Managing Thrips on Roses with Combinations of Neonicotinoide and Biological Insecticides[1]

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ABSTRACT The purpose of this research was to develop a bio-intensive pest management system for the thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae), on hybrid roses by incorporating biopesticides [spinosad, emamectin benzoate, and *Beauveria bassiana* (Balsamo) Vuillemin] with neonicotinoides (imidacloprid and acetamiprid) at half the labeled dose. Soil and spray treatments with these insecticides and their combinations were done at 45-d intervals in 2009 and at 60-d intervals in 2010. An imidacloprid drench was the most effective treatment both years. Spinosad-alone, imidacloprid + spinosad, imidacloprid + emamectin benzoate, imidacloprid + *B. bassiana*, acetamiprid alone, acetamiprid + spinosad, acetamiprid + emamectin benzoate, and acetamiprid + *B. bassiana* also gave significant control of thrips at four days after spraying. In 2009, spinosad-alone or in combination with imidacloprid remained effective in controlling thrips populations significantly up to 10 d after insecticide treatment. In 2010, the spinosad-alone treatment gave similar results, but spinosad in combination with imidacloprid (half the labeled dose) showed significant thrips control up to 16 d after insecticide applications.

KEY WORDS *Scirtothrips dorsalis*, imidacloprid, spinosad, insecticide combinations, neonicitinoides

The thrips species, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae), is a recognized pest of many plants, including vegetables, roses, greenhouse-grown plants, and cotton (Boll et al. 2007). Thrips are one of the major pests of roses, causing 28–95% damage (Gahukar 2003). It is important to detect and manage thrips on roses, even at low densities, because even a few individuals on flowers may result in rose petal discoloration (Bertaux et al. 2003). Thrips are tiny insects that reproduce rapidly, congregate in tight places that make pesticide coverage difficult, and feed with rasping-piercing-sucking mouth parts, resulting in deformation of flowers and leaves (Duraimurugan & Jagadish 2011). Tolerance for thrips on floriculture crops is particularly low.

In addition, when thrips feed on plants infected with the *tomato spotted wilt virus* or *impatiens necrotic spot virus*, they can vector these diseases to other plants (Boonham et al. 2002, Sakurai et al. 2004). Once plants are infected, it is too late to do anything except dispose of the diseased plants. Thus, the best way to prevent virus infection is to control thrips from the beginning of plant growth.

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Synthetic insecticides are used frequently to control thrips in greenhouses, and populations of some thrips species have developed resistance to different groups of insecticides (Schreiber et al. 1989, 1990, Immaraju et al. 1992, Zhao et al. 1995). Fortunately, biopesticides have been gaining interest among those concerned with developing environmentally friendly and safe integrated crop management systems, with compatible approaches and tactics for pest management (Copping & Menn 2000). At present, microbial insecticides are a main component of the biopesticide industry (Shi 2000). One major constraint for using microbial insecticides is that they are comparatively slow in action compared with other chemical insecticides. One demand of researchers is to develop fast and environmentally safe pest management systems using biopesticides. Literature is available for the control of thrips with neonicotinoides and bioinsecticides, however the combined use and effect of those combinations is lacking. The purpose of this research is to develop a bio-intensive pest management system for thrips, *S. dorsalis*, on hybrid roses by incorporating bioinsecticides [spinosad, emamectin benzoate, and *Beauveria bassiana* (Balsamo) Vuillemin (Hypocreales: Cordycipitaceae)] with neonicotinoides (imidacloprid and acetamiprid).

Imidacloprid, a neonicotinoide, is used worldwide in seed treatments, soil treatments, and foliar applications for the control of sucking insects, including aphids, thrips, whiteflies, and fungus gnats in the greenhouse (Ishaaya & Degheele 1998). Lopez et al. (2008) found that the contact toxicity of spinosad was higher than other biorational insecticides tested against thrips on greenhouse cotton plants. Spinosad and imidacloprid decreased thrips populations significantly in an onion crop when applied weekly during the crop season (Workman & Martin 2002). Cloyd & Sadof (2000) reported that spinosad and acephate were effective at controlling thrips on greenhouse-grown plants.

Materials and Methods

Eighty red-colored hybrid tea roses were purchased from a nursery (Ram Nursery, Chandigarh) on 2 March 2009. Using normal cultural practices, they were grown in pots in an open space outside the Zoology Department, Panjab University, Chandigarh, India. Soon thereafter, a natural infestation of *S. dorsalis* was observed on the potted rose plants. Similarly, in 2010 these plants were infested with a natural population of thrips.

Registered formulations of spinosad, emamectin benzoate, *Beauveria bassiana*, imidacloprid, and acetamiprid (Table 1) were evaluated for effectiveness on infestations of *S. dorsalis* on the potted rose plants. Fertilizers and fungicide treatments were applied when needed to all treatments, including the control. Thirteen treatment combinations with three replications each were evaluated. Treatments were imidacloprid (soil-drench application), imidacloprid (foliar spray), acetamiprid (foliar spray), spinosad (foliar spray), emamectin benzoate (foliar spray), *Beauveria bassiana* (foliar spray), imidacloprid + spinosad (foliar spray), imidacloprid + emamectin benzoate (foliar spray), imidacloprid + *B. bassiana* (foliar spray), acetamiprid + spinosad (foliar spray), acetamiprid + emamectin benzoate (foliar spray), acetamiprid + *B. bassiana* (foliar spray), and an untreated control. During 2009, drench and spray treatments were applied on approximately a 45-d interval on 20 March, 15 May, 30 June, 17 August, 30

Table 1. Insecticides used in treatment combinations for control of *Scirtothrips dorsalis* on tea hybrid roses.

Insecticide common name	Trade name	Application rate	Manufacturer
imidacloprid	Confidor 17.8% SL	1 ml in 4.5 liter water, drench treatment	Bayer Crop Science, Mumbai India
imidacloprid	Confidor 17.8% SL	0.4 ml/2 liter water spray treatment	Bayer Crop Science, Mumbai India
acetamiprid	Dhanpreet 20%SP	0.2 g/2 liter water spray treatment	Dhanuka Agritech Limited, Gurgaon, India
spinosad	Tracer 45% SC	0.7 ml/2 liter water spray treatment	Dow Agro Sciences, Mumbai, India
emamectin benzoate	Proclaim 5G	0.2 g/2 liter water spray treatment	Syngenta India Limited, Mumbai, India
Beauveria bassiana	Biosoft	8 g/2 liter water spray treatment	Agriland Biotech Limited, Gujrat India

September, and 2 November. Because thrips populations were very low in March–May 2009, treatment applications were not started until June in 2010. Therefore, in 2010, drench and spray treatments were applied only four times at approximately 60-d intervals on 15 June, 14 August, 13 October, and 5 December. Both years, thrips numbers were counted four days before treatment (DBT) and 4, 10, and 16 d after treatment (DAT) by the insecticides. Five leaflets were collected from each treatment plot, placed in plastic bags, and taken to the laboratory where leaves were shaken vigorously inside a plastic rectangular box (20.3 × 20.3 × 30.5 cm) that had a black checkered sheet with a sticky surface so that the nymphs and adults would stick to it so they could be counted with the help of a magnifying glass. The method of extracting and observing thrips was modified from Henneberry et al. (1964). Data were analyzed by ANOVA and means were compared using Tukey's HSD test; data were analyzed for homogeneity using Welch's tests (JMP, SAS Institute 2005).

Results and Discussion

All treatments except the imidacloprid drench (applied x DBT) had no significant difference in thrips numbers at four DAT. The imidacloprid drench remained the most effective treatment throughout both seasons (Table 2). This may be because imidacloprid is a systemic insecticide that remains in the plant and is translocated to the leaves. The drench application also is less exposed to the environment. This systemic and residual effect was also observed with imidacloprid foliar applications; however imidacloprid drench was more persistent. Spinosad, imidacloprid + spinosad, imidacloprid + emamectin benzoate, imidacloprid + *B. bassiana*, acetamiprid, acetamiprid + spinosad, acetamiprid + emamectin benzoate, and acetamiprid + *B. bassiana* gave significant control of thrips at 4 DAT (Table 3). Imidacloprid, acetamiprid, and their combinations with three biological insecticides were effective at 10 DAT (Table 4). In 2009,

Table 2. Mean (±SEM) number of thrips (mature and immature forms) on hybrid tea rose plants at four days before insecticide sprays for two years (2009–2010).

Treatments	30 June 2009 (3rd Spray)	17 August 2009 (4th Spray)	30 September 2009 (5th Spray)	2 November 2009 (6th Spray)	15 June 2010 (1st Spray)	14 August 2010 (2nd Spray)	13 October 2010 (3rd Spray)	5 December 2010 (4th Spray)
Control	14.0 ± 1.4 a[a]	14.5 ± 1.5 a	16.2 ± 1.7 a	15.2 ± 0.7 a	10.1 ± 1.5 a	17.4 ± 1.9 a	17.6 ± 1.7 a	18.8 ± 1.6 a
imidacloprid − drench	4.2 ± 0.8 b	4.8 ± 0.6 b	4.4 ± 0.9 b	2.7 ± 0.6 d	5.7 ± 0.7 a	5.8 ± 0.7 b	3.8 ± 0.9 b	2.0 ± 0.5 f
imidacloprid − foliar	11.7 ± 1.3 a	12.3 ± 1.4 a	13.4 ± 1.6 a	3.7 ± 0.5 d	9.4 ± 1.3 a	12.3 ± 1.7 a	12.5 ± 1.6 a	2.7 ± 0.4 def
acetamiprid	13.3 ± 1.3 a	14.3 ± 1.7 a	15.4 ± 2.0 a	5.2 ± 0.7 cd	10.0 ± 1.2 a	17.2 ± 2.0 a	15.5 ± 2.0 a	3.8 ± 0.5 cdef
spinosad	12.0 ± 1.4 a	13.0 ± 1.3 a	13.8 ± 1.6 a	7.3 ± 0.7 bc	8.1 ± 0.9 a	15.6 ± 1.6 a	13.3 ± 1.6 a	5.5 ± 0.5 cdef
Beauveria bassiana	13.5 ± 1.3 a	14.5 ± 1.3 a	15.6 ± 1.6 a	8.7 ± 0.9 b	9.7 ± 1.0 a	17.4 ± 1.6 a	16.5 ± 1.6 a	10.4 ± 0.9 b
emamectin benzoate	11.5 ± 0.9 a	12.5 ± 0.9 a	13.2 ± 1.2 a	8.2 ± 0.8 bc	7.5 ± 1.1 a	15.0 ± 1.2 a	14.2 ± 1.2 a	6.1 ± 0.6 cde
imidacloprid + spinosad	11.5 ± 0.6 a	12.5 ± 0.6 a	13.2 ± 0.7 a	3.2 ± 0.5 d	10.9 ± 1.5 a	15.0 ± 0.7 a	12.6 ± 0.7 a	2.3 ± 0.3 ef
imidacloprid + *B. bassiana*	11.5 ± 1.2 a	12.3 ± 1.3 a	13.2 ± 1.4 a	8.7 ± 0.4 b	11.3 ± 1.6 a	14.8 ± 1.5 a	15.7 ± 1.4 a	6.5 ± 0.3 cd
imidacloprid + emamectin benzoate	12.2 ± 1.2 a	13.0 ± 1.3 a	12.0 ± 1.4 a	7.5 ± 0.9 bc	8.9 ± 1.3 a	15.6 ± 1.5 a	12.3 ± 1.4 a	5.6 ± 0.7 cdef
acetamiprid + spinosad	11.0 ± 1.3 a	11.7 ± 1.4 a	12.6 ± 1.5 a	5.0 ± 0.6 cd	11.0 ± 1.5 a	14.0 ± 1.7 a	12.2 ± 1.5 a	3.7 ± 0.4 cdef
acetamiprid + *B. bassiana*	11.0 ± 1.2 a	11.2 ± 1.4 a	12.6 ± 1.5 a	9.5 ± 0.7 b	10.0 ± 1.0 a	13.4 ± 1.6 ab	15.9 ± 1.5 a	7.1 ± 0.5 bc
acetamiprid + emamectin benzoate	12.3 ± 1.4 a	13.2 ± 1.5 ab	14.2 ± 1.8 a	7.7 ± 0.7 bc	11.7 ± 2.3 a	15.8 ± 1.8 a	12.6 ± 1.8 a	5.8 ± 0.5 cdef
F (df), *P* treatment	3.6 (12, 67), 0.0004	3.4 (12, 67), 0.0006	3.6 (12, 67), 0.0004	26.4 (12, 67), 0.0004	1.5 (12, 67), 0.1638	3.4 (12, 67), 0.0006	4.6 (12, 67), <0.0001	37.1 (12, 67), <0.0001
F (df), *P* treatment (Welch)	5.7 (12, 25), <0.0001	8.9 (12, 25), <0.0001	8.9 (12, 25), <0.0001	21.4 (12, 25), <0.0001	1.3 (12, 25), 0.2622	8.9 (12, 25), <0.0001	13.8 (12, 25), <0.0001	18.3 (12, 25), <0.0001

[a]Means in the same column followed by a common letter are not significantly different ($P = 0.05$, Tukey's HSD test).

Table 3. Mean (±SEM) number of thrips (mature and immature forms) on hybrid tea rose plants at four days after insecticide sprays for two years (2009–2010).

Treatment	30 June 2009 (3rd Spray)	17 August 2009 (4th Spray)	30 September 2009 (5th Spray)	2 November 2009 (6th Spray)	15 June 2010 (1st Spray)	14 August 2010 (2nd Spray)	13 October 2010 (3rd Spray)	5 December 2010 (4th Spray)
Control	16.1 ± 1.9 a[a]	11.4 ± 0.8 a	16.4 ± 1.0 a	11.0 ± 1.3 a	12.1 ± 1.4 a	16.1 ± 2.1 a	20.4 ± 2.0 a	16.1 ± 1.5 a
imidacloprid − drench	4.0 ± 0.5 de	4.0 ± 0.5 e	3.7 ± 0.3 f	1.5 ± 0.3 bc	3.0 ± 0.4 de	4.7 ± 0.7 cde	3.3 ± 0.4 de	1.6 ± 0.2 d
imidacloprid − foliar	4.8 ± 0.5 cde	4.5 ± 0.4 de	4.3 ± 0.6 ef	1.3 ± 0.4 bc	3.6 ± 0.8 cde	3.7 ± 0.7 e	3.8 ± 0.8 de	2.2 ± 0.3 d
acetamiprid	6.0 ± 0.7 cde	5.0 ± 0.6 cde	5.8 ± 0.6 cdef	2.5 ± 0.2 bc	4.5 ± 0.5 cde	6.0 ± 0.5 bcde	6.6 ± 1.2 cde	2.8 ± 0.3 d
spinosad	8.3 ± 0.8 bcde	9.8 ± 0.6 ab	8.0 ± 0.7 bcd	3.5 ± 0.3 bc	6.3 ± 0.7 bcde	9.7 ± 0.8 b	8.3 ± 0.9 bcde	4.3 ± 0.3 cd
Beauveria bassiana	11.3 ± 1.4 ab	8.7 ± 0.9 ab	8.7 ± 0.9 bc	3.3 ± 0.5 bc	8.5 ± 1.1 ab	9.3 ± 0.9 bc	14.0 ± 1.9 b	8.5 ± 1.4 b
emamectin benzoate	9.2 ± 1.1 bcd	8.2 ± 0.8 bc	8.2 ± 0.8 bcd	3.2 ± 0.3 bc	6.8 ± 0.8 bcd	9.3 ± 0.6 bc	10.5 ± 1.6 bc	6.8 ± 0.6 bc
imidacloprid + spinosad	3.5 ± 0.4 e	3.2 ± 0.5 e	3.2 ± 0.5 f	1.3 ± 0.3 c	2.6 ± 0.3 e	3.0 ± 0.6 e	2.5 ± 0.4 e	2.0 ± 0.4 d
imidacloprid + *B. bassiana*	6.7 ± 1.1 bcde	8.7 ± 0.4 ab	8.7 ± 0.4 bc	4.2 ± 0.3 bc	5.0 ± 0.8 bcde	8.8 ± 0.7 bcd	9.0 ± 0.5 bcd	3.8 ± 0.5 cd
imidacloprid + emamectin benzoate	7.8 ± 0.8 bcde	7.5 ± 0.9 bcd	7.5 ± 0.9 bcde	3.1 ± 0.3 bc	5.8 ± 0.6 bcde	7.0 ± 0.6 bcde	7.0 ± 0.6 cde	3.3 ± 0.5 cd
acetamiprid + spinosad	4.7 ± 0.4 cd	5.0 ± 0.6 cde	5.0 ± 0.6 def	1.0 ± 0.4 bc	3.5 ± 0.3 de	4.2 ± 0.6 de	5.5 ± 0.9 cde	2.8 ± 0.5 d
acetamiprid + *B. bassiana*	10.0 ± 0.6 bc	9.5 ± 0.7 ab	9.5 ± 0.7 b	3.1 ± 0.5 b	7.5 ± 0.5 bc	9.2 ± 0.8 bc	10.5 ± 1.2 bc	5.2 ± 0.5 bcd
acetamiprid + emamectin benzoate	8.8 ± 0.7 bcd	7.7 ± 0.7 bcd	7.7 ± 0.7 bcde	2.8 ± 0.7 bc	6.6 ± 0.5 bcd	7.3 ± 0.5 bcde	8.2 ± 1.0 bcde	4.0 ± 0.7 cd
F (df), *P* treatment	12.1 (12, 67), <0.0001	14.8 (12, 67), <0.0001	25.1 (12, 67), <0.0001	20.1 (12, 67), <0.0001	12.1 (12, 67), <0.0001	14.2 (12, 67), <0.0001	17.7 (12, 67), <0.0001	29.9 (12, 67), <0.0001
F (df), *P* treatment (Welch)	15.0 (12, 25), <0.0001	15.0 (12, 25), <0.0001	18.8 (12, 25), <0.0001	8.8 (12, 25), <0.0001	11.8 (12, 25), <0.0001	10.9 (12, 25), <0.0001	17.3 (12, 25), <0.0001	15.3 (12, 26), <0.0001

[a]Means in the same column followed by a common letter are not significantly different ($P = 0.05$, Tukey's HSD test).

Table 4. Mean (±SEM) number of thrips (mature and immature forms) on hybrid tea rose plants at 10 days after insecticide sprays for two years (2009–2010).

Treatments	30 June 2009 (3rd Spray)	17 August 2009 (4th Spray)	30 September 2009 (5th Spray)	2 November 2009 (6th Spray)	15 June 2010 (1st Spray)	14 August 2010 (2nd Spray)	13 October 2010 (3rd Spray)	5 December 2010 (4th Spray)
Control	13.6 ± 1.7 a[a]	13.2 ± 0.9 a	17.6 ± 1.3 a	11.1 ± 0.8 a	20.4 ± 2.5 a	16.4 ± 1.7 a	21.1 ± 1.3 a	16.2 ± 1.5 a
imidacloprid – drench	4.2 ± 0.5 c	3.7 ± 0.5 d	3.3 ± 0.5 f	2.3 ± 0.2 ef	3.3 ± 0.6 d	4.5 ± 0.9 de	3.5 ± 0.5 g	1.7 ± 0.2 d
imidacloprid – foliar	3.5 ± 0.6 c	4.8 ± 0.6 d	4.3 ± 0.7 ef	3.0 ± 0.5 def	5.3 ± 0.9 cd	3.5 ± 0.7 e	5.3 ± 0.7 fg	2.2 ± 0.3 d
acetamiprid	4.0 ± 0.4 c	5.7 ± 0.7 cd	6.1 ± 0.7 ef	3.8 ± 0.4 bcdef	6.0 ± 0.7 cd	4.0 ± 0.9 de	8.5 ± 0.7 efg	2.8 ± 0.3 d
spinosad	9.3 ± 0.9 b	12.0 ± 1.1 a	12.0 ± 1.1 bcd	5.3 ± 0.6 bcd	14.0 ± 1.3 b	9.0 ± 0.9 bcd	13.9 ± 1.1 bcde	4.3 ± 0.3 cd
Beauveria bassiana	9.2 ± 0.8 b	11.7 ± 0.9 a	15.5 ± 1.2 ab	5.8 ± 0.6 bc	13.7 ± 1.3 b	13.3 ± 1.2 ab	16.7 ± 1.2 abc	8.5 ± 1.4 b
emamectin benzoate	7.7 ± 0.8 bc	9.5 ± 0.9 abc	14.0 ± 1.6 abcd	5.3 ± 0.6 bcd	11.5 ± 1.2 bc	10.3 ± 0.5 bc	16.8 ± 1.6 ab	6.8 ± 0.6 bc
imidacloprid + spinosad	4.0 ± 0.6 c	4.0 ± 0.4 d	8.8 ± 1.1 def	2.0 ± 0.4 f	6.0 ± 0.8 cd	5.6 ± 1.2 cde	6.3 ± 1.1 fg	2.0 ± 0.4 d
imidacloprid + *B. bassiana*	7.6 ± 0.6 bc	10.7 ± 0.6 ab	15.2 ± 1.6 abc	5.8 ± 0.3 bc	11.5 ± 0.9 bc	10.2 ± 1.0 bc	15.5 ± 1.6 bcd	3.8 ± 0.5 cd
imidacloprid + emamectin benzoate	7.2 ± 0.8 bc	7.3 ± 0.5 bcd	13.7 ± 1.6 abcd	5.2 ± 0.7 bcd	10.7 ± 1.2 bc	10.2 ± 1.4 bc	10.3 ± 1.6 cdef	3.3 ± 0.5 cd
acetamiprid + spinosad	3.7 ± 0.4 c	4.5 ± 0.6 d	5.3 ± 0.6 ef	3.3 ± 0.4 cdef	5.5 ± 0.6 cd	6.2 ± 0.9 cde	9.3 ± 0.6 defg	2.8 ± 0.5 d
acetamiprid + *B. bassiana*	9.5 ± 0.4 b	11.5 ± 1.1 a	14.0 ± 0.7 abcd	6.2 ± 0.5 b	14.3 ± 0.6 b	10.2 ± 0.9 bc	15.0 ± 0.7 bcd	5.2 ± 0.5 bcd
acetamiprid + emamectin benzoate	9.0 ± 0.6 b	10.3 ± 1.2 ab	9.8 ± 0.7 cde	4.8 ± 0.4 bcde	13.5 ± 0.9 b	10.3 ± 0.8 cde	14.5 ± 0.7 bcde	4.0 ± 0.7 cd
F (df), *P* treatment	13.8 (12, 67), <0.0001	17.9 (12, 67), <0.0001	18.4 (12, 67), <0.0001	21.3 (12, 67), <0.0001	15.7 (12, 67), <0.0001	12.8 (12, 67), <0.0001	17.4 (12, 67), <0.0001	26.4 (12, 67), <0.0001
F (df), *P* treatment (Welch)	12.9 (12, 25), <0.0001	19.9 (12, 25), <0.0001	24.1 (12, 25), <0.0001	16.3 (12, 25), <0.0001	20.6 (12, 25), <0.0001	11.9 (12, 25), <0.0001	22.2 (12, 25), <0.0001	21.5 (12, 25), <0.0001

[a]Means in the same column followed by a common letter are not significantly different ($P = 0.05$, Tukey's HSD test).

Table 5. Mean (±SEM) number of thrips (mature and immature forms) on hybrid tea rose plants at 16 days after insecticide sprays for two years (2009–2010).

Treatments	30 June 2009 (3rd Spray)	17 August 2009 (4th Spray)	30 September 2009 (5th Spray)	2 November 2009 (6th Spray)	15 June 2010 (1st Spray)	14 August 2010 (2nd Spray)	13 October 2010 (3rd Spray)	5 December 2010 (4th Spray)
Control	12.1 ± 1.2 a[a]	12.5 ± 1.5 a	15.3 ± 2.0 a	16.6 ± 0.5 a	30.6 ± 3.7 a	18.7 ± 1.7 a	22.1 ± 1.8 a	16.4 ± 1.8 a
imidacloprid − drench	4.5 ± 0.9 cd	4.1 ± 0.5 b	15.1 ± 1.1 b	2.0 ± 0.4 d	5.0 ± 0.9 d	4.8 ± 0.6 c	6.9 ± 0.8 d	1.7 ± 0.5 f
imidacloprid − foliar	3.5 ± 0.6 d	8.8 ± 1.0 ab	17.1 ± 1.1 ab	2.5 ± 0.4 d	7.8 ± 1.4 cd	12.3 ± 1.4 b	9.0 ± 1.0 cd	4.2 ± 1.1 ef
acetamiprid	4.0 ± 0.9 d	9.7 ± 1.2 a	14.1 ± 1.6 a	2.0 ± 0.4 d	9.0 ± 1.0 cd	14.3 ± 1.7 ab	12.0 ± 1.1 bcd	6.2 ± 1.0 def
spinosad	9.0 ± 0.9 abc	8.8 ± 1.0 ab	18.8 ± 1.9 a	5.2 ± 0.6 bc	21.0 ± 1.9 b	13.0 ± 1.3 ab	16.1 ± 1.6 abc	8.2 ± 0.7 bcde
Beauveria bassiana	13.3 ± 1.2 a	10.0 ± 1.0 a	19.4 ± 1.0 a	6.2 ± 0.6 bc	20.6 ± 1.9 b	14.5 ± 1.3 ab	20.9 ± 1.9 a	12.5 ± 1.2 abc
emamectin benzoate	10.3 ± 0.5 ab	8.5 ± 0.8 ab	15.8 ± 1.4 a	6.2 ± 0.5 bc	17.3 ± 1.8 bc	12.5 ± 0.9 b	18.0 ± 1.4 ab	8.2 ± 1.0 bcde
imidacloprid + spinosad	6.1 ± 0.9 bcd	8.3 ± 0.5 ab	15.3 ± 0.8 a	2.5 ± 0.4 d	9.0 ± 1.3 cd	12.5 ± 0.6 b	9.2 ± 0.5 cd	6.3 ± 0.8 cdef
imidacloprid + *B. bassiana*	10.3 ± 0.9 ab	9.8 ± 0.9 a	16.0 ± 1.8 a	7.2 ± 0.3 ab	17.3 ± 1.4 bc	12.3 ± 1.2 b	17.7 ± 1.8 ab	11.3 ± 1.3 abcd
imidacloprid + emamectin benzoate	7.5 ± 0.8 ab	9.1 ± 0.9 ab	15.3 ± 1.7 a	7.2 ± 0.6 ab	16.1 ± 1.9 bc	13.0 ± 1.3 ab	16.7 ± 1.3 abc	8.7 ± 0.7 bcde
acetamiprid + spinosad	5.7 ± 1.1 bcd	8.0 ± 0.9 ab	12.5 ± 1.2 a	2.0 ± 0.4 d	8.3 ± 1.0 cd	11.7 ± 1.4 b	16.8 ± 2.1 abc	8.5 ± 0.8 bcde
acetamiprid + *B. bassiana*	10.2 ± 1.0 ab	11.5 ± 1.3 a	16.8 ± 1.8 a	5.2 ± 0.8 bc	21.4 ± 1.0 b	11.2 ± 1.4 bc	16.1 ± 1.9 abc	14.0 ± 2.0 ab
acetamiprid + emamectin benzoate	10.2 ± 1.4 bcd	9.3 ± 1.1 ab	16.7 ± 2.1 a	4.5 ± 0.4 c	20.3 ± 1.3 b	13.2 ± 1.5 ab	19.0 ± 2.2 ab	11.7 ± 1.7 abcd
F (df), *P* treatment	10.3 (12, 67), <0.0001	3.6 (12, 67), 0.0004	4.4 (12, 67), <0.0001	22.3 (12, 67), <0.0001	15.7 (12, 67), <0.0001	5.3 (12, 67), <0.0001	8.8 (12, 67), <0.0001	10.8 (12, 67), <0.0001
F (df), *P* treatment (Welch)	11.9 (12, 25), <0.0001	12.4 (12, 25), <0.0001	6.1 (12, 25), <0.0001	23.9 (12, 25), <0.0001	25.6 (12, 25), <0.0001	9.9 (12, 25), <0.0001	12.6 (12, 25), <0.0001	12.2 (12, 25), <0.0001

[a]Means in the same column followed by a common letter are not significantly different ($P = 0.05$, Tukey's HSD test).

spinosad-alone or in combination with imidacloprid remained effective up to 10 DAT. In 2010, although the spinosad-alone treatments gave similar results, spinosad in combination with imidacloprid (half the labeled dose) showed significant thrips control up to 16 DAT (Table 5). The addition of emamectin benzoate to imidacloprid did not increase thrips mortality. *Beauveria bassiana* was the least effective spray and it did not significantly reduce thrips numbers in comparison to the control. Riley & Pappu (2004) observed that an imidacloprid soil treatment followed by early applications of thrips-effective foliar insecticides provided significant increase in yields of tomato over other treatments. Control tactics that manage thrips early in the growing season significantly increased tomato yields in years when the incidence *of tomato spotted wilt virus* was high. Hence, an imidacloprid drench (at half labeled dose) in combinations with a foliar application of spinosad could be an important management tool to control thrips populations on roses. Drench application of imidacloprid with need-based foliar application of spinosad will reduce the excessive use of synthetic insecticides (imidacloprid) that are still essential for control of thrips and other sucking pests on roses.

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