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Research Article

Comparing efficacy of biopesticides for the management of insect pests in aromatic rice under organic farming system

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ABSTRACT: Field experiments were conducted in farmer's rice fields at village Saholi, Punjab, India during 2012 and 2013 to test the efficacy of different plant based biopesticides and microbials against insect pests of aromatic rice (*Pusa* 1121 and *Basmati* 386) grown under organic farming system. In all, five biopesticide formulations (2 plant based; 3 microbials) were tested for their efficacy. Neem azal 1% @ 1250 ml/ha showed its supermacy in reducing the incidence of leaf folder (0.97-5.66% DL), dead hearts (0.98-1.67% DH), white ear heads (1.07-2.05%), plant hopper(s) population (0.11-0.40/plant) and resulted in higher grain yields (25.54-36.47 q/ha) compared with ohter treatments. Similarly, the application of Neem azal 1% @ 1000, Dipel WP @ 2.0 kg/ha, *Karanja* oil 2.0% and Myco-Jaal 10% SC @ 2.0 litre per ha significantly reduced the incidence of leaf folder, dead hearts and white earheads increased grain yields in comparison to untreated control. Microbials, by large, were ineffective to control plant hoppers' infestation except Myco-Jaal 10% SC @ 2.0 litre per ha, which managed to control plant hopper(s) population and was on a par with plant based biopesticides.

KEY WORDS: Aromatic rice, biopesticides, leaffolder, planthoppers, stemborer

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INTRODUCTION

Rice is the most important food crop of the developing world. It is the staple food of more than half of the world's population where more than 3.5 billion people depend on rice for more than 20 per cent of their daily calories (IRRI, 2011). It is estimated that global rice consumption will increase by 90 million tons by 2020 (Mohanty, 2009). India is the largest rice growing country accounting for about one-third of the world acreage under the crop. Thus, the increased and sustained production of rice is fundamental to food security in India (NBPGR, 2006). The crop is attacked by several insect pests that can cause severe economic losses throughout its growing cycle (Matteson, 2000). The major insect pests of rice include stem borers, particularly yellow stemborer, *Scirpophaga incertulas* (Walker) (Lepidoptera: Crambidae), leaffolder, *Cnaphalocrocis medinalis* (Guenée) (Lepidoptera: Pyralidae), and plant hoppers; brown planthopper, *Nilaparvata lugens* (Stal) (Hemiptera: Delphacidae) and whitebacked planthopper, *Sogatella furcifera* (Horváth) (Delphacidae). The use of synthetic insecticides is widely adopted for the management of these pests. However, their indiscriminate use has resulted in disturbances of the environment, pest resurgences, resistance to pesticides and lethal effect to non target organisms in the agro-ecosystems in addition to direct toxicity to users (Prakash *et al*., 2008).

Biopesticides based on bacterium, a *Bacillus thuringiensis* (Bt) have been used against stem borer and leaf folder of rice, which have reduced the population of these pests in the laboratory and in the field (Shahid *et al*., 2003; Nigam *et al*., 2010). Similarly, botanical pesticides, important alternative to minimize or replace the use of synthetic pesticides, have been assessed against yellow stem borer and plant hoppers (Chakraborty, 2011; Saxena *et al*., 1987; Senthil Nathan *et al*., 2007). However, most of these studies are concerted to the management of either lepidopteran or sucking pests of rice and that too comparing biopesticides with conventional insecticides. There are few studies which have considered the holistic management of rice insect pests through the use of biopesticides only without which decision making on pest management strategies, especially under organic farming conditions, becomes difficult. In view of this, the present study was undertaken for two consecutive years in organic *basmati* rice under Indian Punjab conditions to evaluate the relative efficacy of different biopesticide formulations at varied doses against lepidopteran as well as sucking insect pests of rice.

MATERIALS AND METHODS

Experimental Layout

Two field experiments were conducted during *Kharif* seasons of 2012 and 2013 at village Saholi, district Patiala, Punjab, India to test the efficacy of different biopesticides against insect pests of aromatic rice. Selection of the location was based on the fact that the fields under consideration were practising organic farming system for the last 10 years with wheat-paddy rotation. Hence it was appropriate to select such fields for accurate inference of the results. During 2012, the trial was conducted with transplanted 35-day old seedlings of *basmati* rice variety *Pusa* 1121. During the *Kharif* season of 2013, the trial was conducted with 30-day old seedlings of variety *Basmati* 386. The transplanted fields were green manured with *Sesbania aculeata* (Willd.) Pers. in both the seasons. A randomized block design was used in the experiments, with a plot size of 50 m^2. Seedlings were transplanted with inter and intra row spacing of 20 x 15 cm. There were sixteen treatments, each with three replications for each year. The treatments included individual application of Dipel WP (*Bacillus thuringiensis*) @ 1.0, 1.5 and 2.0 kg/ha, Myco-Jaal 10% SC (*Beauvaria bassiana*) @ 1.0, 1.5 and 2.0 litre/ha, entomopathogenic nematode, *Steinernema feltiae* @ 1.0, 1.5 and 2.0 billion IJs/ha, Neem azal 1% @ 750, 1000 and 1250 ml/ha, Karanja (*Pongamia glabra*) oil (1.0, 1.5 & 2.0%) and untreated control. The biopesticides were applied at 30, 40, 50, 60 and 70 days after transplanting (DAT) using standard 250 litres of water per ha. For EPN treatments, required number (s) of sponges with nematode strains were soaked in water (3.75 liters) for 4 hours separately. Five ml of tenopal and 50 ml of glycerol were added into it. The prepared solution was sprayed as such. Water spray was used for the untreated control.

Observations on pest incidence

Observations were recorded from randomly selected 20 plants/treatment/replication at 45 and 60 (Days after treatment) DAT for leaf folder damage and dead hearts (DH). The data on number of white earheads (WE) were recorded once at crop maturity. The whitebacked plant hopper and brown plant hopper population was recorded from 20 plants/treatment/replication selected at random at weekly interval starting after 30 days of transplanting. The per cent damage was calculated as

$$\text{Leaf folder damage (\%)} = \frac{\text{Number of damaged leaves (DL)}}{\text{Total number of leaves}} \times 100$$

Stem borer incidence

$$\text{Per cent damage} = \frac{\text{Number of DH / WE}}{\text{Total no. of tillers/panicles}} \times 100$$

Plant hopper(s) damage = Population/20 plants

The grain yields for all the treatments were recorded on whole plot basis at the time of harvest.

Statistical Analysis

The data pertaining to different attributes were analyzed using SPSS version 16.0. The percentage values were subjected to arcsine transformaton for damaged leaves, dead hearts & white ears and square root transformation for plant hopper(s) population before analysis and the treatment means were compared by Duncan's multiple range test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Leaffolder incidence

During *Kharif* 2012, the incidence of leaf folder under different treatments ranged from 5.44 to 21.44 per cent and from 3.22 to 15.43 per cent damaged leaves at 45 and 60 DAT, respectively (Table 1). Least infestation was recorded from Neem azal 1% treated plots and among these plots, lowest incidence was observed from Neem azal 1% @ 1250 ml/ha (3.22 % at 60 DAT), which was statistically at par with Neem azal 1% @ 1000 ml/ha (3.35% at 60 DAT). Treatments of Myco-Jaal 10% SC @ 2000 ml/ha (7.72% at 45 DAT), Dipel WP @ 2.0 kg/ha (8.21% at 60 DAT), *Karanja* oil 2% (8.50% at 60 DAT) and EPN *Steinernema feltiae* @ 2.0 billion IJs/ha (9.75 % at 60 DAT) ranked in descending order in terms of management of pest and were significantly better than control (21.44 and 15.43 % at 45 and 60 DAT, respectively).

The results during *Kharif* 2013 (Table 2) again revealed maximum leaf folder population suppression in Neem azal 1% treated plots with incidence of 0.97, 1.23 and 1.49 per cent at 60 DAT in Neem azal 1% @ 1250, 1000 and 750 ml/ha treatments, respectively. Treatments of Myco-Jaal 10% SC @ 2000 ml/ha (2.01 % at 60 DAT), *Karanja* oil 2% (2.27% at 60 DAT), EPN *Steinernema feltiae* @ 2.0 billion IJs/ha (2.48% at 60 DAT) and Dipel WP @ 2.0 kg/ha (3.11% at 60 DAT) also reduced the leaf folder incidence significantly. Untreated control plots recorded the maximum incidence of 12.09 and 9.47 % at 45 and 60 DAT.

Stemborer incidence

The results during 2012 (Table 1) showed that Neem azal 1% @ 1250 ml/ha was the best treatment with significant lowest incidence of dead hearts (0.98 % at 60 DAT) and white earheads (2.05%) followed by *Karanja* oil 2% (1.14% DH at 60 DAT). Simlarly, Neem azal 1% @ 1000 ml/ha (1.27% DH at 60 DAT and 2.26% WE), Dipel WP @ 2.0 kg/ha (1.77% DH at 60 DAT and 2.26% WE), Neem azal 1% @ 750 ml/ha (1.62% DH at 60 DAT and 2.53% WE) and Myco-Jaal 10% SC @ 2000 ml/ha (1.94% at 60

DAT) also recorded lower incidence. These treatments were significantly better than other treatments with maximum incidence of dead hearts (5.48 and 6.65% at 45 and 60 DAT, respectively) and white ear heads (5.98%) in control plots.

During 2013 also, the similar trend was observed (Table 2) where Neem azal 1% @ 1250 ml/ha was again found to be significantly effective in reducing dead hearts (1.37 and 1.42% at 45 and 60 DAT, respectively) and white ear heads (1.07%) followed by Neem azal 1% @ 1000 ml/ha (1.53 % DH at 45 DAT and 1.42% WE). Likewise lower pest incidence was recorded in Neem azal 1% @ 750 ml/ha (1.73 % DH at 45 DAT and 1.86% WE) and Dipel WP @ 2.0 kg/ha (1.92% DH at 60 DAT and 2.02% WE). The maximum incidence of dead hearts (4.59 and 6.60% at 45 and 60 DAT, respectively) and white ear heads (4.63%) was recorded in untreated plots.

Planthopper(s) damage

Overall, the incidence of whitebacked planthopper (WBPH) was higher (0.39-1.18/plant) than brown planthopper (0.11-0.76/plant). Among the various treatments, Neem azal 1% @ 1250 ml/ha significantly reduced the incidence of WBPH (0.39/plant) and BPH (0.11/plant). The observations also indicated lower incidence in other doses of Neem azal 1% (0.48-0.57 WBPH and 0.15-0.17 BPH/plant), *Karanja* oil (0.50-0.59 WBPH and 0.24-0.30 BPH/plant) and Myco-Jaal 10% SC (0.58-0.76 WBPH and 0.24-0.38 BPH/plant). Application of Dipel WP (1.02-1.14 WBPH and 0.60-0.64 BPH/plant) and EPN (1.03-1.10 WBPH and 0.55-0.57 BPH/plant) formulation resulted in maximum range of infestation and these were on a par with untreated plots (1.18 WBPH and 0.76 BPH/plant) (Table 1).

In 2013 also (Table 2), the mean incidence of BPH was lower (0.13-0.79/plant) than WBPH (0.40-1.17/plant). Neem azal 1% @ 1250 ml/ha again observed to be best treatment with lowest incidence of WBPH (0.40/plant) and BPH (0.13/plant). Similarly, Neem azal 1% @ 1000 ml/ha (0.41 WBPH and 0.14 BPH/plant), *Karanja* oil 2.0% (0.47 WBPH and 0.21BPH/plant) and Myco-Jaal 10% SC @ 2000 ml/ha (0.23 BPH/plant) also recorded lower incidence. The maximum incidence was recorded in untreated plots (1.17 WBPH and 0.79 BPH/plant) and applications involving *Bt* and EPN formulations showed least control.

Grain yield

The yield analysis of field experiment during 2012 demonstrated the efficacy of application of different biopesticide formulations in increasing grain yield of variety *Pusa* 1121 (Table 1). The Neem azal 1% treated plots recorded highest yields of 35.47-36.47 q/ha. All the 3 doses of Neem azal 1% were significantly better than other treatments in increasing yields. Application of biopesticides like *Karanja* oil 2.0% (35.70 q/ha) and Dipel WP @ 2.0 kg/ha (34.57q/ha) also recorded higher grain yield. Similarly, Dipel WP @ 1.5 kg/ha (33.08q/ha) and *Karanja* oïl 1.5% (32.88 q/ha) showed significantly better yield. The lowest yield of 29.24 q/ha was recorded in untreated control.

During 2013, the highest grain yield of variety *Basmati* 386 was recorded in Neem azal 1% @ 1250 ml/ha (25.54 q/ha) which was on par with Neem azal 1% @ 1000 ml/ha (25.10 q/ha) and was significantly better than other treatments (Table 2). This was followed by Dipel WP @ 2.0 kg/ha (24.44 q/ha), *Karanja* oïl 2.0% (23.53 q/ha) and Myco-Jaal 10% SC @ 2000 ml/ha (23.23 q/ha). Untreated control plots recorded lowest grain yield (19.48 q/ha).

The overall (pooled) results of 2 years experiments carried out in 2012 and 2013 revealed that the application of Neem azal 1% @ 1250 ml/ha (2.98% DL) and 1000 ml/ha (3.13% DL) and Myco-Jaal 10% SC @ 2000 ml/ha (4.82% DL) significantly reduced the incidence of leaf folder (Similarly, application of Neem azal 1% @ 1250 ml/ha (1.36% DH & 1.77% WE) and @ 1000 ml/ha (1.6 DH & 1.97% WE), Dipel WP @ 2.0 kg/ha (2.17% DH & 2.03% WE) and *Karanja* oïl 2.0% (2.41% DH & 2.25% WE) reduced the stem borer incidence. Treatments like Neem azal 1% @ 1000 and 1250 ml/ha (0.39-0.54 WBPH & 0.12-0.17 BPH/plant), *Karanja* oïl 2.0% (0.49 WBPH & 0.23 BPH/plant) and Myco-Jaal 10% SC @ 2000 ml/ha (0.57 WBPH & 0.23 BPH/plant) maintained their supermacy in reducing plant hopper(s) population over other treatments including untreated control.

The overall data on grain yields revealed that highest yields were recorded with Neem azal 1% @ 1250 ml/ha (31.00 q/ha) and @ 1000 ml/ha (30.43 q/ha). This was followed by *Karanja* oïl 2.0% and Dipel WP @ 2.0 kg/ha with grain yields of 29.62 and 29.51 q/ha, respectively. These treatments were significantly better than rest of the treatments. Among the biopesticide treatments, lowest yield was recorded against EPN *Steinernema feltiae* @ 1.0 billion IJs/ha (24.61 q/ha) and Myco-Jaal 10% SC @ 1000 ml/ha (24.88 q/ha) which were on a par with control (24.36 q/ha).

Organic agriculture is developing rapidly globally and today more than 140 countries produce organic food commercially. Almost 11 m ha i.e., about one-third of the world's organically managed land is located in the developing countries (Reddy, 2010). The present study underlines the utility of plant based biopesticides and microbials for the sustainable management of pests of aromatic rice grown

under organic farming conditions. It corroborates with the earlier studies of Chakraborty (2011) who reported that bioformulations based on neem like Nimbicidine @ 2.5ml/ litre (61.46% DH & 62.06% WE over control) and *B. thuringiensis* @ 2g/ litre (58.69% DH & 60.38% WE over control) were found to be superior in reducing the incidence of yellow stem borer, *S. incertulas* and resulted in higher grain yields (32.31-37.19% over control). Nigam *et al.* (2010) while studying the efficacy of insecticides against *C. medinalis* reported that 3 sprays of neem oil @ 5% significantly reduced the leaf folder insfestation (89.46% over control) and increased the grain yield of *Basmati* rice (20.33% over control). They also reported that *Bt* formulations Dipel WP and Biolep WP @ 2.0 Kg/ha were effective against the pest. The present sudies also are in line with those of Shahid *et al.* (2003) who evaluated *Bacillus thuringiensis* against stem borer and leaf folder of rice and reported reduction in population of these pests in the laboratory and the field.

Furthermore, the present study documents the decreased infestation of WBPH and BPH in plots treated with Neem azal 1%, *Karanja* oil (2%) and Myco-Jaal 10% SC when compared with control. Similar results on reduction in the incidence of WBPH have been reported through root soaking of rice seedlings with neem kernel extract (Saxena *et al.,* 1987), and 5 per cent neem cake extract spray reduced emergence of WBPH (Ramraju and Sundarababu 1989). Likewise, neem extract and bioinsecticide namely Biovip produced from *B. bassiana* have been reported to affect the biology of brown planthopper causing reduction in the hopper population at acceptable level at 60 days after spray (Chi *et al*., 2005; Senthil Nathan *et al*., 2007).

From the present study, it is conclusively proved that lepidopteran as well as sucking pests of rice can be managed successfully and yield can be increased by using plant based biopesticides like Neem azal 1% and *Karanja* oil (2%) and microbials like Dipel WP and Myco-Jaal 10% SC. These formulations may provide an effective and eco-friendly alternative to conventional synthetic insecticides and can provide with choices to farmers pracitising organic cultivation during selection of suitable chemicals against rice pests. In future, these biopesticides may play a prominent role in the integrated pest management of rice pests especially under organic farming systems.

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Table 1. Impact of different biopesticide formulations on the incidence of major insect pests and grain yield in organic *basmati* rice variety Pusa 1121 (2012)

Treatment[#]	Damaged leaves (%)		Dead Hearts (%)		% White earheads[**]	WBPH+ (No./plant)	BPH+ (No./plant)	Yield[**] (q/ha)
	45 DAT	60 DAT	45 DAT	60 DAT				
Dipel WP @ 1.0 Kg/ha	14.36 (22.19)^{de}	12.26 (20.45)^{f}	2.75 (9.52)^{bc}	2.03 (8.17)^{bcd}	2.59 (9.24)^{bc}	1.13 (1.46)^{gh}	0.62 (1.27)^{fg}	32.38^{defg}
Dipel WP @ 1.5 Kg/ha	14.21 (22.11)^{de}	8.49 (16.92)^{de}	2.68 (9.41)^{bc}	1.97 (8.04)^{bcd}	2.53 (9.14)^{abc}	1.02 (1.42)^{f}	0.64 (1.28)^{g}	33.08^{bcde}
Dipel WP @ 2.0 Kg/ha	9.30 (17.71)^{bc}	8.21 (16.62)^{de}	2.63 (9.32)^{bc}	1.77 (7.58)^{abc}	2.48 (9.05)^{abc}	1.14 (1.46)^{gh}	0.60 (1.27)^{fg}	34.57^{abcd}
Myco-Jaal 10% SC @ 1000 ml/ha	10.28 (18.69)^{bc}	9.01 (17.43)^{de}	3.21 (10.31)^{cd}	2.14 (8.39)^{cd}	3.44 (10.68)^{e}	0.76 (1.33)^{e}	0.38 (1.17)^{e}	29.47^{gh}
Myco-Jaal 10% SC @ 1500 ml/ha	9.77 (18.18)^{bc}	7.65 (15.97)^{cde}	3.06 (10.06)^{e}	2.04 (8.21)^{bcd}	3.34 (10.52)^{de}	0.65 (1.28)^{d}	0.28 (1.13)^{cd}	30.00^{fgh}
Myco-Jaal 10% SC @ 2000 ml/ha	7.72 (16.05)^{abc}	5.60 (13.66)^{bc}	3.02 (9.99)^{e}	1.94 (7.97)^{bcd}	3.13 (10.18)^{de}	0.58 (1.26)^{bcd}	0.24 (1.11)^{bc}	31.42^{efgh}
EPN *Steinernema feltiae* @ 1.0 billion IJs/ha	10.71 (19.04)^{e}	8.33 (16.73)^{de}	4.00 (11.52)^{e}	3.43 (10.65)^{e}	3.56 (10.87)^{e}	1.10 (1.45)^{fgh}	0.57 (1.26)^{fg}	29.63^{gh}
EPN *Steinernema feltiae* @ 1.5 billion IJs/ha	10.43 (18.81)^{bc}	7.23 (15.56)^{cde}	3.85 (11.31)^{e}	2.72 (9.46)^{de}	3.46 (10.71)^{e}	1.07 (1.44)^{fgh}	0.55 (1.25)^{f}	30.07^{fgh}
EPN *Steinernema feltiae* @ 2.0 billion IJs/ha	9.75 (18.13)^{bc}	6.66 (14.87)^{cd}	3.71 (11.10)^{de}	2.39 (8.89)^{cd}	3.27 (10.39)^{de}	1.03 (1.43)^{fg}	0.55 (1.24)^{f}	30.92^{efgh}

Neem azal 1% @ 750 ml/ha	6.92 (15.22)^{ab}	4.04 (11.51)^{ab}	2.23 (8.57)^{ab}	1.62 (7.29)^{abc}	2.53 (9.14)^{abc}	0.57 (1.25)^{bcd}	0.17 (1.08)^{ab}	35.47^{abc}
Neem azal 1% @ 1000 ml/ha	5.44 (13.46)^{a}	3.35 (10.52)^{a}	1.96 (8.03)^{a}	1.27 (6.44)^{ab}	2.26 (8.63)^{ab}	0.48 (1.21)^{ab}	0.15 (1.07)^{a}	35.77^{ab}
Neem azal 1% @ 1250 ml/ha	5.66 (13.74)^{a}	3.22 (10.29)^{a}	1.67 (7.41)^{a}	0.98 (5.66)^{a}	2.05 (8.23)^{a}	0.39 (1.18)^{a}	0.11 (1.05)^{a}	36.47^{a}
Karanja Oil (1.0%)	16.70 (24.05)^{e}	11.43 (19.71)^{f}	4.04 (11.58)^{e}	2.74 (9.51)^{de}	2.87 (9.74)^{cd}	0.59 (1.26)^{cd}	0.33 (1.15)^{de}	32.67^{cdef}
Karanja Oil (1.5%)	16.16 (23.65)^{e}	9.27 (17.70)^{e}	3.95 (11.45)^{e}	1.98 (8.08)^{bcd}	2.91 (9.80)^{cd}	0.50 (1.23)^{bc}	0.30 (1.14)^{cde}	32.88^{bcdef}
Karanja Oil (2.0%)	11.14 (19.48)^{cd}	8.50 (16.92)^{de}	3.67 (11.03)^{de}	1.14 (6.09)^{a}	2.57 (9.21)^{abc}	0.51 (1.23)^{bc}	0.24 (1.11)^{bcd}	35.70^{ab}
Control	21.44 (27.55)^{f}	15.43 (23.11)^{g}	5.48 (13.53)^{f}	6.65 (14.91)^{f}	5.98 (14.15)^{f}	1.18 (1.47)^{h}	0.76 (1.33)^{h}	29.24^{h}

Means in acolumn followed by the same letters are not significantly different according to DMRT at P = 0.05. Data in parentheses are arcsine transformed values for % damaged leaves, dead hearts & white ears and square root transformed values for plant hopper(s) population.

DAT: Days after transplanting

**Observations at maturity

$^{\#}$Biopesticides applied at 30, 40, 50, 60 & 70 DAT

$^{+}$Mean of 8 observations starting at 30 DAT

Table 2. Impact of different biopesticide formulations on the incidence of major insect pests and grain yield in organic *basmati* rice variety Pusa 386 (2013)

Treatment$^{\#}$	Damaged leaves (%)		Dead Hearts (%)		% White earheads**	WBPH+ (No./plant)	BPH+ (No./plant)	Yield** (q/ha)
	45 DAT	60 DAT	45 DAT	60 DAT				
Dipel WP @ 1.0 Kg/ha	7.47 (15.84)^{gh}	3.72 (11.10)^{gh}	2.15 (8.14)^{abcd}	2.78 (9.58)^{cdefg}	2.33 (8.74)^{bc}	0.96 (1.40)^{de}	0.62 (1.27)^{de}	21.00cdef
Dipel WP @ 1.5 Kg/ha	6.63 (14.88)^{fgh}	3.47 (10.72)^{fgh}	2.03 (8.16)^{abcd}	2.33 (8.77)^{bcd}	2.07 (8.24)^{bc}	0.85 (1.36)^{cde}	0.54 (1.24)^{d}	22.17^{bcdef}
Dipel WP @ 2.0 Kg/ha	6.17 (14.35)^{efg}	3.11 (10.12)^{efgh}	1.92 (7.93)^{abcd}	2.37 (8.84)^{bcde}	2.02 (8.16)^{bc}	0.94 (1.39)^{de}	0.58 (1.26)^{d}	24.44^{ab}
Myco-Jaal 10% SC @ 1000 ml/ha	6.18 (14.36)^{efg}	3.17 (10.25)^{efgh}	2.70 (9.42)^{d}	3.76 (11.16)^{h}	2.63 (9.29)^{c}	0.75 (1.32)^{bcd}	0.34 (1.16)^{bc}	20.28^{ef}
Myco-Jaal 10% SC @ 1500 ml/ha	5.62 (13.68)^{defg}	2.65 (9.35)^{defg}	2.35 (8.78)^{bcd}	3.14 (10.19)^{defgh}	2.44 (8.96)^{c}	0.53 (1.23)^{abc}	0.30 (1.14)^{ab}	20.53^{def}
Myco-Jaal 10% SC @ 2000 ml/ha	3.94 (11.36)^{bcd}	2.01 (8.09)^{defg}	2.07 (8.20)^{abcd}	2.39 (8.85)^{bcde}	2.11 (8.34)^{bc}	0.58 (1.25)^{abc}	0.23 (1.11)^{ab}	23.23^{abcd}
EPN *Steinernema feltiae* @ 1.0 billion IJs/ha	7.48 (15.86)^{gh}	4.03 (11.57)^{h}	2.75 (9.52)^{d}	3.70 (11.06)^{h}	2.67 (9.38)^{c}	0.94 (1.39)^{de}	0.53 (1.24)^{d}	19.58^{f}
EPN *Steinernema feltiae* @ 1.5 billion IJs/ha	5.91 (14.06)^{efg}	3.42 (10.63)^{fgh}	2.33 (8.75)^{bcd}	3.62 (10.93)^{gh}	2.71 (9.46)^{c}	0.91 (1.38)^{de}	0.54 (1.24)^{d}	20.03^{f}
EPN *Steinernema feltiae* @ 2.0 billion IJs/ha	5.07 (13.00)^{def}	2.48 (9.02)^{cdef}	2.56 (9.19)^{cd}	3.40 (10.60)^{fgh}	2.31 (8.71)^{bc}	0.83 (1.34)^{cde}	0.49 (1.22)^{cd}	20.84^{cdef}
Neem azal 1% @ 750 ml/ha	3.19 (10.25)^{abc}	1.49 (6.94)^{abc}	1.73 (7.53)^{abc}	2.13 (8.38)^{abc}	1.86 (7.82)^{abc}	0.51 (1.23)^{abc}	0.17 (1.08)^{ab}	23.05^{abcde}
Neem azal 1% @ 1000 ml/ha	2.51 (9.08)^{ab}	1.23 (6.32)^{ab}	1.53 (7.07)^{ab}	1.70 (7.46)^{ab}	1.42 (6.83)^{ab}	0.41 (1.19)^{ab}	0.14 (1.07)^{ab}	25.10^{a}
Neem azal 1% @ 1250 ml/ha	2.05 (8.21)^{a}	0.97 (5.63)^{a}	1.37 (6.66)^{a}	1.42 (6.78)^{a}	1.07 (5.92)^{a}	0.40 (1.18)^{a}	0.13 (1.06)^{a}	25.54^{a}

Karanja Oil (1.0%)	8.07 (16.42)^{h}	3.86 (11.30)^{h}	2.35 (8.80)^{bcd}	3.20 (10.29)^{efgh}	2.66 (9.37)^{c}	0.52 (1.23)^{abc}	0.30 (1.14)^{ab}	20.85^{cdef}
Karanja Oil (1.5%)	7.48 (15.86)^{gh}	3.55 (10.83)^{fgh}	2.28 (8.67)^{bcd}	3.05 (10.04)^{defgh}	2.24 (8.59)^{bc}	0.51 (1.23)^{abc}	0.26 (1.12)^{ab}	22.98^{abcde}
Karanja Oil (2.0%)	4.38 (12.01)^{cde}	2.27 (8.59)^{bcde}	2.14 (8.40)^{abcd}	2.70 (9.42)^{cdef}	1.92 (7.92)^{bc}	0.47 (1.21)^{ab}	0.21 (1.10)^{ab}	23.53^{abc}
Control	12.09 (20.30)^{i}	9.47 (17.89)^{i}	4.59 (12.36)^{e}	6.60 (14.86)^{i}	4.63 (12.35)^{d}	1.17 (1.47)^{e}	0.79 (1.34)^{e}	19.48^{f}

Means in acolumn followed by the same letters are not significantly different according to DMRT at P = 0.05. Data in parentheses are arcsine transformed values for % damaged leaves, dead hearts & white ears and square root transformed values for plant hopper(s) population .

DAT: Days after transplanting

[**]Observations at maturity

[#]Biopesticides applied at 40, 50, 60 & 70 DAT

[+]Mean of 7 observations starting at 30 DAT

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