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RELATIVE EFFECTS OF THE INSECTICIDE THIAMETHOXAM (ACTARA™) ON THE PREDATOR *PODISUS NIGRISPINUS* AND THE TOBACCO WHITEFLY IN NECTARIED AND NECTARILESS COTTON

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Abstract

The predaceous stinkbug *Podisus nigrispinus* (Heteroptera: Pentatomidae) feeds on plants as well as arthropod prey. Thus, the question arises whether feeding on plants might expose the predator to systemic insecticides via ingestion of the active ingredient or their metabolites through plant sap of treated plants. This interaction was investigated with nectaried and nectariless cotton plants cropped in pots and the systemic insecticide thiamethoxam at 0.5, 1 and 2 mg (AI) per plant. Developmental time of *P. nigrispinus* was extended and fresh adult body weight was reduced by feeding on prey and treated plants. Nymphs caged on treated plants with the highest thiamethoxam concentration at 15d after application produced only 13.2% of adults. However, females emerged from nymphs caged on plants and all thiamethoxam concentrations at day 30 after application presented similar reproductive characteristics, except for age of first oviposition, which was delayed on plants treated with the highest thiamethoxam concentration. Thiamethoxam at 0.5 mg (AI) per plant restrained tobacco whitefly, *Bemisia tabaci* colonization only during the first 15d after application for both cotton plants, and similar immature densities were sampled at day 35 after application on treated and untreated plants. On the other hand, treated plants with 1 and 2 mg (AI) per plant applied as a drench and cropped in pots were protected from tobacco whitefly for up to 45d of exposure to a whitefly colony.

Introduction

The use of the systemic neonicotinoid thiamethoxam has been widely adopted to prevent attack of early-season pests in cotton and other crops. Although effective against sucking pests, neonicotinoid compounds have limited efficacy against caterpillars, and require much higher dosages than those effective against sucking pests (Elbert et al. 1991, Maiensfisch et al. 2001). In multipest ecosystems such as cotton, the establishment of an integrated pest management (IPM) program requires conservation of generalist predators that simultaneously attack a wide variety of unrelated pest species including those not affected by the insecticide treatments. For this reason conservation of predaceous stinkbug (PSB) such as *Podisus nigrispinus* (Heteroptera: Pentatomidae) is a tactic well suited for an IPM program in multipest crop systems like cotton.

Re-colonization of treated fields by natural enemies is an essential aspect of IPM programs, and the speed and magnitude of this process depends in large measure on proximity and population sizes in neighboring untreated areas and on reproduction of surviving. Cotton provides an additional incentive for re-colonization of natural enemies through provisioning of extrafloral nectaries. Availability of nectar provides a linkage between natural enemies and the cotton plant, but also provides a means of contact between systemic insecticides and natural enemies. Because of the potential for natural enemies to access systemic insecticides in the cotton plant, the following study was conducted. Further, due to its broad spectrum of insect targets and the variety of formulation types (Actara 25 WG, 1 GR, 240 SC; and Cruiser 350 FS, 70 WS), thiamethoxam use soon will be extended to many pests and crops in which the predator *P. nigrispinus* is found. Thus, we examined the residual effects of the systemic insecticide thiamethoxam (within recommended range of dosages for control of cotton pests) on nymphal development and reproduction of PSB caged on cotton plants. In addition, we evaluated the effects of thiamethoxam concentration in preventing colonization of nectaried and nectariless cotton plants by tobacco whitefly *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) Biotype B.

Material and Methods

Stinkbug Predator Culture

Podisus nigrispinus culture was established from adults collected in a passion fruit orchard at the Agronomy Department Farm of the Federal Rural University of Pernambuco, Recife, PE, Brazil. Adults and nymphs were maintained according to methodology described in Torres & Zanuncio (2001) and fed with yellow mealworm pupa.

Cotton Plant Types and Thiamethoxam Treatment

Cotton seed (*Gossypium hirsutum* L.) of the genotypes Precocious CNPA1 nectaried and Precocious CNPA2 nectariless were provided by the Seed Department of the Cotton Research Center of EMBRAPA, Campina Grande, Paraiba State, Brazil. The plants were cultivated in pots (1 per pot of 25 cm diameter and, height 20 cm) filled with a mixture of soil and humus (4:1). Additional fertilizers were watered into the pots at 10d intervals [N supplied by Nitrato de Cálcio Hydro™ (84.5 g/l) and K by Kristalon marron Hydro™ (100 g/l) (Fertibras Co. Ltd)] through irrigation.

Cotton plants were treated with 20 ml of insecticide solution drenched at the base of each plant 20 days after sprouting. The treatments applied were 0.0 (untreated), 0.5, 1 and 2 mg (AI) per plant using the labeled product thiamethoxam (Actara 250 WG [flowable], Syngenta, Brazil). Thirty 24h-old and previously fed 2nd-instar *P. nigrispinus* nymphs were caged on treated and untreated plant leaves.

Effects on PSB Development

Residual effects of thiamethoxam on the PSB were investigated 15, 30 and 45d after insecticide application: (corresponding to plant ages of 35-, 50- and 65-d-old). Survival of nymphs was scored daily until adult emergence. The nymphal survival and duration of instars from the 2nd-instar to adult emergence, and fresh weight of newly-molted adults were analyzed with a three-way ANOVA using the PROC ANOVAF of SAEG 5.0 to determine the effects of the cotton genotypes, insecticide concentration, and time after insecticide application on PSB, and the means compared with the Tukey test ($P = 0.05$).

Effects on PSB Reproduction

Three-day old females and males from nymphs reared on each insecticide treatment at day 30 after treatment were paired during the first 15d adult lifetime when the males were discarded. At 2-day intervals, oviposition and mortality of females were scored until their deaths. The data sets were analyzed using ANOVA to assess insecticide concentration effects as a function of both cotton plants, and comparisons of significantly different means were performed by Tukey test ($P = 0.05$).

Exposure to Whitefly Colonization

For each thiamethoxam concentration 15 plants were moved to a room in a partially open-sided greenhouse containing cotton plants infested with tobacco whitefly, *B. tabaci* Biotype B, immatures and adults. After permitting tobacco whitefly colonization onto treated and untreated plants, the first evaluation of the transferred plants was carried out 15d after insecticide application and exposure to whiteflies (e.g., plant 35-d old). Evaluations were repeated at 10-d intervals, concluding with the fourth evaluation (i.e., plant 65-d old). Whitefly eggs, nymphs and pupae were counted under a stereoscopic microscope (20-40x magnification) covering 1 cm width area along both sides of the principal vein of upper full-developed leaf taken from the plant prior evaluation.

Results and Conclusions

Predator Development on Caged Cotton Plants after Systemic Insecticide Application

Cotton plant types (nectaried vs. nectariless) had no significant effect on developmental time of nymphs or adult fresh body weight of PSB. Likewise, the interaction of cotton plants, insecticide concentrations and time after application was not significant, except for nymph survival under residual time effects. However, the survival of nymphs was affected by thiamethoxam concentrations and by time after insecticide application. Survival of nymphs was the characteristic most affected by the studied factors, and the insecticide effects declined significantly with increasing time after application (Fig. 1). The thiamethoxam concentration 0.5 mg (AI) per plant did not affect nymph survival 15, 30 and 45d after application (DAA) on either type of cotton plant. The 1 mg (AI) per plant concentration reduced survival of nymphs at 15 and 30 DAA, although the effects on nectariless plants were less pronounced than on nectaried plants. On the other hand, thiamethoxam at 2 mg (ai) per plant affected nymphal survival up to 30 DAA on nectariless cotton plants, and up to 45 DAA on nectaried cotton plants (Fig. 1).

Cotton plant type did not interact with concentration effects of thiamethoxam on PSB developmental time and adult fresh body weight. On the other hand, the thiamethoxam concentrations and their residual effects strongly affected stinkbug predator development and adult fresh weight. The effect of thiamethoxam rates on nymph developmental time was greater at 15d and 30 DAA than at 45 DAA in nectaried cotton, and at 15d than at 30d and 45d in nectariless cotton plants (Fig. 2). Nymphs caged on plants 15 DAA had their developmental times extended in both cotton types. This effect was more evident for plants treated with 2 mg (AI) of thiamethoxam, which delayed nymphal development 5.9 and 4.7d in nectaried and nectariless cotton plants, respectively. However, this effect was reduced as the thiamethoxam concentrations decreased to 1 and 0.5 mg (AI) per plant and with increasing time after application. On days 30 and 45 DAA, developmental times for nymphs reared on nectaried cotton plants continued to be affected by the insecticide concentration, whereas nymphs reared on nectariless cotton plants exhibited similar nymphal periods between treated and untreated plants (Fig. 2).

Effects on PSB Reproduction

Due to reduced survival of nymphs on treated cotton plants (only 13.2% on plants treated with 2 mg (AI) per plant during the first evaluation), the effects of insecticide treatment on reproduction of *P. nigrispinus* were assessed only for adults from nymphs confined to plants 30 DAA. Females of *P. nigrispinus* derived from nymphs caged 30 DAA had similar adult life history traits on both plant types and among insecticide concentrations, except for age at first ovipostion that delayed in average of 2d for females on both plant types treated with the highest thiamethoxam concentration.

Whitefly Colonization on Nectaried and Nectariless Cotton Plants Treated with Thiamethoxam

Tobacco whitefly *B. tabaci* did not show any preference for colonizing either nectaried or nectariless cotton plants. Nor did cotton plant type interact with thiamethoxam concentrations and residual time of insecticide in preventing infestation of cotton plants by tobacco whitefly. On the other hand, thiamethoxam concentrations and residual times had highly significant effects on whitefly populations. The whitefly population on plants treated with 1 and 2 mg (AI) per plant was lower than on untreated plants up to the end of evaluations 45 DAA (i.e., 65 d of plant age) (Fig. 3). The mean number of immature whiteflies per sample (e.g. 1 cm width along both sides of the principal leaf vein) in all thiamethoxam treatments was significantly lower than in the untreated control at 15 DAA (Fig. 3A and B). In untreated plants, whitefly immature density was higher than on most treated plants in all evaluations for both cotton plants. However, immature densities in the 0.5 mg (AI) per plant treatment did not differ from the untreated plants at 25 DAA and all subsequent evaluation dates for both cotton plant types. Immature whitefly densities increased steadily toward the end of the experimental period on both nectaried and nectariless cotton plants treated with 0.5 mg (AI) (Fig. 3A and B). On the other hand, the thiamethoxam at 1 and 2 mg (AI) per plant drench applied 20d after plant sprouting was effective for 45 DAA in suppressing the colonization and growth of tobacco whitefly populations in both plant types (Fig. 3A and B). A sharp decrease in density of immature whiteflies was detected on untreated nectariless cotton plants at 55d of plant age (Fig. 3B). However, the immature densities increased at a similar rate on plants treated with 0.5 mg (AI) as on untreated plants at day 65 of plant age.

Our data support the characterization of thiamethoxam as a powerful tool for managing tobacco whitefly regardless of whether cotton genotypes are nectaried or nectariless. Residual effects on whiteflies of a single application either with 1 or 2 mg (AI) per plant may last up to 45d. Due to the efficacy of thiamethoxam on tobacco whitefly, the use of the lowest effective concentration such as 1 mg (AI) per plant reduces the adverse impact on beneficial arthropods as observed in this study for PSB at day 30 after application. Promoting not-too-long residual effects and rotation of insecticides possessing different modes of action are important, considering that intensive use and prolonged exposure of tobacco whitefly to thiamethoxam may encourage development of resistance to this insecticide, as has been experienced in Southern Spain with the neonicotionoid imidacloprid and with organophosphate insecticides (Elbert et al. 2000).

Early-season management of sucking pests in cotton has been based upon the use of systemic insecticides through soil and seed treatment, or with drench application. Reduction of the adverse impact of this approach on beneficial arthropods can be achieved through selection of appropriate insecticidal concentrations that control early-season pests while preserving valuable entomophages. Our findings suggest that the use of thiamethoxam at 1 mg (AI) per plant prevents whitefly colonization longer than using 0.5 mg (AI), and similar to 2 mg (AI) per plant, and with shorter residual effects on PSB survival than the its use at 2 mg (AI). The use of this lowest effective thiamethoxam concentration with its shorter residual effects on PSB provides an advantage in controlling early-season pests and in addressing control of later-season pests through conservation of beneficial arthropods.

References

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Table 1. Life history characteristic[a] of *Podisus ningrispinus* females from nymphs reared on thiamethoxam treated necteried and nectariless cotton plants 30 days after drench treatment.

Plant	Rate, mg AI per plant	Age at 1st oviposition (days)	Total number of eggs	Total number of nymphs	Longevity (days)
Nectariless	0.0 (*n*= 7)[b]	3.6 ± 0.81 b	370.3 ± 202.92 a	305.0 ± 155.70 a	30.0 ± 13.82 a
	0.5 (*n*= 7)	4.8 ± 1.46 b	332.5 ± 186.57 a	239.6 ± 146.33 a	36.5 ± 10.56 a
	1.0 (*n*= 6)	3.8 ± 0.44 b	270.2 ± 195.20 a	208.6 ± 103.86 a	25.6 ± 16.45 a
	2.0 (*n*= 6)	5.6 ± 1.14 a	231.0 ± 208.19 a	203.5 ± 183.14 a	31.2 ± 4.08 a
Nectaried	0.0 (*n*= 7)	4.1 ± 1.01 b	365.3 ± 180.90 a	295.0 ± 145.57 a	31.0 ± 10.22 a
	0.5 (*n*= 7)	4.0 ± 1.61 b	302.4 ± 202.80 a	259.0 ± 156.34 a	32.4 ± 15.16 a
	1.0 (*n*= 6)	4.2 ± 0.84 b	240.5 ± 165.23 a	178.1 ± 113.26 a	30.2 ± 12.55 a
	2.0 (*n*= 4)	6.1 ± 1.94 a	220.6 ± 181.12 a	163.6 ± 123.10 a	26.1 ± 9.01 a

[a]Means (± SD) within column followed by the same letter do not different comparing thiamethoxam concentration for each cotton plant (*P* = 0.05, Tukey's test).
[b]Number of females.

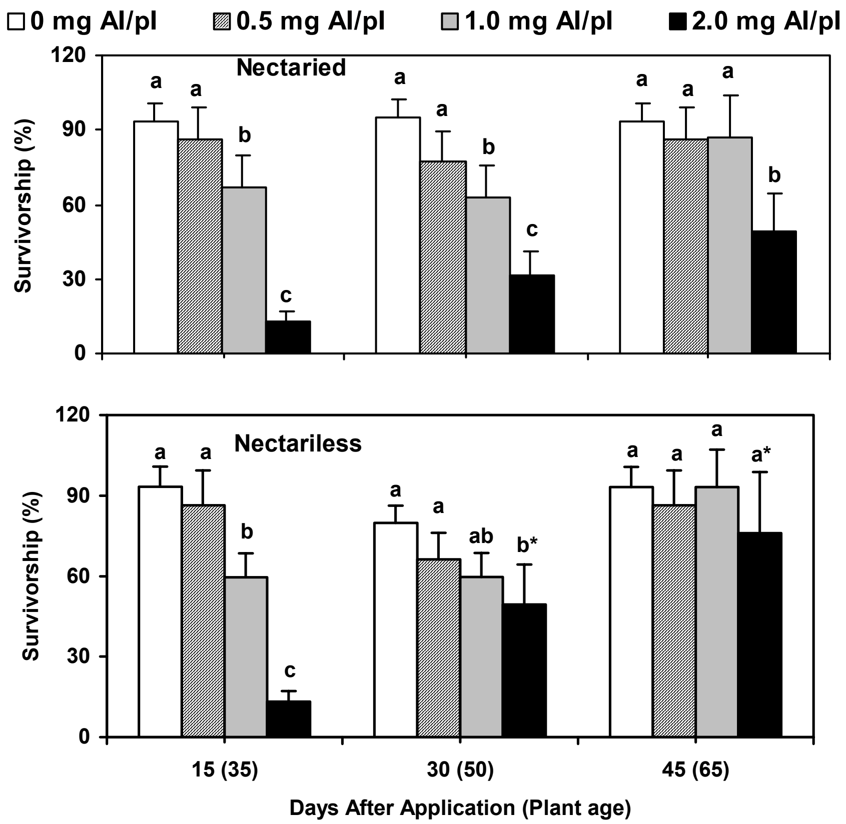

Figure 1. Mean ± SD of *Podisus nigrispinus* survivorship from 2nd-instar to adult emergence caged on nectaried and nectariless cotton plants untreated and treated with 0.5, 1.0 and 2.0 mg (AI) of thiamethoxam per plant under open-sided greenhouse conditions. Bars within same date having an identical letters are not significantly different at the 0.05 level by Tukey's test. *Means of survival differ between nectaried and nectariless cotton plants by Student test 0.05 level.

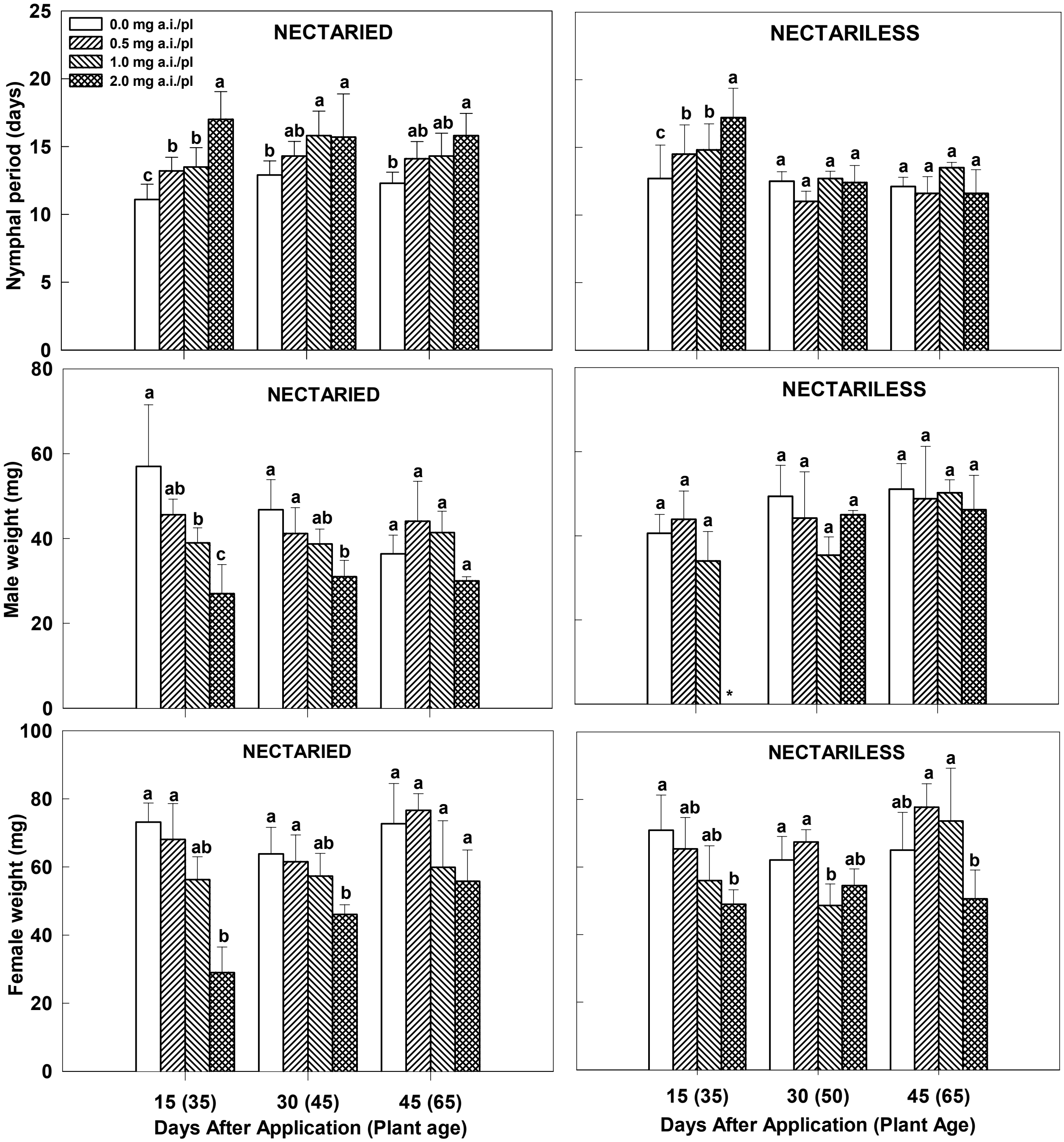

Figure 2. Nymphal periods and weight of *Podisus nigrispinus* males and females (means ± SD) caged at second instar on nectaried and nectariless cotton plants at 15, 30 and 45 days after treatment with thiamethoxam by drench. Bars under the same letters did not differ significantly comparing thiamethoxam concentration for each date within the same cotton plant ($P = 0.05$, Tukey's test). *No male was harvested for analysis at 15d treatment in nectariless cotton plant.

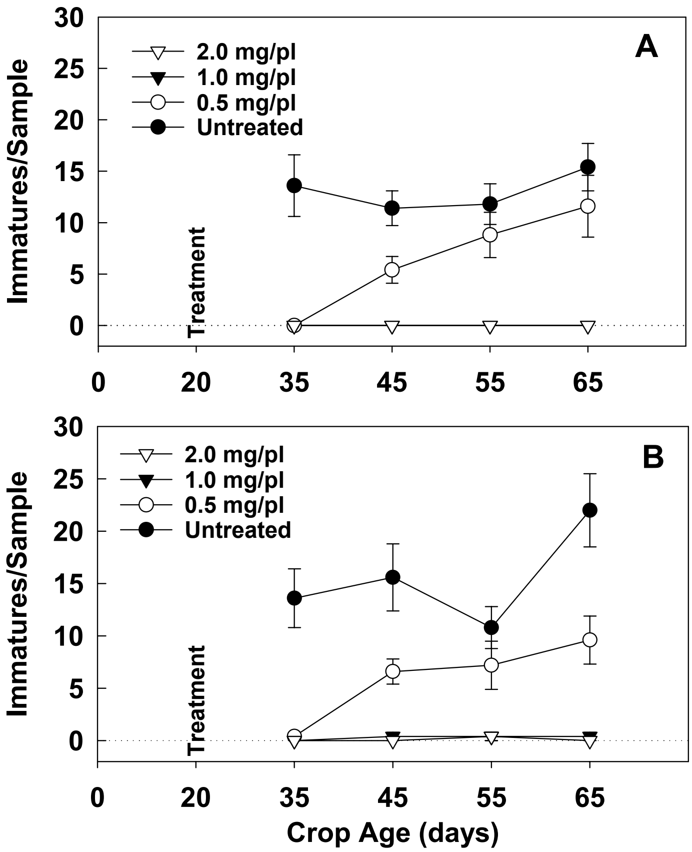

Figure 3. *Bemisia tabaci* Biotype B immature (eggs + nymphs + pupae) from nectaried (A) and nectariless (B) cotton plants cultivated in pots under open-sided greenhouse conditions treated with thiamethoxam as drench 20d after sprouting and an untreated control.