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Tomato bug, *Nesidiocoris tenuis* (Reuter): A zoophytophagous insect

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Abstract
Tomato bug, *Nesidiocoris tenuis* (Reuter) is known for its predatory habits on the major insect pests. It preys on eggs and neonate larvae of fruit borer, leaf eating caterpillar, stem borer and tomato pin worm. It also feeds on whitefly, thrips, aphids and mites. The increasing population of this zoohytophagous insect could infest to plant reproductive parts in absence of prey. The sesame, tobacco, bottle guard, tomato, potato *etc.* are potential hosts for this bug. These predatory bugs are presently used with successful augmentation in southern Europe to control *T. absoluta* and other pests. Tomato bug has significant synergist effect while used with biopesticides and synthetic insecticides in insect pest management.

Keywords: Mirid bug, Zoophagy, Phytophagy, *Nesidiocoris tenuis* (Reuter)

Introduction
Plant bugs—Miridae, the largest family of the Heteroptera, or true bugs, are globally important pests of crops such as alfalfa, apple, cocoa, cotton, sorghum, and tea [66]. Some of them function as predators of crop pests and have been used successfully in biological control. Certain omnivorous plant bugs have been considered both harmful pests and beneficial natural enemies of pests on the same crop, depending on environmental conditions or the perspective of an observer. Some predatory mirids are important in controlling noxious arthropods, whereas phytophagous species may produce significant damage in agricultural crops [55]. Although *Nesidiocoris tenuis* (Reuter) has been recorded as a pest of various field and glasshouse crops in Asia and Europe, little information is available on the extent of the damage it causes and the associated economic losses [38]. A Mirid bug, *N. tenuis* is also a serious pest of bottle gourds (*Lagenaria siceraria* L), tomatoes and cucurbitaceae in India [21, 58]. In France, *N. tenuis* was first found on tomatoes under glass house in 1986 [27]. Many mirids are omnivorous, feeding both on prey and plants [54] and their role as pests or predators is not clearly defined.
Tomato bug, *N. tenuis* is one of the most controversial dicyphines when considering its benefits as a predator in relation to the injuries it causes by plant feeding. This plant bug is common in tomato and other vegetable crops along the Mediterranean coast and in other places with a similar climate, such as the Canary Islands [13]. The role of this omnivorous species in tomato is ambiguous because it feeds on many arthropod pests but also feeds on vegetative and reproductive plant parts [11]. It produces necrotic rings on stems and leaf petioles, flower dropping, punctures on fruits and ultimately wilting in tomato [11, 54, 47]. Patel [40] reported that in tobacco, miridbug cause damage to the reproductive parts. In contrary Chari *et al.* [12] reported that *N. tenius* could work as one of the key mortality factor for *Spodoptera litura* (Fabricius) and *Scrobipalpa heliopa* (Lower) under natural condition. So far, it is mainly regarded as a predator and the feeding lesions that it considered irrelevant in relation to the benefits it produces as a pest control agent in the Canary Islands and northern Italy [13]. With a view to explore the predatory potential of the tomato bug, *N. tenuis* considering its phytophagy habit present review carried out to widen the strength as viable biocontrol agent for managing insect pest of economic important crops.
As per UK CAB International

Taxonomic nomenclature
Domain: Eukaryota
Kingdom: Metazoa

Phylum: Arthropoda
Subphylum: Uniramia
Class: Insecta
Order: Hemiptera
Suborder: Heteroptera
Family: Miridae
Genus: Nesidiocoris
Species: *Nesidiocoris tenuis*
(https://www.cabi.org/isc/datasheet/16251)

Preferred Scientific Name
Nesidiocoris tenuis (Reuter, 1895)

Preferred Common Name
Tomato bug

Other Scientific Names
Cyrtopeltis crassicornis, *Cyrtopeltis ebaeus* Odhiambo, 1961, *Cyrtopeltis javanus* Poppius, 1914, *Cyrtopeltis tenuis* Reuter, 1895, *Dicyphus nocivus* Fulmek, 1925, *Dicyphus persimilis* Poppius, 1910, *Dicyphus tamaricis* Puton, 1886, *Engytatus tenuis*, *Engytatus volucer* (Kirkaldy), *Gallobelicus crassicornis* Distant, 1904, *Nesidiocoris volucer* Kirkaldy, 1902.

Host plants:
Cucurbitaceae (cucurbits)
Lagenaria siceraria L. (bottle gourd)
Nicotiana tabacum L. (tobacco)
Paulownia
Sesamum indicum L. (sesame)
Solanaceae
Solanum lycopersicum L. (tomato)
Solanum melongena L. (aubergine)
Solanum tuberosum L. (potato)
(https://www.cabi.org/isc/datasheet/16251)

Distribution
It was reported from Mediterranean countries to Europe, North Africa, Middle East, Japan, Australia, Pacific Islands, North America, Cuba, Venezuela [25, 67], Iran [26], Philippines and India [47, 61].
As per UK CAB International, (1971) tomato bug reported in country like, Asia {Bangladesh, China, Hong Kong, Cocos Island, India (Andhra Pradesh, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharastra, Rajasthan, Tamilnadu, Uttar Pradesh, West Bengal), Indonesia, Java, Sumatra, Iran, Iraq, Israel, Japan, Jordan, Korea, Malaysia, Sabah, Myanmar, Nepal, Phillipins, Saudi Arabia, Sri Lanka, Syriya, Taiwan, Vietnam, Yemen} Africa, North America, Central America and Caribbean, South America, Europe, Oceania.
(https://www.cabi.org/isc/datasheet/16251#F52BF5A7-88CA-4486-985B-9C86FC4F1C40)

Life cycle and description
Females laid up to 10 eggs, and the preoviposition, oviposition and postoviposition periods averaged 1.44, 4.48 and 0.76 days, respectively. The egg stage lasted from 3.94 days at 70% RH to 11.60 days at 30% RH. The life-cycle was completed in 29.3 days at 31^{o}C [40]. Patel and Patel [41] reported bionomics of the *N. tenuis* at varying temperatures. Females laid an average of 5.96 eggs. The egg stage, 5 nymphal instars, adult male and female life-span, and the preoviposition, oviposition and postoviposition periods lasted 3.98-4.58, 3.38-4.79, 3.11-4.91, 3.5-4.68, 3.12-4.56, 2.66-4.12, 4.16-4.96, 5.62-6.6, 1.44, 4.48 and 0.76 days, respectively. Adult having pale whitish green body with 3–3.3 mm size. Middle of the first segment and base of the second segment of antenna is black. A dark ring at the apex of the 2nd antennal segment as well as 3rd and 4th segment is brown. At the rear edge of the corium there is a small dark brown spot and at the tip of the cuneus there is a small dark brown spot [17]. Life cycle includes egg, 5 nymphal instars and adult, it completed its life cycle in 31.0 to 48.44 days [16]. Sanchez [51] reported that the development time for eggs and nymphs and female fertility for *N. tenuis* at 15, 20, 25, 30, 35 and 40 +/- 1 ^{0}C, using tomato, *Solanum esculentum* (Miller), as substrate and eggs of *Ephestia kuehniella* Zeller as substitute prey. At 40 ^{0}C, *N. tenuis* was unable to develop and barely reproduced. Egg development ranged from 30.8 days at 15 ^{0} C to 6.3 days at 35 ^{0}C. The cumulative thermal requirements for the eggs were 148.6-degree days and the lower thermal threshold, 10.3 ^{0}C. The duration of the nymphal instar decreased from 55.9 days at 15 ^{0}C to 8.6 days at 35 ^{0}C. The thermal constant for the nymphs was 182.3 degrees days and the lower thermal threshold 11.7 ^{0}C. No nymphs survived at 40 ^{0}C, and the highest mortalities were at extreme temperatures (15 and 35 ^{0}C). Female and male weights were influenced significantly by temperature. The fertility of *N. tenuis* females was reduced greatly at 15 and 40 ^{0} C. The highest fertility during an observation period of 18 days following female emergence (79.5-60.0 nymphs per female) was within the temperature range of 20 to 35 ^{0}C. Fertility was related directly to female weight and temperature (r (2) = 0.932). Based on development, reproduction data and thermal requirements, the optimum temperature range for *N. tenuis* was established as being between 20 and 30 ^{0}C. Overall, *N. tenuis* is the most thermophilous of all dicyphines from vegetable crops in the Mediterranean area studied so far.

Zoophagy habit
Studies carried out by Patel, [40] on the predacious habits of the bug showed that *N. tenuis* could prey on several pests of tobacco, including eggs and first-instar larvae of *S. litura.* Whitefly nymphs and eggs of *E. kuehniella* are very suitable prey for *N. tenuis* [43]. Marcos and Rejesus [28] reported from Phillipins that *Cyrtopeltis tenius* an important mortality factor for egg predation of *Helicoverpa armigera* and *H. assulta* under tobacco growing season. Patel and Yadav [42] reported that intercropping did not affect the activity of the predatory mirid *N.tenuis,* and appeared to increase egg parasitism by *Trichogramma*. Investigation in the greenhouse and field at Italy, was carried out by Arzone *et al.* [6] to assess their suitability for introduction to biological and integrated control programmes. *Macrolophus caliginosus*, was effective in reducing numbers of *Trialeurodes vaporariorum* in field of tomatoes. *Nesidiocoris tenuis* [*Cyrtopeltis tenuis*], never previously reported from Italy, gave good control of the aleyrodid on greenhouse-grown tomatoes. The effectiveness of controlling *Bemisia tabaci* (Gennadius) on tomato in commercial greenhouses by releasing *N. tenuis* was evaluated by Nakano *et al.* [34] and result suggested that the *N. tenuis* colonized the tomato plants, and toward the end of the growing period, as the population density of *N. tenuis* increased, the population density of *B. tabaci* decreased. Pre-plant or post plant releases of *N. tenuis* are effective for controlling *T. vaporariorum* on tomatoes in greenhouse [39].

Tomato bug, *N. tenuis* associated with *B. tabaci* on tomato was recorded from Maharashtra, India [19]. The study was carried out by Gavkare and Sharma [20] to see feeding potential of of *N. tenuis* on the two spotted spider mite, *Tetranychus urticae* Koch, under laboratory conditions. Results of this study indicated that all stages of the bug are highly predacious against *T. urticae.* When the population density of *B.tabaci* was low, *N. tenuis* aggregated on the upper leaves. However, when the population density of *B. tabaci* was increased on the middle leaves, *N. tenuis* also increased on the middle leaves. These results suggest that *N. tenuis* is capable of aggregating in an area where *B. tabaci* are distributed and preying on them [62]. Predation experiments found that *N. tenuis* preyed on first and second stadium larvae, but not on third and fourth stadium *S. litura* larvae. *N. tenuis* also preyed upon *T. urticae* females that had been reported to be less suitable prey species [49].

The study carried out by Sanchez *et al* [53] to determine the numerical response of *N. tenuis* to different levels of abundance of *T. absoluta* and its potential for controlling it when infesting tomato crops. *N. tenuis* densities of about 0.2 individuals per leaf during the linear population growth phase of *T. absoluta* (0.5 to 3 larvae per leaf) did not prevent outbreaks. The yield of tomatoes was higher in the treatments with *N. tenuis* than in those without, but the percentage of damaged fruit (>50%) was similar. Biondi *et al.* [7] investigated in laboratory conditions the influence of two alternative plants, *Dittrichia viscosa* L. (Asteraceae) and *Sesamum indicum* L., with or without prey, on *N. tenuis* damage and its biological control services on *Tuta absoluta* (Meyrick) eggs. Both *D. viscosa* and *S. indicum*, as companion plants in dual-choice bioassays, significantly reduced the damage of the mirid on tomato. *S. indicum* was more attractive than *D. viscosa* for feeding and oviposition and its presence did not interfere with the predation on *T. absoluta* eggs. The potential of the three plants as prey less rearing substrate for the mirid, and only *S. indicum* showed to be a suitable host plant for *N. tenuis* development and oviposition. A reduction in infested fruit of 95.1 and 94.5% was achieved, respectively, in plots where *N. tenuis* and *Trichogramma evanescens* Westwood were released together. However, no significant difference was found between the plots with *N. tenuis* alone and the combination *of N. tenuis* and *T. evanescens* [30].

The study on in two subsequent trials was carried out by Calvo *et al.* [10] in which different release rates were evaluated under a rapid immigration of the pest into a tomato greenhouse. In the winter experiment, four treatments were compared: (1) *B. tabaci* (0 *N. tenuis*/plant), (2) *B. tabaci*+0.5 *N. tenuis*/plant, (3) *B. tabaci*+1 *N. tenuis*/plant and (4) *B. tabaci*+2 *N. tenuis*/plant. In the second summer experiment, the treatments were (1) *B. tabaci* (0 *N. tenuis*/plant), (2) *B. tabaci*+0.5 *N. tenuis*/plant and (3) *B. tabaci*+1 *N. tenuis*/plant. All the evaluated rates significantly reduced the population of whitefly and gave adequate control of the pest. Predatory bug, *N. tenuis* was more efficient against *T. absoluta* eggs than *M. pygmaeus, M. pygmaeus* [57]. A predator species from the family Miridae was found, reared, and identified as *Nesidiocoris tenuis* (Reuter 1895).

This species is reported by Sohrabi and Hosseini [59] for the first time on tomato leafminer in Iran. The tomato leafminer, *T. absoluta* and whitefly, *B. tabaci* often appear simultaneously in tomato crops and this might affect control capacity. An early release system developed for *N. tenuis* could provide a good control of *T. absoluta* in tomato [9]. The reduction of *T. absoluta* (83%) by *N. tenuis* was higher than that of *B. tabaci* (32%), suggesting a preference of *N. tenuis* for *T. absoluta*.

Augmentation of *N. tenuis* was as effective as conventional insecticide treatment, and plant damage was low and did not affect yield. Results indicated that reduced pesticide use enables indigenous natural enemies, particularly *N. tenuis*, to successfully control *T. absoluta* and prevent crop damage in open-field tomatoes [56]. A mirid bug, *N. tenuis* has significant contributions in the control of greenhouse pests such as whiteflies, thrips, leafminers, lepidopterans, and spider mites. By means of gut-content analysis, it was found that the percentage of *N. tenuis* preying on *B. tabaci* and *Augme palmi* Karny was approximately 40% in the field [23]. Calvo *et al.* [11] revealed that reductions of greater than 90% of the whitefly population and correspondingly high numbers of *N. tenuis* were observed with release rates. Mirid bug, *N. tenuis* may be considered a useful predator of small pests in tomato crops if kept under these thresholds [52]. Seasonal inoculative releases of mirids *Macrolophus pygmaeus* (Rambur) and *N. tenuis* / m^2 were carried out in Sardinia (Italy), by Nannini *et al.* [36] on 24 crops. In the greenhouses surveyed mirid population density never exceeded 1.8 individuals per plant, thereby resulting in inadequate control of moth infestation. Two indigenous predators, *M. pygmaeus* and *N. tenuis*, preyed actively on *T. absoluta* eggs and all larval stages, although they preferred first-instar larvae. This result demonstrated that both mirids can adapt to this invasive pest, contributing to their value as biological control agents in tomato crops [63]. Moreno *et al.* [32] demonstrated that both predators, *M, pygmaeus* and *N. tenuis* feed on both whiteflies, {*B. tabaci* and *T. vaporariorum*}, the interaction of parasitoids, {*Eretmocerus mundus* (Mercet) and *Encarsia pergandiella* Howard} with unidirectional intraguild predation (predators on parasitoids) could potentially reduce their combined impact on their joint prey/host. A zoophytophagous mirid bug, *N. tenuis* was recorded as predator on eggs and early larval stages of *T. absoluta* under field conditions [60].

An experiments was conducted by Devi *et al.* [14] to evaluate the role of *N. tenuis* in the natural suppression of *H. armigera* populations revealed that the predator was found throughout the cropping season and effectively suppressed the population of the fruit borer. The predatory activity of *N. tenuis* was greater than the amount of damage it caused to tomatoes [64]. Better results were achieved at Sardinia (Italy) when the mirid bug releases were carried out in late summer, or when other whitefly natural enemies (native mirids or released *Encarsia formosa*) were established on the crops as well [35]. It has been established that some egg parasitoids, such as *Trichogramma pertiosum* Riley, *Trichogramma achaeae* Nagaraja and Nagarkatti, and *Trichogramma brassicae* (Bezdenko), and pirate bugs *M. pygmaeus*, *Macrolophus caliginosus* (Wagner), *Podisus negrispinus* (Dallas), *N. tenuis* and *Nabis pseudoferus* Remane may successfully decrease the tomato leaf miner population [46]. Mollá *et al.* [31] demonstrated that when *Bacillus thuringiensis* treatments were applied immediately after the initial detection of *T. absoluta* on plants, they do not interfere with *N. tenuis* establishment in the crop because *T. absoluta* eggs are available. A treatments of *B. thuringiensis* – *N. tenuis* later in the growing season would no longer be necessary because mirid alone would control the pest. A comparative study by Bouagga, *et al.* [8] to assess the establishment and the efficacy of *N. tenuis, M. pygmaeus*, and *Dicyphus maroccanus* Wagner on the two sweet pepper key pests; the thrips and the whitefly, was conducted. Both, *N. tenuis* and *M. pygmaeus* were able to establish on sweet pepper and significantly reduced the number of thrips, *Frankliniella occidentalis* and whitefly, *B. tabaci* adults, larvae and nymphs. *M. pygmaeus* had the highest density at 20 °C, whereas *N. tenuis* was more abundant at 27 °C. In contrast, *D. maroccanus* was less abundant under both temperatures studied; and did not reduce neither *F. occidentalis* nor *B. tabaci* infestations in this crop. None of the three mirids were observed to cause any damage to the pepper plant.

Deleterious impact of Insecticide on Mirid bug:

The side effects of four plant protection products, Emamectin benzoate, kresoxim-methyl + boscalid, abamectin and dimethoate (toxic standard), were evaluated on *N. tenuis.* The result revealed that Kresoxim-methyl + boscalid showed moderately low toxicity (2.5% - 7.5%) at 24 and 48 hours after pesticide application which indicates that it can be safely used in IPM greenhouses with *N. tenuis* populations. Emamectin benzoate was moderately toxic (74.4% - 78.5%) while abamectin (100%) and dimethoate (100%) were toxic [44]. Wanumen, *et al.* [65] evaluated route of pesticide intake on predator *N. tenuis* for the first time. Under laboratory conditions, prey treated with six insecticides (flubendiamide, spirotetramat, deltamethrin, flonicamid, metaflumizone and sulfoxaflor) were offered to *N. tenuis* for 3 days. Flonicamid and flubendiamide were classified as slightly harmful products, although they did not have a lethal effect. Spirotetramat and deltamethrin were categorized as harmless. The results demonstrated the compatibility of methoxyfenozide with adults of the three species; *E. mundus*, *Orius laevigatus* (Fieber) and *N. tenuis* of natural enemies. In contrast, abamectin caused some direct mortality [18].

Phytophagy habit

In tobacco flower shedding was increased up to 80 percent in presence of *N. tenuis* and it damaged reproductive parts [40]. Sanchez and Lacasa [52] stated that *N. tenuis* caused yield loss in tomato in the absence of prey. The mirids were present in most samples taken in tomato and tobacco, while the incidence remained over 40% in both crops [29]. It can turn phytophagous in absence of prey and reported as a pest on sesame [2]. Similarly, Sanchez [50] gave the probability of yield loss (*N. tenuis*: whitefly ratios > 0.168) for tomato crop. Calvo *et al.* [11] recorded the necrotic rings soon after the transplanting in the crop and incidence of flower droppings due to *N. tenuis* in tomato. When both predator, *M. pygmaeus* and *N. tenuis* species coexisted, *N. tenuis* adult females caused more damage to tomato plants, suggesting that their coexistence could affect the crop [33]. In the extreme conditions of prey shortage mirid bug attempt on the plant with the vegetative growth and fruiting processes [5]. Patel [40], reported that *N. tenuis* is becoming an important pest of tobacco. It was found on bottle gourd and tomato also. Infestation of tobacco was highest (100%) in December-May, and 83.5% of the bugs were found on the inflorescence. In a survey was carried out by Prasad *et al.* [45] of the incidence of *N. tenuis* on tobacco in the Shimoga district of Karnataka, India, the proportion of plants infested was found to average 22.25%. The number of bugs per flower bud averaged 11-23, as compared with 2-5 per pair of leaves. Dionyssios *et al.* [15] showed that predator, *N. tenuis* has low potential to cause damage on tomato stem and flowers even when it occurs at high density. In West Bengal, India, it is reported to be the most serious pest of sesame, with significant increases in crop yield resulting from the application of chemical insecticides [37].

Symptoms

The internal and external symptoms caused by *N. tenuis* feeding on solanaceous crops are provided by El-Dessouki *et al.* [16]. Chemical changes in plant tissue as a result of feeding by *N. tenuis* are detailed by Raman *et al.* [48] and El-Dessouki *et al.* [16].

On tomatoes, adults feed on the stems, leaves and flowers, with necrosis often developing at the site of feeding [48, 3]. Shedding of flowers and pods in tomatoes may also be a result of feeding by this insect [22]. On sesame, feeding is concentrated on the growing point, leading to stunting and loss of plant vigour [37]. In tobacco, flower shedding was observed in presence of *N. tenuis* and it damaged reproductive parts [40].

Type of symptoms caused by *N. tenuis* on various plant parts

Fruit - internal feeding, premature drop,

Growing point - dwarfing, stunting,

Inflorescence - blight, necrosis, fall or shedding, internal feeding, lesions on glumes

Leaves - honeydew or sooty mould, internal feeding, necrotic areas, necrotic areas, Stems - discoloration of bark, internal feeding, necrosis.

(https://www.cabi.org/isc/datasheet/16251)

Vector of plant disease

Aramburu *et al.* [4] reported that *Parietaria mottle virus* (PMoV) was transmitted very efficiently to *Nicotiana benthamiana* plants by *N. tenuis* at Valencia, Spain. Jin *et al.* [24] also reported *N. tenuis* and *Halyoporpha picus* as vectors of mycoplasma like organism causing witches' broom disease of *Paulownia* spp. in Beijing, China.

Chemical Control

Field tests were carried out to devise a suitable insecticidal schedule for use against insect pests of tomato, particularly *Myzus persicae* (Sulz.), *Lipaphis erysimi* (Kalt.), *Brachycaudus helichrysi* (Kalt.), *Amrasca devastans* (Dist.) and *N. tenuis*. Based on yield, 2 applications of phosphamidon at a 2-weekly interval followed by an application of mevinphos 2 weeks later proved most effective, followed by the schedules demeton-methyl (methyl demeton)/carbaryl, endosulfan/malathion and lindane/dichlorvos [1].

Due to the variable regulations around (de-)registration of pesticides, not including any specific chemical control recommendations. Although based on research experiment control is highlighted in respective heads. For further information, we suggest to visit the following resources:

- EU pesticides database (www.ec.europa.eu/sanco_pesticides/public/index.cfm)
- PAN pesticide database (www.pesticideinfo.org)
- Central Insecticide Bord, (http://cibrc.nic.in/)

Conclusion

Tomato bug *Nesidiocoris tenuis* (Reuter) (Hemiptera: Miridae) is an effective predator of pests of tomato crops and a promising biocontrol agent of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in the Mediterranean area. This bug is a zoophytophagy and feeds on insects like lepidopterans and sucking pests. Despite its reputation as a predator, it is described as a pest of different crops in India *viz*., sesame, tobacco, bottle gourds, tomatoes and cucurbits in the absence of its insect hosts. It produces necrotic rings on stems and leaf petioles, flower dropping, punctures on fruits and cause wilting in tomato in absence of suitable pray. It also plays vital role in controlling of eggs and neonate larvae of *Helicoverpa* spp, *Spodoptera* spp., *Scrobipalpa heliopa* and *Tuta absoluta*. Apart from these it can also control the soaring population of whitefly, thrips, aphids and mites. It can exert to the biological control of small key arthropods in solanaceous plants of importance, such as tomato and tobacco, despite the affectations that *N. tenuis* could cause in the tomato crop due to its dual condition of predator and phytophagous, which can be an object of further studies. The future line of the work on this bug may be carried out as under,

1. To investigate the predatory potential of mirid bug, *Nesidiocoris tenuis* (Reuter) in laboratory as well as in field against lepidopteran pest and sucking pest.
2. To work out damage potential and to evaluate economic loss caused by mirid bug, *Nesidiocoris tenuis* (Reuter).
3. To explore shelter crops of mirid bug *Nesidiocoris tenuis* (Reuter) that can be used as companion crop for managing insect pest of economically important crop.

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