 b
T7	0 – 0 – NPK (Untreated control)	0	0.25 a	0.75 a	7.76 a	1.00 a	1.25 a	2.25 a	3.50 a	1.50 b	4.00 a

[1]Fol = Foliar application; Soil = Soil application. *BAM = BAM-FX at 1 oz per acre (foliar application or soil application); Pes = pesticide; NPK = N-P-K at standard rate. Means within a column followed by the same letters do not differ significantly ($P > 0.05$; Waller-Duncan K-ratio t Test).

height when compared with the plants receiving BAM-FX without pesticide application (T1, T2).

For plant width, plants responded similarly to that observed in the instance of plant height (Table 7). Untreated control plants (T7) and standard plants (T6) receiving N-P-K had higher root width than plants receiving BAM-FX (T1–T4). Application methods (spray or drench) of BAM-FX and use of pesticides did not cause any difference in plant width. However, plants (T5) receiving BAM-FX along with N-P-K plus pesticides had the highest plant width among all treatments ($F = 5.01$; df = 6,133; $P = 0.001$).

All plants (T5–T7) receiving N-P-K had higher root length and width than the plants (T1–T4) receiving BAM-FX (root length: $F = 5.11$; df = 6,133; $P = 0.001$; root width: $F = 33.88$; df = 6,133; $P = 0.001$) (Table 7). The highest root width and length was observed when plants (T5) received BAM-FX in combination with N-P-K and pesticides.

Effect of BAM-FX on Leaf Elements Level

Percentages of elements in tomato leaves were unable to be statistically analyzed; instead we compared them to normal ranges (Table 8). Percentages of nitrogen in tomato leaves appeared higher in T5 (BAM-FX plus N-P-K plus pesticides) and T7 (untreated control) receiving N-P-K (within the normal range of 2.8–6.0%), than in T6 receiving N-P-K and pesticides, which were below the normal range (Table 8). The level of leaf potassium appeared below normal range (2.5–4.99%) in all treatments. Copper and aluminum levels were high for all treatments. Abundances of the remaining elements did not appear to differ among treatments.

Effect of BAM-FX on Fruit Production

In both yr, the mean number of fruits per plant was significantly fewer on all plants receiving BAM-FX (T1–T4) than the plants receiving N-P-K (T5–T7) (Table 9). BAM-FX applied once in the soil without any application of pesticide produced the lowest number of fruits per plant. Significantly higher numbers of fruits were recorded on plants receiving BAM-FX plus N-P-K plus pesticides (T5). The absence of BAM-FX in treatment T6 receiving N-P-K and pesticide significantly reduced the mean numbers of fruits in both yr. It is apparent from this study that BAM-FX alone did not increase the mean numbers of fruits, but it increased fruit production when used in a program with N-P-K and effective pesticides.

Discussion

In the present study, we recorded higher numbers of sweetpotato whitefly adults on the treatment (T7) that received the standard rate of N-P-K fertilizer. On each sample date, BAM-FX treated plants, with or without pesticides, or plants having N-P-K once at planting had fewer sweetpotato whitefly than plants having standard N-P-K fertilizer. Increased sweetpotato whitefly populations, which corresponded to and possibly resulted from increased nitrogen fertilization, also were reported by Bi et al. (2002). In the present study, reduced nitrogen levels in tissues from tomato plants treated with BAM-FX having no nitrogen fertilizer may have been less attractive or more repulsive to sweetpotato whitefly adults than tissues of the control plants (T7), which received conventional fertilizer. Herbivorous insects tend to increase their abundance, growth, and reproduction when fed a nitrogen-rich diet (Auclair et el. 1957; Dixon 1970; Weibull 1987; Sandstrom & Pettersson 1994). Increasing nitrogen fertilization may increase dietary nitrogen compounds available to phloem-feeding insects, and potentially affect their population growth (Jansson & Smilowitz 1986; Jauset et al. 1998, 2000; Godfrey et al. 1999).

The reduction in population abundance of sweetpotato whitefly adults and immature stages in tomato in different BAM-FX treatments

Table 7. Plant height and width, and root length and width of tomato plants treated with various treatments of BAM-FX and N-P-K granular fertilizer in 2014.

Treatments	BAM[1] – Pes –NPK*	Plant height (cm)	Plant width (cm)	Root length (cm)	Root width (cm)
T1	Soil – 0 – 0	52.13 cd	28.50 cd	28.50 cd	5.21 c
T2	Fol – Pes – 0	48.88 d	24.63 d	24.63 d	4.70 c
T3	Soil – Pes – 0	54.63 c	30.75 cd	30.75 cd	4.47 d
T4	Soil – Pes – NPK	54.13 c	33.38 c	33.38 c	6.19 b
T5	0 – Pes – NPK	88.75 a	72.75 a	72.75 a	8.11 a
T6	0 – Pes – NPK (Standard)	78.13 b	62.88 b	62.88 b	7.74 a
T7	0 – 0 – NPK (Untreated control)	84.00 a	59.88 b	59.88 b	7.88 a

[1]Fol = Foliar application; Soil = Soil application. *BAM = BAM-FX at 1 oz per acre (foliar application or soil application); Pes = pesticide; NPK = N-P-K at standard rate. Means within a column followed by the same letters do not differ significantly ($P > 0.05$; Waller-Duncan K-ratio t Test).

Table 8. Levels of nutrients in tomato leaves treated with various treatments of BAM-FX and N-P-K granular fertilizer in 2014.

Treatments	BAM[1] – Pes – NPK*	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Al (ppm)	B (ppm)	Na (%)
T1	Fol – 0 – 0	2.1	0.55	1.01	7.78	0.52	0.82	628	163	40	36	977	52	0.24
T2	Soi – 0 – 0	2.2	0.68	0.84	8.63	0.61	0.91	481	182	39	39	815	53	0.27
T3	Fol – Pes – 0	2.0	0.50	0.87	8.41	0.47	0.66	515	256	46	30	842	50	0.20
T4	Soil – Pes – 0	1.9	0.47	0.95	7.91	0.51	0.56	397	244	44	28	630	51	0.20
T5	Soil – Pes – NPK	3.2	0.60	1.78	6.27	0.55	0.95	302	119	37	42	430	54	0.33
T6	Soil – Pes – NPK (Standard)	1.8	0.51	1.22	7.63	0.50	1.35	406	179	52	27	640	67	0.22
T7	0 – 0 – NPK Untreated control	3.5	0.58	1.82	5.43	0.49	0.74	373	133	47	41	581	52	0.26
Normal range		2.8–6.0	0.25–0.80	2.5–4.99	1.0–2.99	0.4–0.99	0.3–1.2	40–301	40–501	5–21	20–51	0–251	25–77	0–0.2

[1]Fol = Foliar application; Soil = Soil application. *BAM = BAM-FX at 1 oz per acre (foliar application or soil application); Pes = pesticide; NPK = N-P-K at standard rate.

may also be due to the production of defense compounds by the plants in response to insect feeding damage. Schwachtje and Baldwin (2008) indicated that a plant's defense mechanism in response to insect attack is coordinated by different signaling pathways, depending on the primary metabolites. This response may vary depending on the insect that feeds on the plant. *Bemisia tabaci* feeding on *Gossypium hirsutum* L. (Malvaceae) resulted in an increase in sucrose concentration (Schmidt et al. 2009), whereas no change of sucrose concentration resulted when *Aphis gossypii* Glover (Hemiptera: Aphididae) fed on the same plant (Gomez et al. 2006). Due to the absence of N-P-K fertilizer in BAM-FX treatments, the total concentration of nitrogen and amino acid might have decreased below normal level compared to the control leaves (T7), which reduced palatability to the insect pests, resulting in a decrease in their population abundance. Sharma et al. (2016) recorded a drop in the total mass of amino acids in infested leaves of *Eucalyptus macrorhyncha* (F. Muell. ex. Benth) (Myrtaceae). Saltzmann et al. (2008) reported that a high concentration of amino acids, essential or nonessential, increase palatability of host tissues to insects, resulting in an increase in insect population abundance.

The low abundance of thrips on tomato during this study can be explained by the fact that tomato is a poor host for thrips (Khan 2018). It was not considered as a host of melon thrips until recently (Capinera 2000). Common blossom thrips and western flower thrips feed and reproduce on tomato, but their abundance was very low during this study.

Among nutrients, nitrogen, phosphorus, and potassium are considered primary nutrients, which must be in the soil or in the growing medium in appropriate levels for the normal growth of plants. Plants use nitrogen to synthesize amino acids, proteins, chlorophyll, nucleic acids, and enzymes (Hopkins 1995). Phosphorus hastens maturity, forms nucleic acid, and is vital for photosynthesis and cell division (Tajer 2016). Potassium strengthens cell walls, affects water uptake by plants cells, acts as a catalyst of iron uptake, and increases resistance against pests. Potassium is involved in activating key enzymes involved in respiration and photosynthesis (Jin et al. 2011). Thus, low levels of nitrogen and high levels of phosphorus and potassium negatively affect plant growth (Godfrey & Hutmacher 1997), abundance of sweetpotato whitefly adults and nymphs, and overall population.

In this study, plant height, width, root width, number of fruits, and plant performance generally were higher values for N-P-K treatments (including the control) than for the BAM-FX treatments. The reduced growth performance of BAM-FX treatments could be related to the lack of appropriate levels of usable nitrogen, phosphorus, and potassium in the soil, and the possible interactions of other elements. However, the higher values for all growth parameters were recorded when BAM-FX was included in a program with N-P-K.

The absence of nitrogen fertilizer in BAM-FX treatments apparently limited the tissue nitrogen content, resulting in low plant biomass and possibly increasing the production of secondary metabolites in plant tissues. Both factors can negatively affect insect vectors when they attempt to colonize tomato plants, thereby limiting transmission of virus (Auclair et el. 1957; Dixon 1970; Weibull 1987; Sandstrom & Pettersson 1994). When levels of nitrogen in plant tissues are reduced, less nitrogen is available for herbivorous insects to consume and use to synthesize amino acids. Furthermore, the resulting secondary metabolites in plants are often defensive compounds, which may serve as repellents or antifeedants to insects.

Because tomato yellow leaf curl virus is transmitted by sweetpotato whitefly adults, it should not be surprising that both the insect vector and virus showed similar differences among treatments. Here, differences occurred on all sample dates, and more adults were found on the controls than on BAM-FX treatments. Tomato chlorotic spot virus is transmitted by *F. schultzei* and *F. occidentalis*, and only immature insect

Table 9. Mean ± SEM number of tomato fruits per plant treated with various treatments of BAM-FX and N-P-K granular fertilizer in 2014 and 2016.

Treatments	BAM[1] – Pes – NPK*	2014	2016
T1	Fol – 0 – 0	3.2 ± 0.37 cd	4.9 ± 0.22 d
T2	Soil – 0 – 0	2.3 ± 0.24 d	3.5 ± 0.21 e
T3	Fol – Pes – 0	3.4 ± 0.39 cd	6.1 ± 0.280 c
T4	Soil – Pes – 0	4.3 ± 0.37 c	5.4 ± 0.21 cd
T5	Soil – Pes – NPK	16.3 ± 0.64 a	17.3 ± 0.45 a
T6	Soil – Pes – NPK (Standard)	11.8 ± 0.94 b	13.9 ± 0.33 b
T7	0 – 0 – NPK (Untreated control)	12.6 ± 1.32 a	12.9 ± 0.36 b

[1]Fol = Foliar application; Soil = Soil application. *BAM = BAM-FX at 1 oz per acre (foliar application or soil application); Pes = pesticide; NPK = N-P-K at standard rate. Means (SEM) within a column followed by the same letters do not differ significantly ($P < 0.05$; Waller-Duncan K-ratio t Test). 2014: $F = 48.96$; df = 5,114; $P = < 0.0001$; 2015: $F = 228.54$; df = 5,114; $P = < 0.0001$.

stages feeding on infected plants can acquire the virus. Upon transformation of infected larvae into adults, they disperse to other plants and transmit the viruses when feeding. Plants treated with BAM-FX may have become less attractive (or more repellent) to thrips for feeding; hence, the abundance of these viruses was much lower on these plants than on the controls with standard nitrogen fertilization. As previously indicated, low nitrogen resulted in low plant biomass, and possible production of secondary metabolites, both limiting factors for virus transmission (Auclair et al. 1957; Dixon 1970; Weibull 1987; Sandstrom & Pettersson 1994). Another possible reason could be the expression of characters (genes) in host plants in response to the feeding of sweetpotato whitefly, thrips adults, and their immatures, which played a defensive role for insects and their transmitted diseases. Dubey et al. (2013) identified that infestation by aphids and whiteflies down-regulated several kinases, which enhanced disease resistance in host plants.

Most of the secondary and minor elements (phosphorus, magnesium, sulphur, manganize, zinc, boron, sodium) were found within the normal range in leaf tissues. However, calcium, iron, copper, and aluminium levels were higher than the normal levels, while nitrogen and potassium were slightly below the normal range. The interaction between different elements plays a significant role in plant physiological processes, which may affect attraction, repellence, and hardiness of plants, thereby affecting insect and disease populations. For example, nitrogen fertilization plays an important role in increasing, decreasing or ameliorating zinc deficiency in plants (Hafeez et al. 2013). Zinc is important for water uptake and transport by plants, and reduces adverse effects from heat and salt stresses (Kasim 2007; Disante et al. 2010; Peck & McDonald 2010; Tavallali et al. 2010). Overall, such changes impact plant growth, resulting in increase or decrease of pest populations and their transmitted diseases. Information about the above factors in relation to insects and diseases is rare, and should be a significant subject for future research studies.

BAM-FX was clearly less effective in increasing plant growth and yields than the N-P-K fertilizer that was provided to the control treatment. BAM-FX facilitates the movement of nutritional ions in plants, and when combined with ordinary fertilizers, it may become more effective at increasing plant growth and yields than using only BAM-FX or fertilizer. Although plant productivity was usually reduced in the absence of fertilizers and the nutrients they provide, BAM-FX showed good potential for pest suppression. Compared to plants with a standard fertilization, BAM-FX provided effective reduction of sweetpotato whitefly and a virus it transmits, the tomato yellow leaf curl virus. BAM-FX did not suppress thrips and the tomato chlorotic spot virus that they transmit. The use of BAM-FX to manage tomato pests, especially sweetpotato whitefly and tomato yellow leaf curl virus, therefore, may be beneficial to growers. However, further studies should be conducted using BAM-FX in combination with proper use of N-P-K fertilizer, which might be useful for increasing yield and suppressing pests.

Acknowledgments

We thank C. M. Sabines and Massy Senaie for collecting data on various parameters of this study. C. G. Martin assisted in organizing data. This study was conducted with the support of Zero Gravity Solutions Inc., Boca Raton, Florida, USA.

References cited

Auclair JL, Maltaise JB, Carter JJ. 1957. Factors in resistance of peas to the pea aphid, *Acyrthosiphon pisum* (Harr.) (Homoptera: Aphididae). II. Amino acid. Canadian Entomologist 89: 457–464.

Bi JL, Toscano NC, Madore MA. 2002. Effect of urea fertilizer application on soluble protein and free amino acid content of cotton petioles in relation to silverleaf whitefly (*Bemisia argentifolii*) populations. Journal of Chemical Ecology 29: 747–761.

Brown JK, Frohlich DR, Rosell RC. 1995. The sweetpotato or silverleaf whiteflies: biotypes of *Bemisia tabaci* or a species complex? Annual Review of Entomology 40: 511–534.

Campbell CR. 1992. Determination of total nitrogen in plant tissue by combustion, pp. 21–23 *In* Plank CO [ed.], Plant Analysis Reference Procedures for the Southern Region of the United States. Southern Cooperative Series Bulletin 368. Georgia Agricultural Experiment Station, Experiment, Georgia, USA.

Capinera J. 2000. Melon thrips, *Thrips palmi* Karny (Insecta: Thysanoptera: Thripidae). Electronic Data Information Source (EDIS), Publication EENY135. University of Florida, Gainesville, Florida, USA.

De Barro PJ, Liu SS, Boykin LM, Dinsdale AB. 2011. *Bemisia tabaci*: a statement of species status. Annual Review of Entomology 56: 1–19.

Disante KB, Fuentes D, Cortina J. 2010. Response to drought of Zn-stressed *Quercus suber* L. seedlings. Environmental and Experimental Botany 70: 96–103.

Dixon AFG. 1970. Quality and availability of food for a sycamore aphid population, pp. 271–287 *In* Watson A [ed.], Annual Populations in Relation to Their Resources. Blackwell Scientific, Oxford, United Kingdom.

Dubey NK, Goel R, Ranjan A, Idris A, Singh SK, Bag SK, Chandrashekar K, Pandey KD, Singh PK, Sawant SV. 2013. Comparative transcriptome analysis of *Gossypium hirsutum* L. in response to sap sucking insects: aphids and whitefly. BioMed Central (BMC) Genomics 14: 241. doi: 10.1186/1471-2164-14-241

FAOSTAT Database. 2004. Tomato World Production Statistics. http://www.growtomatoes.com/tomato-world-production-statistics/ (last accessed 11 Jun 2019).

Florida Tomato Committee. 2014. Annual Report. Maitland, Florida, USA. https://www.floridatomatoes.org/ (last accessed 11 Jun 2019).

Funderburk J, Reitz S, Olson S, Stansly P, Smith H, McAvoy G, Demirozer O, Snodgrass C, Paret M, Leppla N. 2011. Managing thrips and tospoviruses in tomato. EDIS Publication ENY859/IN895. University of Florida, Gainesville, Florida, USA.

Godfrey LD, Hutmacher R. 1997. Interaction of cotton nitrogen fertility practices and cotton aphid population dynamics in California cotton. https://www.cdfa.ca.gov/is/ffldrs/frep/pdfs/completedprojects/97-0365M98-04Godfrey.pdf (last accessed 11 Jun 2019).

Godfrey LD, Keillor K, Hutmacher RB, Cisneros J. 1999. Interaction of cotton aphid population dynamics and cotton fertilization regime in California cotton, pp. 1008–1011 *In* Dugger P, Richer D [eds.], Proceedings, Beltwide

Cotton Conferences, 1983–1999. National Cotton Council of America, Memphis, Tennessee, USA.
Gomez SK, Oosterhuis DM, Hendrix DL, Johnson DR, Steinkraus DC. 2006. Diurnal pattern of aphid feeding and its effect on cotton leaf physiology. Environmental and Experimental Botany 55: 77–86.
Hafeez B, Khanif YM, Saleem M. 2013. Role of zinc in plant nutrition - a review. American Journal of Experimental Agriculture 3: 374–391.
Hopkins WG. 1995. Introduction to Plant Physiology. John Wiley and Son, Inc., New York, USA.
Isaac RA, Johnson Jr WC. 1992. Determination of P, K, Ca, Mg, Mn, Fe, Al, B, Cu, and Zn in plant tissue by emission spectroscopy, pp. 41–43 *In* Plank CO [ed.], Plant Analysis Reference Procedures for the Southern Region of the United States. Southern Cooperative Series Bulletin 368. Georgia Agricultural Experiment Station, Experiment, Georgia, USA.
Jansson RK, Smilowitz Z. 1986. Influence of nitrogen on population parameters of potato insects: abundance, population growth and within plant distribution of the green peach aphid, *Myzus persicae* (Homoptera: Aphididae). Environmental Entomology 15: 49–55.
Jauset AM, Sarasua MJ, Avilla J, Albajes R. 1998. The impact of nitrogen fertilization of tomato on feeding site selection and oviposition by *Trialeurodes vaporariorum*. Entomologia Experimentalis et Applicata 86: 175–182.
Jauset AM, Sarasua MJ, Avilla J, Albajes R. 2000. Effect of nitrogen fertilization level applied to tomato on the greenhouse whitefly. Crop Protection 19: 255–261.
Jin SH, Huang JQ, Li XQ, Zheng BS, Wu JS, Wang ZJ, Liu GH, Chen M. 2011. Effects of potassium supply on limitations of photosynthesis by mesophyll diffusion conductance in *Carya cathayensis*. Tree Physiology 31: 1142–1151.
Kasim WA. 2007. Physiological consequences of structural and ultra-structural changes induced by Zn stress in *Phaseolus vulgaris*. 1. Growth and photosynthetic apparatus. International Journal of Botany 3: 15–22.
Kennedy JW. 2016. Bioavailable Minerals for Plant Health. United States Patent #US 9,266,786 B2.
Khan RA. 2018. Sustainable management approach for controlling thrips (Thysanoptera: Thripidae) and their transmitted tospoviruses in tomatoes in south Florida. Ph.D. Dissertation (in progress). Entomology and Nematology Department, University of Florida, Gainesville, Florida, USA.
Londoño A, Capobianco H, Zhang S, Polston JE. 2012. First record of tomato chlorotic spot virus in the USA. Tropical Plant Pathology 37: 333–338.
Marullo R, De Grazia A. 2013. Territorial distribution, classification and relationships amongst Italian Thysanoptera. Bulletin of Insectology 66: 127–134.
Mound LA. 1997. Biological diversity, pp. 197–225 *In* Lewis T [ed.], Thrips as Crop Pests. CAB International, New York, USA.
Noble CV, Drew RW, Slabaugh V. 1996. Soil survey of Dade County area, Florida. USDA, Natural Resources Conservation Service, Washington, DC, USA.
Peck AW, McDonald GK. 2010. Adequate zinc nutrition alleviates the adverse effects of head stress in bread wheat. Plant and Soil 337: 355–374.
Riley DG, Joseph SV, Srinivasan R, Diffie S. 2011. Thrips vectors of tospoviruses. Journal of Integrated Pest Management 2. https://doi.org/10.1603/IPM10020 (last accessed 11 Jun 2019).
Rotenberg D, Jacobson AL, Schneweis DJ, Whitfield AF. 2015. Thrips transmission of tospoviruses. Current Opinion in Virology 15: 80–89.
Saltzmann KD, Giovanini MP, Zheng C, William CE. 2008. Virulent Hessian-fly larvae manipulate the tree amino acid content of host wheat plants. Journal of Chemical Ecology 34: 1401–1410.
Sandstrom J, Pettersson J. 1994. Amino acid composition of phloem sap and the relation to intraspecific variation in pea aphid (*Acyrthosiphon pisum*) performance. Journal of Insect Physiology 40: 947–955.
SAS Institute. 2013. The SAS system for Windows. Ver. 9.3. SAS Institute Inc., Cary, North Carolina, USA.
Schmidt L, Schurr U, Rose US. 2009. Local and systemic effects of two herbivores with different feeding mechanisms on primary metabolism of cotton leaves. Plant, Cell and Environment 32: 893–903.
Schwachtje J, Baldwin IT. 2008. Why does herbivore attack reconfigure primary metabolism? Plant Physiology 146: 845–851.
Sharma A, Allen J, Madhavan S, Raman A, Taylor GS, Fletcher MJ. 2016. How do free-living, lerp-forming, and gall-inducing Aphalaridae (Hemiptera: Psylloidea) affect the nutritional quality of *Eucalyptus* leaves? Annals of the Entomological Society of America 109: 127–135.
Tajer A. 2016. What is the function of phosphorus (P) in plants? Greenway Biotech, Inc., Santa Fe Springs, California, USA. https://www.greenwaybiotech.com/blogs/news/whats-the-function-of-phosphorus-p-in-plants (last accessed 11 Jun 2019).
Tavallali V, Rahemi M, Eshghi S, Kholdebarin B, Ramezanian A. 2010. Zinc alleviates salt stress and increases antioxidant enzyme activity in the leaves of pistachio (*Pistacia vera* L. 'Badami') seedlings. Turkish Journal of Agriculture and Forestry 34: 349–359.
Thrips Wiki. 2017. Thrips Wiki - providing information on the world's thrips. http:/thrips.info/wiki/ (last accessed 11 Jun 2019).
Waller RA, Duncan DB. 1969. A Bayes rule for the symmetric multiple comparisons problem. Journal of the American Statistical Association 64: 1484–1503.
Webb SE, Stansly PA, Schuster DJ, Funderburk JE, Smith H. 2001. Insect management for tomatoes, peppers and eggplants. Publication ENY 461. Entomology and Nematology Department, University of Florida, Gainesville, Florida, USA. https://edis.ifas.ufl.edu/in169 (last accessed 11 Jun 2019).
Weibull J. 1987. Season changes in the free amino acids of oat and barley phloem sap in relation to plant growth stage and growth of *Rhopalosiphum padi*. Annals of Applied Biology 111: 729–737.
Zhang S, Seal D, Wang Q, McAvoy E. 2015. An outbreak of tomato chlorotic spot virus (TCSV) in South Florida. Vegetarian Newsletter 597. Horticultural Science Department, University of Florida, Gainesville, Florida, USA. http://old-hos.ifas.ufl.edu/newsletters/vegetarian/issue-no-597.