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

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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 Seal1,* , Rafia Khan1, Wagner Vendrame1, and Christine Waddill1

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, four 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 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 ninñas 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 consistente en menor en las parcelas tratadas con pesticida BAM-FX más que en las parcelas tratadas con N-P-K. La cantidad media de triops de flores comunes (Frankliniella schultzei Trybom; Thysanoptera: Thripidae) y triops 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 inconsistente 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...
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other negative consequences. Various alternative management pro-
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imal and soil conditions is still unknown and needs to be evalu-
floral thrips, Franki liquiella schulzeti Trybom; Thysanoptera: Thripidae; and western
flower thrips, Franki liquiella occidentalis (Pergande); Thysanoptera: 
(De Barro et al. 2011). With the increase of biotypes, 20 known already, 
host species number may exceed far more than 900. Sweetpotato
thrips transmit 100 plant viruses, including tomato yellow leaf curl 
and bean golden yellow mosaic virus. Major crop losses due to 
sweetpotato whitefly feeding and virus transmission occurs through-
out the world.

Thrips belonging to different species are damaging pests of toma-
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 oviposi-
tion, 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 tospovi-
rus (tomato chlorotic spot virus) damaging to tomato was detected in 
south Florida in 2012 (Lodono et al. 2012; Ziang et al. 2015). 
Common blossom thrips (F. schulzeti) and western flower thrips (F. occi-
dentals) are known vectors of tospoviruses like tomato chlorotic spot 
us, tomato spotted wilt virus and groundnut ring spot virus (Fun-
derburk 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 observa-
tion). 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 com-
mmercial growers to combat the insect pests of tomato and other ve-
egetables. This practice often results in development of resistance and 
other negative consequences. Various alternative management pro-
grams can be considered to reduce the sole dependence on chemical
pesticides. Balance nutrients to increase plant vigor, varietal resis-
tance, 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 vulner-
able 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 
sects and the viruses they transmit. Although the principle seems 
reasonable, the effectiveness of the product under variable environ-
mental and soil conditions is still unknown and needs to be evalu-
at. We explored this idea to determine the potential of BAM-FX in 
acting 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 to-
ato 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 Ag-
icultural Sciences, located at 25.513055°N, 80.504722°W in Home-
stead, 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 ml, Cansilt 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 irri-
ration. 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 
$m^3$), which is considered 100% of field capacity.

The treatment plots, each 12.19 m long, were arranged in a ran-
domized complete block design with 4 replications. BAM-FX was ap-
plied 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 treat-
ments) 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
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 (Tora®, 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 CO₂ 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-cm² sections on each leaf by using a Leica Wild M32 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 M32 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 (R²) 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**

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<tbody>
<tr>
<td></td>
<td>9 Jan</td>
<td>15 Jan</td>
<td>22 Jan</td>
</tr>
<tr>
<td>T1</td>
<td>Fol – 0 – 0</td>
<td>0.25 c</td>
<td>0.35 b</td>
</tr>
<tr>
<td>T2</td>
<td>Soil – 0 – 0</td>
<td>0.10</td>
<td>0.80 b</td>
</tr>
<tr>
<td>T3</td>
<td>Fol – Pes – 0</td>
<td>0.15 c</td>
<td>0.65 b</td>
</tr>
<tr>
<td>T4</td>
<td>Soil – Pes – 0</td>
<td>0.20 c</td>
<td>0.60 b</td>
</tr>
<tr>
<td>T5</td>
<td>Soil – Pes – NPK</td>
<td>0.65 bc</td>
<td>1.15 ab</td>
</tr>
<tr>
<td>T6</td>
<td>0 – Pes – NPK (Standard)</td>
<td>0.75 b</td>
<td>1.90 a</td>
</tr>
<tr>
<td>T7</td>
<td>0 – 0 – NPK (Untreated control)</td>
<td>1.55 a</td>
<td>1.95 a</td>
</tr>
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</table>

*Fol = Foliar application; Soil = Soil application. BAM = BAM-FX at 1 oz per acre (folic acid 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).
In the 2014 study, mean numbers of sweetpotato whitefly nymphs 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: $F = 4.11$; $df = 6,132$; $P = 0.001$; 21 Dec: $F = 8.49$; $df = 6,132$; $P = 0.001$; 29 Jan: $F = 23.0$; $df = 6,132$; $P = 0.001$ (Table 3). A similar pattern of reduction in the number of sweetpotato whitefly nymphs in BAM-FX treated plants (T1–T5) also was recorded in the 2016 study (14 Dec: $F = 8.93$; $df = 6,77$; $P = 0.001$; 11 Jan: $F = 5.33$; $df = 6,77$; $P = 0.001$; 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) showed 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.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>2014</th>
<th>2016</th>
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<tr>
<td></td>
<td>9 Jan</td>
<td>15 Jan</td>
</tr>
<tr>
<td>T1</td>
<td>Soil – 0 – 0</td>
<td>0.20 c</td>
</tr>
<tr>
<td>T2</td>
<td>Fol – Pes – 0</td>
<td>0.25 bc</td>
</tr>
<tr>
<td>T3</td>
<td>Soil – Pes – 0</td>
<td>0.10 c</td>
</tr>
<tr>
<td>T4</td>
<td>Soil – Pes – NPK</td>
<td>0.20 c</td>
</tr>
<tr>
<td>T5</td>
<td>0 – Pes – NPK</td>
<td>0.40 bc</td>
</tr>
<tr>
<td>T6</td>
<td>0 – Pes – NPK (Standard)</td>
<td>0.65 ab</td>
</tr>
<tr>
<td>T7</td>
<td>0 – NPK (Untreated control)</td>
<td>1.10 a</td>
</tr>
</tbody>
</table>

*Sol = 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: \( F = 1.95; \text{df} = 6,104; P > 0.05 \); 21 Dec: \( F = 1.73; \text{df} = 6,104; P = 0.1205 \); 28 Dec: \( F = 3.03; \text{df} = 6,104; P = 0.0089 \); 4 Jan: \( F = 3.24; \text{df} = 6,104; P = 0.0058 \); 11 Jan: \( F = 1.41; \text{df} = 6,104; P = 0.2178 \); 18 Jan: \( F = 1.62; \text{df} = 6,104; P = 0.1488 \)). In this study, western flower thrips showed a weak relationship with the incidence of tomato chlorotic spot virus (\( R^2 = 0.093, \text{Coeff Var} = 76.95 \)).

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) (\( F = 6.21; \text{df} = 6,21; P = 0.001 \)). 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 (\( F = 6.21; \text{df} = 6,21; P = 0.001 \)). On the third sampling date (21 Jan), there were no tomato yellow leaf curl virus infected plants; as in the previous sampling date (\( F = 19.53; \text{df} = 6,21; P = 0.001 \)) sampling dates, tomato yellow leaf curl virus incidence was recorded on all

### 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.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>BAM* – Pes – NPK*</th>
<th>2014</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 Soil – 0 – 0</td>
<td>0.10 b 0.15 abb 0.37 b</td>
<td>0.70 bc 0.25 c 0.58 b 0.42 cd 0.42 c 0.83 c 0.65 b</td>
<td>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 cd 0.75 b</td>
</tr>
<tr>
<td>T2 Fol – Pes – 0</td>
<td>0.15 b 0.20 ab 0.45 b</td>
<td>1.10 b 0.08 c 0.25 b 0.33 cd 0.33 c 0.42 cd 0.75 b</td>
<td>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 cd 0.75 b</td>
</tr>
<tr>
<td>T3 Soil – Pes – 0</td>
<td>0 b 0.25 ab 0.25 b 0.40 c</td>
<td>0.17 c 0.25 b 0.33 cd 0.33 c 0.17 ef 0.00 c</td>
<td>0.17 c 0.25 b 0.33 cd 0.33 c 0.17 ef 0.00 c</td>
</tr>
<tr>
<td>T4 Soil – Pes – NPK</td>
<td>0.15 b 0.05 b 0.20 b 0.55 c</td>
<td>0.08 c 0.25 b 0.08 cd 0.08 c 0.0 f 0.10 c</td>
<td>0.08 c 0.25 b 0.08 cd 0.08 c 0.0 f 0.10 c</td>
</tr>
<tr>
<td>T5 0 – Pes – NPK</td>
<td>0.25 ab 0.20 ab 0.25 b 0.70 bc</td>
<td>0.42 bc 0.50 b 0.67 c 1.67 b 0.67 cd 0.45 b</td>
<td>0.42 bc 0.50 b 0.67 c 1.67 b 0.67 cd 0.45 b</td>
</tr>
<tr>
<td>T6 0 – Pes – NPK (Standard)</td>
<td>0.25 ab 0.55 a 0.90 b 0.70 a</td>
<td>0.83 ab 2.00 a 1.83 b 1.33 b 2.17 ab 0.85 b</td>
<td>0.83 ab 2.00 a 1.83 b 1.33 b 2.17 ab 0.85 b</td>
</tr>
<tr>
<td>T7 0 – 0 – NPK (Untreated control)</td>
<td>0.55 a 0.55 a 7.65 a</td>
<td>2.70 a</td>
<td>1.33 a 2.08 a 3.00 a 4.50 a 2.65 a</td>
</tr>
</tbody>
</table>

1Fol = 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 test).
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 growth (F = 77.15; df = 6,133; P = 0.001).

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.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>BAM† – Pes – NPK*</th>
<th>2014</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9 Jan</td>
<td>15 Jan</td>
<td>22 Jan</td>
</tr>
<tr>
<td>T1</td>
<td>Soil – 0 – 0</td>
<td>0 b</td>
<td>0.25 bc</td>
</tr>
<tr>
<td>T2</td>
<td>Fol – Pes – 0</td>
<td>0 b</td>
<td>0 c</td>
</tr>
<tr>
<td>T3</td>
<td>Soil – Pes – 0</td>
<td>0 b</td>
<td>0 c</td>
</tr>
<tr>
<td>T4</td>
<td>Soil – Pes – NPK</td>
<td>0 b</td>
<td>0 c</td>
</tr>
<tr>
<td>T5</td>
<td>0 – Pes – NPK</td>
<td>1.25 a</td>
<td>1.50 a</td>
</tr>
<tr>
<td>T6</td>
<td>0 – Pes – NPK (Standard)</td>
<td>1.00 a</td>
<td>1.00 ab</td>
</tr>
<tr>
<td>T7</td>
<td>0 – NPK (Untreated control)</td>
<td>1.00 a</td>
<td>1.25 a</td>
</tr>
</tbody>
</table>

†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.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>9 Jan</td>
<td>15 Jan</td>
</tr>
<tr>
<td>T1</td>
<td>Soil – 0 – 0</td>
<td>0</td>
<td>0 a</td>
</tr>
<tr>
<td>T2</td>
<td>Fol – Pes – 0</td>
<td>0</td>
<td>0 a</td>
</tr>
<tr>
<td>T3</td>
<td>Soil – Pes – 0</td>
<td>0</td>
<td>0 a</td>
</tr>
<tr>
<td>T4</td>
<td>Soil – Pes – NPK</td>
<td>0</td>
<td>0 a</td>
</tr>
<tr>
<td>T5</td>
<td>0 – Pes – NPK</td>
<td>0.25 a</td>
<td>1.00 a</td>
</tr>
<tr>
<td>T6</td>
<td>0 – Pes – NPK*</td>
<td>0.50 a</td>
<td>0.75 a</td>
</tr>
<tr>
<td>T7</td>
<td>0 – 0 – NPK</td>
<td>0.25 a</td>
<td>0.75 a</td>
</tr>
</tbody>
</table>

1Fol = 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 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 al. 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.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>BAM – Pes – NPK*</th>
<th>Plant height (cm)</th>
<th>Plant width (cm)</th>
<th>Root length (cm)</th>
<th>Root width (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Soil – 0 – 0</td>
<td>52.13 cd</td>
<td>28.50 cd</td>
<td>5.21 c</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>Fol – Pes – 0</td>
<td>48.88 d</td>
<td>24.63 d</td>
<td>4.70 c</td>
<td></td>
</tr>
<tr>
<td>T3</td>
<td>Soil – Pes – 0</td>
<td>54.63 c</td>
<td>30.75 cd</td>
<td>4.47 d</td>
<td></td>
</tr>
<tr>
<td>T4</td>
<td>Soil – Pes – NPK</td>
<td>54.13 c</td>
<td>33.38 c</td>
<td>6.19 b</td>
<td></td>
</tr>
<tr>
<td>T5</td>
<td>0 – Pes – NPK</td>
<td>88.75 a</td>
<td>72.75 a</td>
<td>8.11 a</td>
<td></td>
</tr>
<tr>
<td>T6</td>
<td>0 – Pes – NPK*</td>
<td>78.13 b</td>
<td>62.88 b</td>
<td>7.74 a</td>
<td></td>
</tr>
<tr>
<td>T7</td>
<td>0 – 0 – NPK</td>
<td>84.00 a</td>
<td>59.88 b</td>
<td>7.88 a</td>
<td></td>
</tr>
</tbody>
</table>

1Fol = 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.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>N (%)</th>
<th>P (%)</th>
<th>K (%)</th>
<th>Ca (%)</th>
<th>Mg (%)</th>
<th>S (%)</th>
<th>Fe (%)</th>
<th>Zn (ppm)</th>
<th>B (ppm)</th>
<th>Cu (ppm)</th>
<th>Mn (ppm)</th>
<th>Al (ppm)</th>
<th>Na (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAM - Pes - NPK*</td>
<td>2.1</td>
<td>0.55</td>
<td>1.01</td>
<td>0.84</td>
<td>8.63</td>
<td>0.52</td>
<td>0.82</td>
<td>628</td>
<td>163</td>
<td>40</td>
<td>36</td>
<td>138</td>
<td>36</td>
</tr>
<tr>
<td>Fol - 0</td>
<td>2.2</td>
<td>0.68</td>
<td>1.04</td>
<td>0.87</td>
<td>8.41</td>
<td>0.47</td>
<td>0.66</td>
<td>391</td>
<td>97</td>
<td>33</td>
<td>29</td>
<td>121</td>
<td>40</td>
</tr>
<tr>
<td>Soil - Pes - 0</td>
<td>2.0</td>
<td>0.50</td>
<td>1.04</td>
<td>0.87</td>
<td>8.41</td>
<td>0.47</td>
<td>0.66</td>
<td>391</td>
<td>97</td>
<td>33</td>
<td>29</td>
<td>121</td>
<td>40</td>
</tr>
<tr>
<td>Soil - Pes - NPK</td>
<td>3.2</td>
<td>0.60</td>
<td>1.04</td>
<td>0.87</td>
<td>8.41</td>
<td>0.47</td>
<td>0.66</td>
<td>391</td>
<td>97</td>
<td>33</td>
<td>29</td>
<td>121</td>
<td>40</td>
</tr>
<tr>
<td>Soil - Pes - NPK (Standard)</td>
<td>3.5</td>
<td>0.78</td>
<td>1.04</td>
<td>0.87</td>
<td>8.41</td>
<td>0.47</td>
<td>0.66</td>
<td>391</td>
<td>97</td>
<td>33</td>
<td>29</td>
<td>121</td>
<td>40</td>
</tr>
<tr>
<td>0 - NPK Untreated control</td>
<td>2.8-6.0</td>
<td>0.25-0.80</td>
<td>2.5-4.99</td>
<td>1.0-2.99</td>
<td>0.4-0.99</td>
<td>0.3-1.2</td>
<td>0.4-0.99</td>
<td>371</td>
<td>133</td>
<td>47</td>
<td>37</td>
<td>133</td>
<td>47</td>
</tr>
<tr>
<td>Normal range</td>
<td>0-2.5</td>
<td>0-0.35</td>
<td>0-2.5</td>
<td>0-0.35</td>
<td>0-2.5</td>
<td>0-0.35</td>
<td>0-2.5</td>
<td>0-0.35</td>
<td>0-2.5</td>
<td>0-0.35</td>
<td>0-2.5</td>
<td>0-0.35</td>
<td>0-2.5</td>
</tr>
</tbody>
</table>

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 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. Bent) (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.
stages feeding on infected plants can acquire the virus. Upon transmogrification 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, manganese, zinc, boron, sodium) were found within the normal range in leaf tissues. However, calcium, iron, copper, and aluminum levels were higher than the normal ranges. The interaction of secondary elements, which might be useful for increasing yield and suppressing pests. BAM-FX did not suppress thrips and the tomato chlorotic spot virus (TCSV) (De Barro et al. 2011). However, 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 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.

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