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SURVEY AND MANAGEMENT OF MAJOR INSECT PESTS OF SUMMER PADDY

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ABSTRACT

Roving survey was conducted for the major insect pests of summer paddy in north eastern zone of Karnataka. At vegetative stage, the incidence of yellow stem borer *Scirpophaga incertulas* (Walker) was highest in Vijayanagar district (2.38%), whereas, the occurrence of brown planthopper *Nilaparvata lugens* (Stal) (1.61/hill), green leafhopper *Nephotettix nigropictus* (Stål) (1.66/ hill) and rice gall fly *Orseolia oryzae* (Wood-Mason) (6.10%) was maximum in Koppal. The incidence of rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) (1.33%) was highest in Raichur. All the five insects pest of summer paddy surveyed were abudant in Koppal at reproductive stage. The efficacy of bioagents was evaluated. *Bacillus thuringiensis* (Berliner) formulations. Dipel was effective with least *S. incertulas* (1.93%) and *C. medinalis* damage (1.72%) whereas, azadirachtin and Dipel recorded the lowest *S. incertulas* (2.64% and 2.72%) and *C. medinalis* (1.67% and 1.71%), respectively. Similarly, azadirachtin and *Metarhizium anisopliae* recorded lowest *N. lugens* (1.90 hoppers/ hill) and *N. nigropictus* (0.70 hoppers/ hill) after three sprays at 15 days interval.

Key words: *Scirpophaga incertulas*, *Nilaparvata lugens*, *Nephotettix nigropictus*, *Orseolia oryzae*, *Cnaphalocrocis medinalis*, summer paddy, *Bacillus thuringiensis*, bioagents, roving survey, *Metarhizium anisopliae*, botanicals, bioefficacy, biopesticides, *Beauveria bassiana*, *Lecanicillium lecanii*

Rice (*Oryza sativa* L.) is the world's most important crop and staple food of more than half of the world's population, grown in a wide range of environments. The total rice growing area in the world is 167 million ha with the production of 700 million tons (Anon., 2020). Among the rice producing countries, India occupies the number one position with area of 44.15 million ha, followed by China with 29.3 million ha. The major irrigation project, tungabhadra is referred as the "Rice Bowl of Karnataka" contributing nearly 65.00% of the total area of paddy in Karnataka (Shanabhoga et al., 2020). Tungabhadra project (TBP) command area includes Ballari, Koppal, Vijayanagar and Raichur districts. Lower production and productivity of rice has been attributed to a number of factors, among them losses caused by the insect pests are considered as one of the important biotic factors. In India, average losses in paddy production due to insect pests is 25.00% (Chintalapati et al., 2023). More than 1400 insect species are known to attack standing crop and stored rice in the world. Yellow stem borer (YSB), *Scirpophaga incertulas* (Walker) (Lepidoptera: Pyralidae) is a monophagous and most destructive pest of paddy, which is widely distributed in Indian subcontinent (Devi and Varma, 2022). It is most destructive, because of its ubiquitous distribution and chronic pattern of infestation. The yield loss due to *S. incertulas* is as high as 87.66%, if not taken any control measures (Jaglan and Chaudhary, 2021). The brown planthopper (BPH) *Nilaparvata lugens* (Stal) (Hemiptera: Delphacidae) and white backed planthopper (WBPH) *Sogatella furcifera* (Horvath) (Hemiptera: Delphacidae) have long been known as pests of rice in south Asia and south-east Asia. Planthopper populations were severe at Gangavathi, Kampli and Koppal areas and in Mandya regions of Karnataka covering tungabhadra and cauvery commands area (Hurali et al., 2020).

The farmers of TBP area have been growing paddy since many years by incorporating excessive nitrogenous fertilizers, heavy irrigation, non-adaptation of alternate wetting and drying and use of indiscriminate doses of insecticides. This results in the multiplication of rice pests. To control these pests farmers have been spraying insecticides which results in the killing of natural enemies like spiders, mirid bugs, Trichogramma etc, and also leads to development of resistance and resurgence. Moreover, it is expansive and polluting the environment. These bioagents reduce the pest population below economic threshold level, does not cause resistance, resurgence and residues problems (Sanchez-Bayo, 2021). This study is on the survey of pests in summar paddy and on the efficacy of some bioagents.

MATERIALS AND METHODS

Roving survey was conducted on summer paddy during 2020-21 in TBP area of Ballari and Siruguppa taluks of Ballari district, Hagaribommanahalli and Huvina Hadagali taluks of Vijayanagar district, taluk of Raichur district and Gangavathi taluk of Koppal district at twice in a season during the vegetative and reproductive stage. Observations on the incidence of *S. incertulas* (number of dead heart or white ear to the total number of tillers/panicles), leaf folder *Cnaphalocrocis medinalis* Guenée (Lepidoptera: Crambidae) (number of damaged leaves to total number of leaves), gall midge (number of silver shoot to total number of tillers), number of leafhopper and planthopper were recorded on 10 randomly selected hills and converted into % incidences. *Bacillus thuringiensis* (Berliner**)** formulations were evaluated against *S. incertulas* and *C. medinalis*. The experiment was conducted at farmers field (15.256514°, 77.120098°), Yerriswamy, Jalihal village, Ballari taluk and the experiment was laid out in randomized complete block design with six treatments and four replications. The size of each treatment plot was 5m×5m (25 m^2). The seedlings of cultivar 'Kaveri sona (555)' was raised in a well-prepared seed bed and transplanted 30 days aged seedlings in finely prepared puddled plots. One to two seedlings were planted/ hill with a spacing of 15x10 cm from row to row and plant to plant. Agronomical practices were followed as per the package of practices except for the crop protection activities. The *B. thuringiensis* formulations like Dipel (Sumitomo Chemical India Ltd., 2 mL/ L), BARC *Bt* (BARC, Mumbai, 2 g/ L), B. gudi *Bt* (Native strain, 2 ml/l)*,* NBAIR *Bt* (NBAIR, Bengaluru, 2 mL/ L) and Maharashtra *Bt* (International Pamaacea Ltd. 2 g/ L) were sprayed using high volume knapsack sprayer on 20th, 35th and 50th days after transplanting.

Entomopathogens and plant-based insecticides were evaluated against major insect pests of summer paddy. The experiment was laid out in randomized complete block design with seven treatments and three replications. Bioagents like *Beauveria bassiana* CFU 2×10^8/ g (UAS, Raichur,4.0 g/ L)*, Metarhizium anisopliae* CFU 2×10^8/ g (UAS, Raichur, 4.0 g/ l)*,* commercial *B. thuringiensis* (dipel, 2.0 ml/ l) and *Lecanicillium lecanii* CFU 2×10^8/ g (UAS, Raichur, 4.0 g/ l) and plant-based insecticides like azadirachtin 3000 ppm (SS Biochem India Pvt Ltd., 3.0 ml/ l) and brahmastra (30 ml/ l) were sprayed on 20th, 35th and 50th days after transplanting. The procedure used for preparation of brahmastra was followed as reported by Palekar (2014). Leaves of neem, custard apple, pongemia, castor, datura of 1 kg each was taken and boiled in 10 l desi cow urine, it was kept for 48 hr for fermentation, then filter and squeeze the extract. This can be stored in bottles for 6 months. Six to eight litres of solution should be mixed in 200 litres water to spray 1 acre of land. Observations were recorded on number of insect pests per plant based on white ears, dead heart symptoms for *S. incertulas* in 10 hills and number of larvae for *C. medinalis* in 10 hills, number of nymphs of *N. lugens* and *N. nigropictus* randomly selected 10 hills from each plot. The pretreatment count was made a day before the spray and the post-treatment observations were recorded on 3rd, 7th and 14th day after each spray for *N. lugens* and *N. nigropictus*. For *S. incertulas* and *C. medinalis* 7th and 14th day after each spray and 10 days before harvest only for *S. incertulas*. 14th day observation will be considered as the pretreatment count for the subsequent spray. The data obtained for various parameters such as incidence of *S. incertulas*, *C. medinalis*, *N. nigropictus* and *N. lugens* were subjected to ANOVA for a randomized complete block design with suitable statistical transformation.

RESULTS AND DISCUSSION

The results of roving survey for the major insect pests of summer paddy indicated that during vegetative stage higher incidence of *S. incertulas* was recorded in Vijayanagar district (2.38%). The major incidence of *C. medinalis* recorded in Ballari (1.15%), Raichur (1.15%) and Vijayanagar (1.33%). Whereas, higher incidence of *N. lugens, N. nigropictus* and *Orseolia oryzae* were recorded in Koppal with 1.61 hoppers/ hill, 1.66 hoppers/ hill and 6.1% respectively. All the pests were below ETL in all the regions except *Orseolia oryzae* (ETL for gall midge 5%). During reproductive stage the major incidence of *S. incertulas* was recorded in Koppal district (7.21%) but in other districts it was ranged from 5.88 to 6.56%, which was above ETL in all districts (ETL 5% white ear). *N. lugens* was ranged from 1.94 to 3.56 hoppers/ hill, *N. nigropictus* was ranged from 1.64 to 2.64 hoppers/ hill, *C. medinalis* damage was ranged from 2.10 to 2.78%. *N. lugens* (ETL 8-10 hoppers/ hill)*, N. nigropictus* (ETL 6-7 adults/hill)*, C. medinalis* (5-10% damage) did not crossed ETL at reproductive stage. There was no incidence of gall midge in all districts at reproductive stage (Table 1). The present findings are in concurrence with the findings of Vijaykumar and Patil (2001) who recorded *S. incertulas* infestation ranged from 0.86 to 1.22% dead hearts during vegetative stage and 1.84% white ears at harvest, green leafhoppers damage was noticed throughout the crop growth with (1.38/hill). Kulagod (2009) noticed the considerable incidence of *S. incertulas* (8.02%) and *N. nigropictus* (6.27/hill) in Uttar Kannada district of Karnataka. Ashrith (2015) observed the higher incidence of *S. incertulas* (13.49%) and *C. medinalis* (13.03%) in Koppal, Karnataka.

The evaluation of *B. thuringiensis* formulations against *S. incertulas* indicated that day before spray, all the treatments were found non-significant ranged from 6.22 to 6.46% dead heart. However, 7 days after the treatment, treatment T_1 (dipel) recorded statistically lowest dead heart (5.19%), which was on par with BARC *Bt*, NBAIR *Bt*, B. gudi *Bt* and Mahastra *Bt* recorded dead heart varied from 5.24 to 5.40%. Significantly highest dead heart was recorded in the treatment T_6 (control) with 6.59%. The similar trend was noticed in 14 days after spray. Seven days after the second spray, numerically lowest dead heart (3.88%) was observed in treatment, dipel which was on par with rest of all *Bt* formulations. BARC *Bt* (4.22%), NBAIR *Bt* (3.94), B. gudi *Bt* (4.03%) and Mahastra *Bt (*4.21%). The treatment, untreated control recorded significantly highest dead heart with 7.39%. The similar trend was observed on 14th day after second spray also. Statistically lowest white ear was recorded in treatment, dipel with 2.87% and 1.93% 7th and 14th day after the third spray respectively, reaming treatments were on par with each other. Significantly highest white ear damage was noticed in treatment control with 8.33 and 8.63% respectively. At ten days before harvest numerically lowest white ear was recorded in the treatment, dipel with 2.27%. Remaining treatments were recorded white ear infestation ranged from 2.34 to 2.95% and at par with each other. However, the treatment, control recorded significantly highest white ear with 11.44% (Table 2).

The efficacy of *B. thuringiensis* formulations against *C. medinalis* indicated that day before spray, all the treatments were found to be non-significant ranged from 5.75 to 5.64% *C. medinalis* damage indicating uniformity in pest population. However, seven days after the first spray treatment T_1 (dipel) recorded statistically lowest *C. medinalis* damage (4.08%), which was on par with BARC *Bt*, NBAIR *Bt*, B. gudi *Bt* and Mahastra *Bt* recorded *C. medinalis* damage ranged from 4.11 to 4.24%. Significantly the highest *C. medinalis* incidence was recorded in the treatment, T_6 (untreated control) with 5.87%. The same trend was noticed on 14th days after first spray, 7th and 14th days after second spray also. Statistically lowest *C. medinalis* damage was recorded in treatment, dipel with 2.11% and 1.72% at 7th and 14th day after third spray. The remaining treatments were on par with each other. Significantly highest *C. medinalis* damage were noticed in treatment, untreated control with 7.61% and 8.21% on 7th and 14th days after third spray respectively (Table 3). The current research findings are in line with the findings of Brownbridge and Onyango (1992) who recorded 80.00% of mortality of *Chilo partellus* with the treatment dipel. Brownbridge (1991), noticed *Bt* formulations caused the mortality of 80.00 when treated against in spotted stem borer *C. partellus* and african army worm *Spodoptera exempta*. Yule and Srinivasan (2013) noticed reduction of pod borer *Maruca vitrata* damage from 42 to 50% in pigeon pea sprayed with *Bt* formulations.

Table 1. Roving survey for the major insect pests of summer paddy (TBP region of Karnataka)

District	Vegetative stage				
	S. incertulas (% dead heart/ white ear)	*N. lugens* (No. of hoppers/ hill)	*N. nigropictus* (No. of hoppers/ hill)	*C. medinalis* (% incidence)	*Orseolia oryzae* (% incidence)
Ballari	2.03	0.89	0.93	1.15	0.68
Vijayanagar	2.38	0.62	0.49	1.15	0.00
Raichur	1.78	0.54	1.19	1.33	1.03
Koppal	1.80	1.61	1.66	0.73	6.10
	Reproductive stage				
Ballari	5.88	2.65	2.22	2.11	0.00
Vijayanagar	6.56	2.18	1.64	2.10	0.00
Raichur	5.72	1.94	2.11	2.04	0.00
Koppal	7.21	3.56	2.64	2.78	0.00

Table 2. Efficacy of *B. thuringiensis* formulations against *S. incertulas*

Treatments	Dosage	Dead heart (%)					White ear (%)		
		First spray			Second spray		Third spray		
		DBS	7 DAS	14 DAS	7 DAS	14 DAS	7 DAS	14 DAS	10 DBH
T_1: Dipel (Commercial)	2 ml/ l	6.46 (14.72)^{a}	5.19 (13.17)^{a}	4.51 (12.26)^{a}	3.88 (11.36)^{a}	3.41 (10.64)^{a}	2.87 (9.75)^{a}	1.93 (7.99)^{a}	2.27 (8.67)^{a}
T_2: BARC *Bt*	4 g/ l	6.32 (14.56)^{a}	5.32 (13.34)^{a}	4.59 (12.37)^{a}	4.12 (11.71)^{a}	3.44 (10.69)^{a}	2.98 (9.94)^{a}	1.96 (8.05)^{a}	2.57 (9.23)^{a}
T_3: B gudi *Bt*	2 ml/ l	6.41 (14.67)^{a}	5.27 (13.27)^{a}	4.66 (12.47)^{a}	4.03 (11.58)^{a}	3.55 (10.86)^{a}	3.01 (9.99)^{a}	2.07 (8.27)^{a}	2.41 (8.93)^{a}
T_4: NBAIR *Bt*	2 ml/ l	6.38 (14.63)^{a}	5.24 (13.23)^{a}	4.58 (12.36)^{a}	3.94 (11.45)^{a}	3.48 (10.75)^{a}	2.94 (9.87)^{a}	2.00 (8.13)^{a}	2.34 (8.80)^{a}
T_5: Mahastra *Bt* (Commercial)	4 g/ l	6.29 (14.52)^{a}	5.40 (13.44)^{a}	4.65 (12.45)^{a}	4.21 (11.84)^{a}	3.85 (11.32)^{a}	3.17 (10.26)^{a}	2.12 (8.37)^{a}	2.95 (9.89)^{a}
T_6: Control	-	6.22 (14.44)^{a}	6.59 (14.87)^{b}	6.89 (15.22)^{b}	7.39 (15.77)^{b}	7.73 (16.14)^{b}	8.33 (16.78)^{b}	8.63 (17.08)^{b}	11.44 (19.77)^{b}
S. Em (±)		NS	0.12	0.15	0.19	0.23	0.36	0.51	0.62
CD @ 5%			0.36	0.45	0.58	0.71	1.09	1.52	1.85

DBS – Days before spray, DAS – Days after spray, DBH – Days before harvest; Values in parenthesis are arcsine transformed; Means followed by same alphabet in columns did not differ significantly (p=0.05) by DMRT

Table 3. Efficacy of *B. thuringiensis* formulations against *C. medinalis*

Treatments	Dosage	*C. medinalis* damage (%)						
		First spray			Second spray		Third spray	
		DBS	7 DAS	14 DAS	7 DAS	14 DAS	7 DAS	14 DAS
T_1: Dipel (Commercial)	2 ml/ l	5.64 (13.74)^{a}	4.08 (11.65)^{a}	3.12 (10.17)^{a}	2.85 (9.72)^{a}	2.42 (8.95)^{a}	2.11 (8.35)^{a}	1.72 (7.54)^{a}
T_2: BARC *Bt*	4 g/ l	5.60 (13.69)^{a}	4.11 (11.70)^{a}	3.15 (10.22)^{a}	2.90 (9.80)^{a}	2.48 (9.06)^{a}	2.15 (8.43)^{a}	1.78 (7.67)^{a}
T_3: B gudi *Bt*	2 ml/ l	5.59 (13.68)^{a}	4.20 (11.83)^{a}	3.27 (10.42)^{a}	3.02 (10.01)^{a}	2.53 (9.15)^{a}	2.21 (8.55)^{a}	1.9 (7.92)^{a}
T_4: NBAIR *Bt*	2 ml/ l	5.75 (13.83)^{a}	4.12 (11.71)^{a}	3.19 (10.29)^{a}	2.91 (9.82)^{a}	2.47 (9.04)^{a}	2.18 (8.49)^{a}	1.81 (7.73)^{a}
T_5: Mahastra *Bt* (Commercial)	4 g/ l	5.44 (13.49)^{a}	4.24 (11.88)^{a}	3.65 (11.01)^{a}	3.12 (10.17)^{a}	2.95 (9.89)^{a}	2.65 (9.37)^{a}	2.08 (8.29)^{a}
T_6: Control	---	5.50 (13.56)^{a}	5.87 (14.02)^{b}	6.17 (14.38)^{b}	6.67 (14.97)^{b}	7.01 (15.35)^{b}	7.61 (16.01)^{b}	8.21 (16.65)^{b}
S. Em (±)		NS	0.09	0.3	0.28	0.45	0.52	0.61
CD @ 5%			0.27	0.9	0.84	1.34	1.56	1.83

DBS – Days before Spray, DAS – Days after spray; Values in parenthesis are arcsine transformed; Means followed by same alphabet in columns did not differ significantly (p=0.05) by DMRT

The results of effect of entomopathogens and plant-based insecticides for management of *S. incertulas* indicated that a day before spray, all the treatments were found non-significant with dead heart, ranged from 6.39 to 6.61%. At fourteen days after the first spray, significantly lowest dead heart (4.03%) was recorded in the treatment T_4 (azadirachtin), which was on par with the treatment, T_3 (dipel) (4.11%) (Table 4). This was followed by the treatment T_1 (*B. bassiana*) (5.32%), T_2 (*M. anisopliae*) (5.38%), T_6 (brahmastra) (5.36%) and T_5 (*L. leccanii*) (5.62%). Significantly highest dead heart was recorded in the treatment, T_7 (control) with 7.12%. Similar trend was observed 14th day after second spray also. Fourteen days after third spray, significantly lowest white ear was observed in the treatment, azadirachtin with 2.64% and significantly highest white ear was recorded in the treatment, control with 8.86%. At ten days after harvest, the treatment, azadirachtin recorded

Table 4. Performance of entomopathogens and plant-based insecticides against *S. incertulas* and *C. medinalis*

Treatments	Dosage	*S. incertulas*					*C. medinalis* (%)			
		Dead heart (%)			White ear (%)					
		First spray		Second spray	Third spray		First spray		Second spray	Third spray
		DBS	14 DAS	14 DAS	14 DAS	10 DBH	DBS	14 DAS	14 DAS	14 DAS
T_1: *Beauveria bassiana*	4.0 g/l	6.55 (14.83)[a]	5.32 (13.34)[b]	4.37 (12.07)[b]	3.93 (11.43)[b]	4.92 (12.82)[b]	5.54 (13.61)[a]	4.19 (11.81)[b]	3.49 (10.77)[b]	2.28 (8.68)[b]
T_2: *Metarhizium anisopliae*	4.0 g/l	6.39 (14.64)[a]	5.38 (13.41)[b]	4.43 (12.15)[b]	3.99 (11.52)[b]	4.98 (12.89)[b]	5.70 (13.81)[a]	4.22 (11.85)[b]	3.52 (10.81)[b]	2.32 (8.76)[b]
T_3: Dipel	2.0 ml/l	6.62 (14.91)[a]	4.11 (11.70)[a]	3.16 (10.24)[a]	2.72 (9.49)[a]	3.71 (11.11)[a]	5.59 (13.68)[a]	4.02 (11.57)[a]	3.17 (10.26)[a]	1.71 (7.51)[a]
T_4: Azadirachtin 3000ppm	3.0 ml/l	6.54 (14.82)[a]	4.03 (11.58)[a]	3.08 (10.11)[a]	2.64 (9.35)[a]	3.63 (10.98)[a]	5.63 (13.73)[a]	3.98 (11.51)[a]	3.12 (10.17)[a]	1.67 (7.43)[a]
T_5: *Lecanicillium lecanii*	4.0 g/l	6.61 (14.90)[a]	5.62 (13.71)[c]	4.67 (12.48)[c]	4.23 (11.87)[c]	5.22 (13.21)[c]	5.65 (13.75)[a]	5.15 (13.12)[c]	4.65 (12.45)[c]	3.80 (11.24)[c]
T_6: Brahmastra	30 ml/l	6.48 (14.75)[a]	5.36 (13.39)[b]	4.41 (12.12)[b]	3.97 (11.49)[b]	4.96 (12.87)[b]	5.67 (13.78)[a]	4.23 (11.87)[b]	3.55 (10.86)[b]	2.36 (8.84)[b]
T_7: Control	--	6.45 (14.71)[a]	7.12 (15.48)[d]	7.96 (16.39)[d]	8.86 (17.32)[d]	12.67 (20.85)[d]	5.60 (13.69)[a]	6.14 (14.35)[d]	7.08 (15.43)[d]	8.31 (16.75)[d]
S. Em (±)		NS	0.08	0.10	0.11	0.17	NS	0.08	0.15	0.17
CD @ 5%			0.25	0.3	0.32	0.51		0.23	0.46	0.52

DBS – Days before spray, DAS – Days after spray, DBH – Days before harvest; Values in parenthesis are arcsine transformed Means followed by same alphabet in columns did not differ significantly (p=0.05)by DMRT

significantly lowest white ear recorded 3.63%, which was at par with treatment dipel (3.71%). Remaining treatment recorded% white ear was ranged from 4.96 to 5.22. Significantly highest white ear of 12.67% was recorded in the control treatment (Table 4). The results indicated that botanicals (Azadirachtin and Brahmastra) found better in managing stem borer damage in rice. This protection can occur through antifeedant and repellent action of the extracts (Sánchez-Bayo, 2021). Fungi based biopesticides have been proved effective against rice stem borer, indicated by reduced damage. The fungi based biopesticides can affect the host as the insect cuticle comes in contact with the fungi during spray or during larval movement (Li and Xia, 2022). The present findings are in analogous with report of Madhu et al. (2020) observed 4.93% dead heart using azadirachtin. Kumar and Singh (2021) reported *B. Bassiana* (3.95%) was most effective after the chemical pesticides followed by *M. anisopliae* (4.13%) and *L. leccanii (*4.42%) in controlling *S. incertulas*.

The results of effect of entomopathogens and plant-based insecticides for management of *C. medinalis* indicated that, a day before spray, all the treatments were found to be non-significant with *C. medinalis* damage ranged from 5.54 to 5.67%. At fourteen days after the first spray, significantly lowest *C. medinalis* damage (3.98%) was recorded in the treatment T_4 (azadirachtin), which was on par with the treatment, T_3 (dipel) (4.02%) (Table 4). This was followed by the treatment, T_1 (*B. bassiana*) (4.19%), T_2 (*M. anisopliae*) (4.22%), T_6 (brahmastra) (4.23%) and T_5 (*L. leccanii*) (5.15%). Significantly highest *C. medinalis* damage was recorded in the treatment, T_7 (control) with 6.14%. Similar observations were recorded in fourteen days after second and third spray also. Significantly lowest *C. medinalis* damage was observed in the treatment, azadirachtin with 1.67%. Significantly highest *C. medinalis* damage was recorded in the treatment in the untreated control with 8.31%. The present results are in line with the reports of Ravichandra et al. (2014), who observed commercial formulation of azadirachtin reduced the *C. medinalis* damage to 4.34%. Similarly, Sagheer et al. (2008), observed the lowest *C. medinalis* damage with the integration of *Trichogramma chilonis*, azadirachtin and *B. thuringiensis.* Similarly (Rizwan et al., 2019) reported *B. bassiana, L. lecanii* and *M. anisopliae* were effective in controlling *C. medinalis* with 73.33, 57.78, and 74.44% mortality rates in the in vitro assay and 56.67, 41.11 and 52.78% in the greenhouse assay respectively.

The results of effect of entomopathogens and plant-based insecticides for management of *N. nigropictus* indicated that, all the treatments were found non-significant with *N. nigropictus* population ranged from

4.61 to 4.71 hoppers/ hill a day before spray. Fourteen days after first spray, significantly lowest *N. nigropictus* were recorded in the treatment T_4 (Azadirachtin) with 3.68 hoppers/ hill, which was at par with the treatment, T_2 (*M. anisopliae*) 3.73 hoppers/ hill. Remaining treatments recorded *N. nigropictus* population ranged from 3.96 to 4.26 hoppers/ hill. Significantly highest *N. nigropictus* were recorded in T_3 (dipel) and T_7 (control), recorded 4.92 and 5.04 hoppers/ hill, respectively. Similar trend was recorded 14th days after second spray also. Fourteen days after third spray, treatment T_4 (azadirachtin) retained significantly lowest *N. nigropictus* population with 0.70 hoppers/ hill, which was on par with treatment, T_2 (*M. anisopliae*) (0.78 hoppers/ hill). Significantly highest *N. nigropictus* population was found in the treatments, T_3 (dipel) and T_7 (control) with 6.66 and 6.84 hoppers/ hill respectively (Table 5). The readings are in line with the findings of Abdullah et al. (2020) who reported that *M. anisopliae* and *B. bassiana* are most effective in managing leafhoppers.

The results of effect of entomopathogens and plant-based insecticides for management of *N. lugens* indicated that, a day before spray, all the treatments were found non-significant with population ranged from 5.81 to 5.91 hoppers/ hill. Fourteen days after first spray, significantly the lowest *N. lugens* were recorded in the treatment, T_4 (azadirachtin) with 4.88 hoppers/hill, which was at par with the treatment, T_2 (*M. anisopliae*) 4.93 hoppers/ hill, this was followed by treatment, T_6 (brahmastra) (5.16 hoppers/ hill) and T_1 (*B. bassiana*) (5.19 hoppers/hill) (Table 5). Next best treatment was the treatment, T_5 (*L. lecanii)* recorded *N. lugens* population of 5.46 hoppers/ hill. Significantly highest *N. lugens* population were recorded in the treatment T_3 (dipel) and T_7 (control) with 6.12 and 6.24 hoppers/hill respectively. Similar trend was noticed on 14th days after second spray also. Fourteen days after third spray, the treatment, azadirachtin was found significantly superior over other treatments, recorded lowest *N. lugens* population of 1.90 hoppers/ hill, which was on par with treatment, T_2 (*M. anisopliae*) (1.96 hoppers/ hill). Significantly the highest *N. lugens* population was found in T_3 (dipel) and T_7 (control) recorded 7.86 and 8.04 hoppers/ hill respectively (Table 5). The effectiveness of azadirachtin might be due to antifeedant and insecticidal properties against leaf and planthopper of rice as reported by Morakchi et al. (2021). The results are in line with the findings of Li et al. (2014) also reported that *B. bassiana* and *B. brangniartii* caused cumulative mortality of adults of *N. lugens* ranging from 17.2 to 79.1% 10 days after inoculation. Atta et al. (2020) observed *B. bassiana* and

Table 5. Performance of entomopathogens and plant-based insecticides against *N. nigropictus* and *N. lugens*

Treatments	Dosage	*N. nigropictus* (No. of hoppers/ hill)				*N. lugens* (No. of hoppers/ hill)			
		DBS	First spray 14 DAS	Second spray 14 DAS	Third spray 14 DAS	DBS	First spray 14 DAS	Second spray 14 DAS	Third spray 14 DAS
T_1:*Beauveria bassiana*	4.0 g/ l	4.61 (2.26)^a	3.99 (2.12)^b	3.37 (1.97)^b	1.06 (1.25)^b	5.81 (2.51)^a	5.19 (2.39)^b	4.57 (2.25)^b	2.26 (1.66)^b
T_2: *Metarhizium anisopliae*	4.0 g/ l	4.66 (2.27)^a	3.73 (2.06)^a	3.09 (1.89)^a	0.78 (1.13)^a	5.86 (2.50)^a	4.93 (2.23)^a	4.23 (2.17)^a	1.96 (1.56)^a
T_3: Dipel	2.0 ml/ l	4.68 (2.28)^a	4.92 (2.33)^d	5.28 (2.40)^d	6.66 (2.68)^d	5.88 (2.53)^a	6.12 (2.57)^d	6.48 (2.64)^d	7.86 (2.89)^d
T_4: Azadirachtin 3000ppm	3.0 ml/ l	4.71 (2.28)^a	3.68 (2.04)^a	3.01 (1.87)^a	0.70 (1.10)^a	5.91 (2.53)^a	4.88 (2.32)^a	4.21 (2.17)^a	1.9 (1.55)^a
T_5: *Lecanicillium lecanii*	4.0 g/ l	4.63 (2.26)^a	4.26 (2.18)^c	3.67 (2.04)^c	1.36 (1.36)^c	5.83 (2.51)^a	5.46 (2.44)^c	4.87 (2.32)^c	2.56 (1.75)^c
T_6: Brahmastra	30 ml/ l	4.66 (2.27)^a	3.96 (2.11)^b	3.34 (1.96)^b	1.03 (1.24)^b	5.86 (2.52)^a	5.16 (2.38)^b	4.54 (2.24)^b	2.23 (1.65)^b
T_7: Control	---	4.66 (2.27)^a	5.04 (2.35)^d	5.37 (2.42)^d	6.84 (2.71)^d	5.86 (2.50)^a	6.24 (2.60)^d	6.57 (2.66)^d	8.04 (2.92)^d
S. Em (±) CD @ 5%	--	NS	0.01 0.04	0.02 0.06	0.03 0.09	NS	0.01 0.04	0.02 0.06	0.03 0.08

DBS – Days before spray, DAS – Days after spray; Values in parenthesis are √x+0.5 transformed; Means followed by same alphabet in columns did not differ significantly (p=0.05) by DMRT

L. lecanii were caused more than 50.00% mortality of *N. lugens* 14 days after exposure.

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AUTHOR CONTRIBUTION STATEMENT

Basavaraj Kalmath conceptualized and framed the research proposal, Veda murthy conducted the experiment, curated data and prepared original draft. Prabhuraj Aralimarad, Vikas Kulkarni and Rachappa Haveri contributed to the samples, analyzed the results and corrected draft. All authors read and approved the manuscript.

CONFLICT OF INTEREST

No conflict of interest

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