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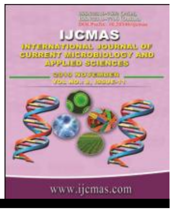

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Effects of Flubendiamide and A Lactic Acid Bacterial Formulation on Stem Borer *Scirpophaga incertulas* Walker and its Parasitoids in Rice

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ABSTRACT

Pesticides are predominantly used to manage rice yellow stem borer (YSB), *Scirpophaga incertulas* Walker, killing both pests and natural enemies. Used as biofertilizers, phytostimulators, rhizoremediators and biopesticides in crop production, lactic acid bacteria (LAB) are likely to reduce the impact of pesticides on natural enemies, if compatible. In this study, an LAB formulation made from milk-powder, cane jaggery and egg was evaluated in combination with flubendiamide against *S. incertulas* and its egg parasitoids (*Tetrastichus schoenobii* Ferriere and *Telenomus* sp.) in replicated field trials and in laboratory. The results indicated that the LAB formulation significantly enhanced not only the efficacy of flubendiamide 20 WG @ 25 or 50 g a.i. ha^{-1}, probably from its adjuvant action, but also the extent of parasitization by the parasitoids, which is discussed.

Keywords

Flubendiamide, Lactic acid bacteria, Yellow stem borer, Egg parasitoids

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Introduction

Primary source of income and employment for more than 200 million households across countries in the developing world (FAO, 2004), rice (*Oryza sativa* L.) is the staple food for nearly half of the world's population, closely associated with food security (FAO, WFP and IFAD, 2012). Limiting its production among insect pests are stem borers and leaf folders (Asghar *et al.*, 2009). Though five species of stem borers occur in India, the yellow stem borer (YSB), *Scirpophaga incertulas* Walker is the most widespread and destructive. The larvae of this monophagous pest bore into the stem and destroy the growing tips by feeding on the internal contents. This in turn disrupts the flow of water and nourishment to the plant, thereby causing 'dead hearts' at the vegetative stage (Jadhao and Khurad, 2012) and 'white ears' at the reproductive stage (Chatterjee and Mondal, 2014), accounting for 50 per cent of all insecticides used in rice targeting them (Huesing and English, 2004). Often farmers apply pesticides just before harvest to avoid injury to crops even as the use of insecticides is considered an essential management practice in rice to ensure the yield potential and grain quality (Silva *et al.*, 2002; Tindall *et al.*, 2005). However, improper and extensive use of pesticides destroys natural enemies, causes resurgence, and results in pesticide residues in food (Jiries *et al.*, 2002; Yu and Zhou, 2005). For instance, the Hymenopteran parasitoids, *Telenomus dignus* (Gahan) (Scelionidae), *Tetrastichus schoenobii* Ferriere (Eulophidae) and *Trichogramma japonicum* Ashmead (Trichogrammatidae) are three important YSB egg parasitoids, which play a pivotal role in YSB population regulation (Rama Gopala Varma *et al.*, 2013). They need to be conserved as well. Generally regarded as safe (GRAS) food-grade microorganisms, the probiotic lactic acid bacteria (LAB) are used to improve human and animal health (FAO/WHO, 2001). It has been estimated that 25% of the European diet and 60% of the diet in many developing countries consist of fermented foods (Stiles, 1996). LAB associated with fermented foods include species of the genera *Carnobacterium, Enterococcus*, *Lactobacillus*, *Lactococcus, Leuconostoc*, *Oenococcus*, *Pediococcus, Streptococcus, Tetragenococcus, Vagococcus* and *Weissella* (Stiles and Holzapfel, 1997; Beasley, 2004), especially *Lactobacillus, Leuconostoc*, *Pediococcus*, *Lactococcus* and *Streptococcus* (Ouwehand *et al.*, 2002). Their inoculants are safe, easy to apply, and non-corrosive to machine (Filya *et al.*, 2000). They have also been exploited in crop production as biofertilizers, phytostimulators, rhizoremediators and biopesticides (Noumavo *et al.*, 2014; Munees and Kibret, 2014). Some LAB species act as silage additives, improving the silage fermentation process (Yunus *et al.*, 2000; Kuikui *et al.*, 2015). They even are capable of degrading pesticides (Zhang *et al.*, 2014). Flubendiamide is one of the recommended insecticides against *S. incertulas*. This study was undertaken to lessen the impact of a commercially available formulation of flubendiamide on egg parasitoids of *S. incertulas* by using a home-made preparation of LAB formulation without affecting the efficacy of flubendiamide.

Materials and Methods

Field experiments were conducted at the Paddy Breeding Station of Tamil Nadu Agricultural University (TNAU), Coimbatore, one each during *Kharif* (May, 2018 – August, 2018) and *Rabi* seasons (December, 2018 – April, 2019). There were six treatments replicated four times in a randomized blocks design (RBD) wherein 21-day old rice seedlings (var. Co 51) were transplanted at a spacing of 20×20 cm in 6 x 5 m^2 size plots with 1 m replication border and 0.5 m treatment border between the plots, receiving regular agronomic practices. In a discriminate fermentation process (David *et al.*, 2018), the lactic acid bacterial formulation was prepared by mixing 100 g milk powder and 1.0 kg cane jaggery, 100 ml one-day fermented grape juice and a beaten egg. This semisolid product containing LAB ferments was first diluted in 4 parts of water, left overnight for rapid LAB multiplication, and sprayed at 2.5 % (25 ml per litre of water) the next day. Two rounds of foliar spray were made at 2-week interval, starting at 35 days after transplanting, using a knapsack battery-operated sprayer with 500 litre spray fluid per hectare. The control plots received no spray. The injury caused by *S. incertulas* (dead hearts / white ears) in percentage was recorded from 10 randomly selected hills per plot at 7-day interval post treatment (Heinrichs *et al.*, 1985).

Stem borer egg masses along with leaf bits (5-7 cm) were collected from each plot at weekly interval to record the extent of parasitization in the laboratory. The collected egg masses on leaves were maintained individually in cloth-covered test tubes secured with rubber band (12 mm dia., 5 cm length) under laboratory conditions (34 ^{0}C, 80 % RH) until the parasitoids and/or the host larvae emerged out from the egg masses (Manju *et al.*, 2002).

The test tubes were kept in trays with 2.5 cm water to maintain the moisture content and they were regularly monitored for the emergence of egg parasitoids and the species. The emerged parasitoids and the stem borer larvae were counted under a low power stereo zoom microscope.

Ten days later, the egg masses were dissected to count the unemerged parasitoid adults, pupae and unhatched yellow stem borer larvae (YSB larva) and included in the totals while analyzing the data. The percent parasitization was calculated using the formula of Reuolin and Soundararajan (2017).

$$\text{Parasitization \%} = \frac{\text{Number of parasitoids emerged}}{\text{Number of parasitoids emerged} + \text{SB larvae hatched} + \text{unhatched eggs}} \times 100$$

The data thus obtained from all the observations were subjected to appropriate statistical analysis after suitable transformations.

Results and Discussion

S. incertulas caused dead heart

In both seasons, the extent of dead hearts caused by *S. incertulas* differed significantly among the treatments (Table 1 - 3). Pooled analysis of the two-season data indicated that the dead heart damage was significantly lower in all sprayed plots than in untreated control plots (Table 3). Among the treatments, the injury was significantly lowest in plots where flubendiamide 20 WG @ 50 g a.i. ha^{-1} + LAB was sprayed (2.44%), followed by flubendiamide 20 WG @ 50 g a.i. ha^{-1} (3.74%), flubendiamide 20 WG @ 25 g a.i. ha^{-1} + LAB (4.1%), and flubendiamide 20 WG @ 25 g a.i. ha^{-1} (5.63%) The damage was also significantly lower in LAB-sprayed plots (14.22 %) than in control plots (18.61 %) but higher than that in other plots. Season wise too, flubendiamide 20 WG @ 50 g a.i. ha^{-1} + LAB was the most effective treatment (1.95 – 2.93 %), followed by flubendiamide 20 WG @ 50 g a.i. ha^{-1} (3.19 – 4.29 %), flubendiamide 20 WG @ 25 g a.i. ha^{-1} + LAB (3.59 – 4.6%), and flubendiamide 20 WG @ 25 g a.i. ha^{-1} (4.78 – 6.48 %) (Table 1 and 2). Though effective, LAB, when sprayed alone, was inferior to flubendiamide in combination with or without LAB (13.32 – 15.11 %). Compared to the level of dead heart in control plots, flubendiamide 20 WG @ 50 g a.i. ha^{-1} + LAB reduced the dead heart damage by 85.19 – 88.77 per cent, flubendiamide 20 WG @ 50 g a.i. ha^{-1} by 78.34 - 81.66 per cent, flubendiamide 20 WG @ 25 g a.i. ha^{-1} + LAB by 76.78 – 79.38 per cent, flubendiamide 20 WG @ 25 g a.i. ha^{-1} 67.31 – 72.52 per cent, and LAB by 23.47 – 23.74 per cent (Fig. 1). Pooled analysis of the data from the two seasons also indicated that flubendiamide 20 WG @ 50 g a.i. ha^{-1} + LAB reduced the injury by 86.87 per cent, followed by flubendiamide 20 WG @ 50 g a.i. ha^{-1} by 79.9 %, flubendiamide 20 WG @ 25 g a.i. ha^{-1} + LAB by 78 per cent, flubendiamide 20 WG @ 25 g a.i. ha^{-1} by 69.75 per cent, and LAB by 23.61 per cent than in control plots.

S. incertulas caused white ears

Similarly, when compared to the control, white ears due to *S. incertulas* were significantly lower in all plots in both seasons (Table 4) and pooled analysis of the data from the two seasons also indicated that white ear injury was significantly lower in all plots than in control plots (Table 4). Among the treatments, white ears were fewer in plots where flubendiamide 20 WG @ 50 g a.i. ha^{-1} + LAB was sprayed (2.06%), followed by flubendiamide 20 WG @ 25 g a.i. ha^{-1} + LAB (2.90%), on par with flubendiamide 20 WG @ 50 g a.i. ha^{-1} (3.12%), and flubendiamide 20 WG @ 25 g a.i. ha^{-1}(4. 95%) The damage was significantly lower in LAB-sprayed plots (12.71 %) than in control plots (16.26 %) but higher than that in other plots.

Egg parasitoids

Parasitization by the YSB eggs by the parasitoids, especially *Tetrastichus schoenobii* and *Telenomus* sp., (Plate 1) was significantly less on plants in plots sprayed with fluebendiamide with or without LAB than on plants in plots sprayed with LAB alone or no-spray control. In both seasons (Table 5 and 6), parasitization by *T. schoenobii* was significantly minimum in plots treated with flubendiamide 20 WG @ 50 g a.i. ha^{-1} with or without LAB (15.5 – 17.54 % in Season – 1 to 19.0 – 21.63 % in Season – 2), followed by flubendiamide 20 WG @ 25 g a.i. ha^{-1} in mixture with or without LAB (20.67 – 29.76 in Season – 1 to 26.74 – 35.95 % in Season – 2). Parasitization by *T. schoenobii* was significantly highest in plots where LAB was sprayed alone (48.34 % in Season – 1 to 55.82 % in Season – 2), followed by control (37.0 % in Season – 1 to 55.82 % in Season – 2). The pooled analysis of the data from the two seasons also indicated the same results with *T. schoenobii* parasitizing most egg masses when LAB or none is sprayed (39.05 – 52.08 %) than when flubendiamide was sprayed at low or high concentration with or without LAB (17.25 – 32.82 %) (Table 7).

Parasitization by the egg parasitoid, *Telenomus* sp. was also significantly highest on egg masses in LAB-sprayed plots (23.82 % in Season – 1, 25.89 % in Season – 2), followed by on egg masses in control plots (16.90 % in Season – 1, 20.51 % in Season – 2), than in other plots where flubendiamide was sprayed with or without LAB (8.42 – 15.28 % in Season – 1 to 6.70 – 19.15 % in Season – 2) (Table 8 and 9). The pooled two-season data also indicated the same trend in parasitization by *Telenomous* sp., significantly higher after LAB spray (24.85 %) and no-spray control (18.71 %), and significantly lower after flubendiamide sprays with or without LAB (6.93 – 17.21 %) (Table 10 and Fig. 2).

Insecticides are indispensable to manage pests like rice stem borers. However, they need to be safer to the natural enemies. Moreover, they can also be made safer. For instance, flubendiamide 20 WG has been reportedly safe to several natural enemies, including spiders and coccinellids in sugarcane field (Madhu Sudhanan *et al.*, 2017), to mirid predators of tomato pests (Wanumen *et al.*,

2016) and rice pests (Lakshmi *et al.,* 2010), and to the predatory mites under laboratory conditions (Maxime *et al.,* 2011). The results of this investigation highlight that the LAB can make it even safer without decreasing its efficacy. It is well known that flubendiamide 20 WG, one of the new generation diamide group of pesticides, is significantly effective against Lepidopteran pests, especially leaf folder and stem borer in rice. Evaluation of this formulation in this study also revealed that it was significantly more effective at the higher dose 50 g a.i. ha^{-1} dose in reducing the dead hearts caused by *S. incertulas* as high as 78.34 - 81.66 per cent.

A different formulation, flubendiamide 480 SC @ 24 and 30 g a.i./ha has earlier been reported as highly effective against rice leaffolder at various places (Sekh *et al.,* 2007; Prasad *et al.,* 2014; Devi and Singh, 2016; Sandhu and Dhaliwal, 2016; Shyamrao and Raghuraman, 2019). However, flubendiamide 20 WG @ 50 g a.i. ha^{-1} was found even more effective when LAB was mixed with this formulation (85.15 – 88.77 %), indicative of its additive effect. Similarly, at the lower dose of 25 g a.i. ha^{-1}, it reduced the dead hearts by 67.31– 72.55 per cent, while, with LAB, it lowered the damage even higher by 76.78 – 79.38 per cent. The lower dose of flubendiamide 25 WG g a.i. ha^{-1} too, with or without LAB, reduced the dead heart by 69.75– 78 per cent as high as the higer dose 50 g a.i. ha^{-1}, reducing the damage by 79.9 – 86.87 per cent (Fig. 1).

This shows the potential of LAB in increasing the efficacy of flubendiamide by 5.0 – 15.0 per cent, probably because of the adjuvant qualities of the formulation resulting in better wetting, sticking and spreading. LAB is ubiquitous members of many plant microbiomes. One of the LAB, *Lactobacilli* are found in phyllosphere, endosphere and rhizosphere of many plants and ferments containing LAB are exploited in agriculture as biocontrol agents, biofertilizers and biostimulants (Lamont *et al.,* 2017). They are gram positive, facultative anaerobic bacteria often found in substrates rich in carbohydrates which they convert into organic acids. Many species of LAB occur as epiphytics (Harshini Priya, 2016).

Probably, their volatiles are likely to modulate the abundance on plants of insects, pests or natural enemies as microbial volatiles attract or repel insects by eliciting behavioural changes (Davis *et al.,* 2013) and Venu *et al.,* (2014) have demonstrated that volatiles derived from microbes are responsible for long distance attraction of fruit flies to their food sources.

In this investigation, LAB itself has helped reduce the stem borer caused damage by 23.47 – 23.74 %, probably it may cause the plants less attractive to stem borer moths, which needs to be studied in future. On the other hand, parasitism by the egg parasitoids was significantly more in LAB-sprayed plots than in all other plots, including unsprayed control.

For instance, *T. schoenobii* and *Telenomus* sp. had been significantly more active after LAB sprays (17.21 - 32.82 %) than after flubeniamide sprays, alone at both concentrations (11.24 - 23.70 %). Generally, YSB egg masses are parasitized by more than one species of parasitiods, *viz.*, *Trichogramma* spp. + *Telenomus spp* (3.46%), *Telenomus* + *Tetrastichus* (21.06%) and *Trichogramma* + *Tetrastichus* (2.35%), the extent of parasitism ranging from 4.0 % to 97.2 % in different parts of India (Senapati *et al.,* 1999; Chakraborty, 2012). When mixed to flubendiamide, LAB appeared to have reduced flubendiamide toxicity only to these beneficial insects but not to *S. incertulas,* i.e. LAB is safer to natural enemies even when mixed with pesticides like flubendiamide.

Table.1 Effect of flubendiamide 20 WG and LAB on dead hearts due to *S. incertulas* in rice in season – 1

Treatments	**Dead hearts (%)**						**Mean**
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	9.29 (17.75)	7.54 (15.94)	8.42 (16.84)	5.91 (14.07)	3.16 (10.23)	4.53 (12.15)	6.48 (14.50)
Flubendiamide 20 WG @ 50 g a.i. /ha	7.45 (15.84)	5.11 (13.07)	6.28 (14.45)	2.86 (9.74)	1.74 (7.57)	2.30 (8.66)	4.29 (11.55)
Flubendiamide 20 WG @ 25 g a.i. /ha +LAB @ 2.5% /ha	7.96 (16.39)	5.32 (13.34)	6.64 (14.86)	3.14 (10.21)	1.97 (8.07)	2.56 (9.13)	4.60 (12.00)
Flubendiamide 20 WG @ 50 g a.i. /ha +LAB @ 2.5% /ha	6.12 (14.32)	3.57 (10.89)	4.85 (12.61)	1.33 (6.63)	0.71 (4.83)	1.02 (5.73)	2.93 (9.17)
LAB alone @ 2.5% /ha	13.86 (21.86)	14.15 (22.09)	14.00 (21.98)	16.89 (24.27)	15.54 (23.21)	16.21 (23.74)	15.11 (22.86)
Untreated check	15.04 (22.82)	18.63 (25.57)	16.84 (24.19)	21.71 (27.77)	23.85 (29.24)	22.78 (28.51)	19.81 (26.35)
Mean	9.95 (18.16)	9.05 (16.82)	9.50 (17.48)	8.64 (15.45)	7.83 (13.86)	8.23 (14.65)	8.87 (16.07)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are *arc sine* transformed values; mean of four replications)

		SE.d	**CD (P=0.05)**				**SE.d**	**CD (P=0.05)**
Between Treatments	:	0.09	0.19		Treatments x DAS	:	0.13	0.26
Between DAS	:	0.05	0.11		Treatments x Spray	:	0.13	0.26
Between Spray	:	0.05	0.11		Treatments x DAS x Spray	:	0.19	0.37
DAS x Spray	:	0.08	0.15					

Table.2 Effect of flubendiamide 20 WG and LAB on dead hearts due to *S. incertulas* in rice in season – 2

Treatments	**Dead hearts (%)**						**Overall Mean**
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	8.42 (16.86)	4.75 (12.59)	6.58 (14.73)	3.50 (10.79)	2.46 (9.03)	2.98 (9.91)	4.78 (12.32)
Flubendiamide 20 WG @ 50 g a.i. /ha	6.33 (14.57)	3.33 (10.51)	4.83 (12.54)	2.28 (8.69)	0.83 (5.23)	1.56 (6.96)	3.19 (9.75))
Flubendiamide 20 WG @ 25 g a.i. /ha +LAB @ 2.5% /ha	6.85 (15.17)	3.75 (11.17)	5.30 (13.17)	2.49 (9.08)	1.27 (6.47)	1.88 (7.78)	3.59 (10.47)
Flubendiamide 20 WG @ 50 g a.i. /ha +LAB @ 2.5% /ha	4.08 (11.66)	2.51 (9.12)	3.30 (10.39)	0.83 (5.24)	0.39 (3.59)	0.61 (4.42)	1.95 (7.40)
LAB alone @ 2.5% /ha	11.54 (19.86)	13.33 (21.42)	12.44 (20.63)	14.59 (22.46)	13.84 (21.84)	14.21 (22.15)	13.32 (21.39)
Untreated check	13.62 (21.66)	16.96 (24.32)	15.29 (22.98)	18.48 (25.46)	20.59 (26.99)	19.54 (26.22)	17.41 (24.60)
Mean	8.47 (16.63)	7.44 (14.85)	7.96 (15.74)	7.03 (13.62)	7.83 (12.19)	6.80 (12.91)	7.38 (14.32)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are *arc sine* transformed values; mean of four replications)

		SE.d	**CD (P=0.05)**				**SE.d**	**CD (P=0.05)**
Between Treatments	:	0.12	0.25		Treatments x DAS	:	0.17	0.35
Between DAS	:	0.07	0.14		Treatments x Spray	:	0.17	0.35
Between Spray	:	0.07	0.14		Treatments x DAS x Spray	:	0.25	0.49
DAS x Spray	:	0.10	0.20					

Table.3 Effect of flubendiamide 20 WG and LAB on dead hearts due to *S. incertulas* in rice in pooled season 1&2 (pooled)

Treatments	**Mean dead hearts**						**Pooled Mean**
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	8.85 (17.30)	6.15 (14.27)	7.50 (15.79)	4.71 (14.43)	2.81 (9.63)	3.76 (11.03)	5.63 (13.41)
Flubendiamide 20 WG @ 50 g a.i. /ha	6.89 (15.20)	4.22 (11.79)	5.55 (13.49)	2.57 (9.21)	1.28 (6.40)	1.93 (7.80)	3.74 (10.65)
Flubendiamide 20 WG @ 25 g a.i. /ha +LAB @ 2.5% /ha	7.41 (15.78)	4.54 (12.25)	5.97 (14.02)	2.82 (9.64)	1.62 (7.27)	2.22 (8.46)	4.10 (11.24)
Flubendiamide 20 WG @ 50 g a.i. /ha +LAB @ 2.5% /ha	5.10 (12.99)	3.04 (10.00)	4.07 (11.50)	1.08 (5.93)	0.55 (4.21)	0.82 (5.07)	2.44 (8.28)
LAB alone @ 2.5% /ha	12.70 (20.86)	13.74 (21.75)	13.22 (21.30)	15.74 (23.36)	14.69 (22.53)	15.21 (22.94)	14.22 (22.12)
Untreated check	14.33 (22.24)	17.80 (24.94)	16.06 (23.59)	20.10 (26.61)	22.22 (28.11)	21.16 (27.36)	18.61 (25.48)
Mean	9.21 (17.39)	8.25 (15.83)	8.73 (16.61)	7.84 (14.53)	7.20 (13.02)	7.52 (13.78)	8.12 (15.20)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are *arc sine* transformed values; mean of four replications)

		SE.d	**CD (P=0.05)**				**SE.d**	**CD (P=0.05)**
Between Treatments	:	0.08	0.15		Treatments x DAS	:	0.11	0.21
Between DAS	:	0.04	0.09		Treatments x Spray	:	0.11	0.22
Between Spray	:	0.04	0.09		Treatments x DAS x Spray	:	0.15	0.30
DAS x Spray	:	0.06	0.12					

Table.4 Effect of flubendiamide 20 WG and LAB on white ears due to *S. incertulas* in rice in season - 1&2 (pooled)

Treatments	**White ears (%)**		**Pooled mean of white ears (%)**
	1st Spray	2nd Spray	
Flubendiamide 20 WG @ 25 g a.i. /ha	5.02 (12.91)	4.87 (12.72)	4.95 (12.81)
Flubendiamide 20 WG @ 50 g a.i. /ha	3.75 (11.13)	2.49 (8.98)	3.12 (10.05)
Flubendiamide 20 WG @ 25 g a.i. /ha +LAB @ 2.5% /ha	3.26 (10.40)	2.54 (9.05)	2.90 (9.72)
Flubendiamide 20 WG @ 50 g a.i. /ha +LAB @ 2.5% /ha	2.89 (9.71)	1.22 (6.35)	2.06 (8.02
LAB alone @ 2.5% /ha	13.71 (21.73)	11.71 (20.01)	12.71 (20.87)
Untreated check	17.28 (24.56)	15.24 (22.98)	16.26 (23.77)
Mean	7.65 (15.07)	6.35 (13.35)	7.00 (14.21)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are *arc sine* transformed values; mean of four replications)

		SE.d	**CD (P=0.05)**
Between Treatments	:	0.29	0.59
Between Spray	:	0.51	1.03
Treatments x Spray	:	0.72	1.46

Table.5 Effect of flubendiamide 20 WG and LAB on *Tetrastichus schoenobii* in rice in season – 1

Treatments	**Per cent parasitization (%)**						**Overall Mean**
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	16.11 (23.66)	22.56 (28.36)	19.33 (25.84)	16.54 (24.00)	27.46 (31.60)	22.00 (27.79)	20.67 (26.81)
Flubendiamide 20 WG @ 50 g a.i. /ha	11.70 (20.00)	17.10 (24.43)	14.40 (22.06)	12.83 (20.99)	20.35 (26.82)	16.59 (23.87)	15.50 (22.97)
Flubendiamide 20 WG @ 25 g a.i. /ha +LAB @ 2.5% /ha	23.52 (29.01)	30.92 (33.78)	27.22 (31.34)	29.23 (32.73)	35.37 (36.49)	32.30 (34.60)	29.76 (32.97)
Flubendiamide 20 WG @ 50 g a.i. /ha +LAB @ 2.5% /ha	13.80 (21.81)	22.48 (28.30)	18.14 (24.99)	11.91 (20.19)	21.97 (27.95)	16.94 (24.06)	17.54 (24.52)
LAB alone @ 2.5% /ha	39.91 (39.18)	53.08 (46.77)	46.50 (42.97)	48.97 (44.41)	51.38 (45.79)	50.18 (45.10)	48.34 (44.03)
Untreated check	28.43 (32.22)	45.58 (42.46)	37.01 (37.32)	34.54 (35.99)	39.44 (38.90)	36.99 (37.45)	37.00 (37.38)
Mean	22.25 (27.53)	31.95 (33.97)	27.10 (30.75)	25.67 (29.71)	32.66 (34.58)	29.17 (32.15)	28.13 (31.45)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are *arc sine* transformed values; mean of four replications)

		SE.d	**CD (P=0.05)**				**SE.d**	**CD (P=0.05)**
Between Treatments	:	0.83	1.65		Treatments x DAS	:	1.16	2.33
Between DAS	:	0.47	0.95		Treatments x Spray	:	1.17	2.33
Between Spray	:	0.22	0.44		Treatments x DAS x Spray	:	1.65	3.30
DAS x Spray	:	0.67	1.65					

Table.6 Effect of flubendiamide 20 WG and LAB on *T. schoenobii* in rice in season – 2

Treatments	**Per cent parasitization**						**Overall Mean**
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	21.11 (27.35)	27.46 (31.60)	24.28 (29.46)	23.21 (28.80)	35.18 (36.38)	29.20 (32.58)	26.74 (31.02)
Flubendiamide 20 WG @ 50 g a.i. /ha	17.34 (24.61)	23.60 (29.06)	20.47 (26.82)	14.82 (22.64)	20.26 (26.75)	17.54 (24.69)	19.00 (25.76)
Flubendiamide 20 WG @ 25 g a.i. /ha +LAB @ 2.5% /ha	31.12 (33.91)	36.75 (37.32)	33.94 (34.50)	32.24 (34.60)	43.75 (41.41)	38.00 (38.00)	35.97 (36.75)
Flubendiamide 20 WG @ 50 g a.i. /ha +LAB @ 2.5% /ha	19.37 (26.11)	28.69 (32.39)	24.03 (29.25)	15.47 (23.16)	22.97 (28.64)	19.22 (25.85)	21.63 (27.55)
LAB alone @ 2.5% /ha	48.51 (44.15)	60.91 (51.30)	54.71 (47.73)	63.16 (52.63)	50.71 (45.40)	56.93 (49.02)	55.82 (48.37)
Untreated check	32.71 (34.89)	39.57 (38.98)	36.14 (36.92)	47.12 (43.35)	45.02 (42.14)	46.07 (42.75)	41.11 (39.84)
Mean	28.30 (31.79)	36.16 (36.77)	32.23 (34.28)	32.67 (34.18)	36.31 (36.78)	34.49 (35.48)	33.46 (34.88)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are *arc sine* transformed values; mean of four replications)

		SE.d	**CD (P=0.05)**				**SE.d**	**CD (P=0.05)**
Between Treatments	:	0.49	0.98		Treatments x DAS	:	0.69	1.39
Between DAS	:	0.28	0.57		Treatments x Spray	:	0.69	1.39
Between Spray	:	0.28	0.57		Treatments x DAS x Spray	:	0.98	1.96
DAS x Spray	:	0.40	0.80					

Table.7 Effect of flubendiamide 20 WG and LAB on *T. schoenobii* in rice in season – 1&2 (pooled)

Treatments	**Mean Per cent parasitization (%)**						**Pooled Mean**
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	18.61 (25.35)	25.01 (29.95)	21.81 (27.65)	19.88 (26.39)	31.32 (33.98)	25.60 (30.18)	23.70 (28.91)
Flubendiamide 20 WG @ 50 g a.i. /ha	14.52 (22.16)	20.35 (26.72)	17.43 (24.44)	13.83 (21.80)	20.31 (26.77)	17.07 (24.28)	17.25 (24.36)
Flubendiamide 20 WG @ 25 g a.i. /ha +LAB @ 2.5% /ha	27.15 (31.31)	33.83 (35.54)	30.49 (33.42)	30.74 (33.65)	39.56 (38.99)	35.15 (36.30)	32.82 (34.86)
Flubendiamide 20 WG @ 50 g a.i. /ha +LAB @ 2.5% /ha	16.59 (23.96)	25.59 (30.28)	21.09 (27.12)	13.69 (21.63)	22.47 (28.28)	18.08 (24.95)	19.58 (26.04)
LAB alone @ 2.5% /ha	44.20 (41.65)	57.00 (49.04)	50.60 (45.35)	56.07 (48.52)	51.04 (45.60)	53.56 (47.06)	52.08 (46.21)
Untreated check	30.57 (33.54)	42.58 (40.71)	36.57 (37.13)	40.83 (39.67)	42.23 (40.52)	41.53 (40.10)	39.05 (38.61)
Mean	25.27 (29.66)	34.06 (35.37)	29.67 (32.52)	29.17 (31.94)	34.49 (35.68)	31.83 (33.81)	30.75 (33.17)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are *arc sine* transformed values; mean of four replications)

		SE.d	**CD (P=0.05)**				**SE.d**	**CD (P=0.05)**
Between Treatments	:	0.48	0.95		Treatments x DAS	:	0.68	1.34
Between DAS	:	0.28	0.55		Treatments x Spray	:	0.68	1.34
Between Spray	:	0.28	0.55		Treatments x DAS x Spray	:	0.96	1.89
DAS x Spray	:	0.39	0.77					

Table.8 Effect of flubendiamide 20 WG and LAB on *Telenomus* sp in rice in season – 1

Treatments	**Per cent parasitization (%)**						**Overall Mean**
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	6.03 (14.11)	15.27 (22.99)	10.65 (18.55)	8.43 (16.78)	11.62 (19.89)	10.03 (18.34)	10.30 (18.45)
Flubendiamide 20 WG @ 50 g a.i. /ha	3.31 (10.20)	11.74 (20.03)	7.52 (15.11)	5.29 (13.20)	8.34 (16.74)	6.82 (14.97)	7.17 (15.04)
Flubendiamide 20 WG @ 25 g a.i. /ha +LAB @ 2.5% /ha	9.41 (17.83)	19.28 (26.03)	14.34 (21.93)	12.50 (20.68)	19.92 (26.51)	16.21 (23.59)	15.28 (22.76)
Flubendiamide 20 WG @ 50 g a.i. /ha +LAB @ 2.5% /ha	5.67 (13.66)	10.12 (18.54)	7.90 (16.10)	6.20 (14.33)	11.68 (19.96)	8.94 (17.14)	8.42 (16.62)
LAB alone @ 2.5% /ha	19.24 (26.00)	28.91 (32.51)	24.08 (29.26)	20.09 (26.63)	27.04 (31.32)	23.56 (28.97)	23.82 (29.12)
Untreated check	13.91 (21.88)	20.27 (26.76)	17.09 (24.31)	15.22 (22.94)	18.21 (25.24)	16.71 (24.09)	16.90 (24.20)
Mean	9.59 (17.28)	17.60 (24.47)	13.60 (20.88)	11.29 (19.09)	16.13 (23.28)	13.71 (21.19)	13.65 (21.03)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are *arc sine* transformed values; mean of four replications)

		SE.d	**CD (P=0.05)**				**SE.d**	**CD (P=0.05)**
Between Treatments	:	0.50	1.00		Treatments x DAS	:	0.71	1.42
Between DAS	:	0.29	0.58		Treatments x Spray	:	0.71	1.41
Between Spray	:	0.29	0.58		Treatments x DAS x Spray	:	1.00	2.00
DAS x Spray	:	0.41	0.82					

Table.9 Effect of flubendiamide 20 WG and LAB on *Telenomus* sp in rice season – 2

Treatments	**Per cent parasitization (%)**						**Overall Mean**
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	9.48 (17.88)	12.25 (20.45)	10.86 (19.17)	14.66 (22.51)	12.21 (20.42)	13.44 (21.46)	12.15 (20.32)
Flubendiamide 20 WG @ 50 g a.i. /ha	7.35 (15.67)	5.88 (13.99)	6.61 (14.83)	8.39 (16.78)	5.17 (13.10)	6.78 (14.95)	6.70 (14.89)
Flubendiamide 20 WG @ 25 g a.i. /ha +LAB @ 2.5% /ha	15.37 (23.06)	19.23 (25.99)	17.30 (24.52)	22.70 (28.44)	19.29 (26.00)	20.99 (27.82)	19.15 (25.87)
Flubendiamide 20 WG @ 50 g a.i. /ha +LAB @ 2.5% /ha	11.32 (19.66)	7.92 (16.21)	9.62 (17.91)	10.33 (18.70)	10.53 (18.94)	10.43 (18.85)	10.03 (18.36)
LAB alone @ 2.5% /ha	20.86 (27.17)	25.21 (30.12)	23.04 (28.64)	31.42 (34.08)	26.07 (30.69)	28.74 (32.38)	25.89 (30.51)
Untreated check	16.07 (23.63)	22.54 (28.34)	19.31 (25.99)	25.93 (30.60)	17.50 (24.72)	21.71 (27.66)	20.51 (26.83)
Mean	13.41 (21.17)	15.50 (22.52)	14.46 (21.85)	18.90 (25.19)	15.13 (22.31)	17.02 (23.75)	15.74 (22.80)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are *arc sine* transformed values; mean of four replications)

		SE.d	**CD (P=0.05)**				**SE.d**	**CD (P=0.05)**
Between Treatments	:	0.49	0.97		Treatments x DAS	:	0.69	1.37
Between DAS	:	0.28	0.56		Treatments x Spray	:	0.69	1.37
Between Spray	:	0.28	0.56		Treatments x DAS x Spray	:	0.97	1.94
DAS x Spray	:	0.40	0.79					

Table.10 Effect of flubendiamide 20 WG and LAB on *Telenomus* sp in rice season – 1&2 (pooled)

Treatments	**Mean Per cent parasitization (%)**						**Pooled Mean**
	1st Spray			2nd Spray			
	7 DAS	14 DAS	Mean	7 DAS	14 DAS	Mean	
Flubendiamide 20 WG @ 25 g a.i. /ha	7.75 (15.99)	13.76 (21.72)	10.76 (18.86)	11.55 (19.64)	11.92 (20.16)	11.73 (19.90)	11.24 (19.38)
Flubendiamide 20 WG @ 50 g a.i. /ha	5.33 (12.94)	8.81 (17.01)	7.07 (14.97)	6.84 (15.00)	6.75 (14.92)	6.80 (14.96)	6.93 (14.97)
Flubendiamide 20 WG @ 25 g a.i. /ha +LAB @ 2.5% /ha	12.39 (20.44)	19.25 (26.01)	15.82 (23.23)	17.60 (24.56)	19.60 (26.25)	18.60 (25.41)	17.21 (24.32)
Flubendiamide 20 WG @ 50 g a.i. /ha +LAB @ 2.5% /ha	8.49 (16.63)	9.02 (17.38)	8.76 (17.00)	8.27 (16.51)	11.11 (19.45)	9.69 (17.98)	9.22 (17.49)
LAB alone @ 2.5% /ha	20.05 (26.59)	27.06 (31.32)	23.56 (28.93)	25.75 (30.35)	26.55 (31.00)	26.15 (30.68)	24.85 (29.82)
Untreated check	14.99 (22.76)	21.40 (27.54)	18.20 (25.15)	20.5 (26.77)	17.85 (24.98)	19.21 (25.88)	18.71 (25.51)
Mean	11.50 (19.23)	16.55 (23.50)	14.03 (21.36)	15.10 (22.14)	15.63 (22.80)	15.36 (22.47)	14.70 (21.91)

(LAB, lactic acid bacteria; DAS, days after spray; values in parentheses are *arc sine* transformed values; mean of four replications)

		SE.d	**CD (P=0.05)**				**SE.d**	**CD (P=0.05)**
Between Treatments	:	0.35	0.70		Treatments x DAS	:	0.50	0.99
Between DAS	:	0.20	0.40		Treatments x Spray	:	0.50	0.99
Between Spray	:	0.20	0.40		Treatments x DAS x Spray	:	0.71	1.40
DAS x Spray	:	0.29	0.57					

Fig.1 Per cent reduction over control of *S. incertulas* caused dead heart damage. Mean of two season data. T_1, Flubendiamide 20 WG @ 25 g a.i. /ha; T_2, Flubendiamide 20 WG @ 50 g a.i. /ha; T_3, Flubendiamide 20 WG @ 25 g a.i. /ha + LAB @ 2.5%/ha; T_4, Flubendiamide 20 WG @ 50 g a.i. /ha +LAB @ 2.5% /ha; T_5, LAB alone @ 2.5%/ha. Vertical bars indicate the SE

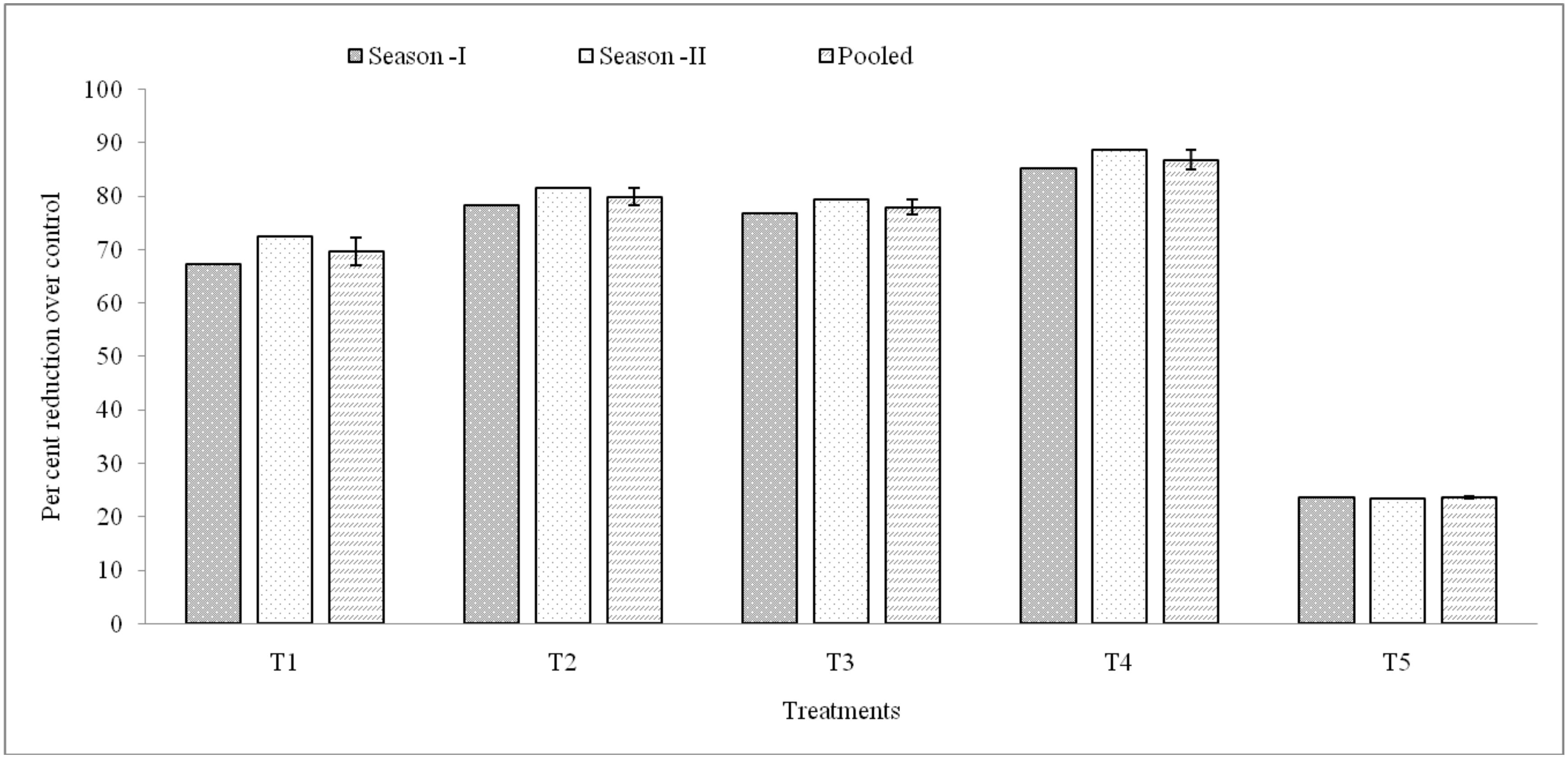

Fig.2 The per cent parasitization of egg parasitoids on *S. incertulas* egg mass. Mean of two season data. T_1, Flubendiamide 20 WG @ 25 g a.i. /ha; T_2, Flubendiamide 20 WG @ 50 g a.i. /ha; T_3, Flubendiamide 20 WG @ 25 g a.i. /ha +LAB @ 2.5% /ha; T_4, Flubendiamide 20 WG @ 50 g a.i. /ha +LAB @ 2.5%/ha; T_5, LAB alone @ 2.5%/ha; T_6, Untreated control. Vertical bars indicate the SE.

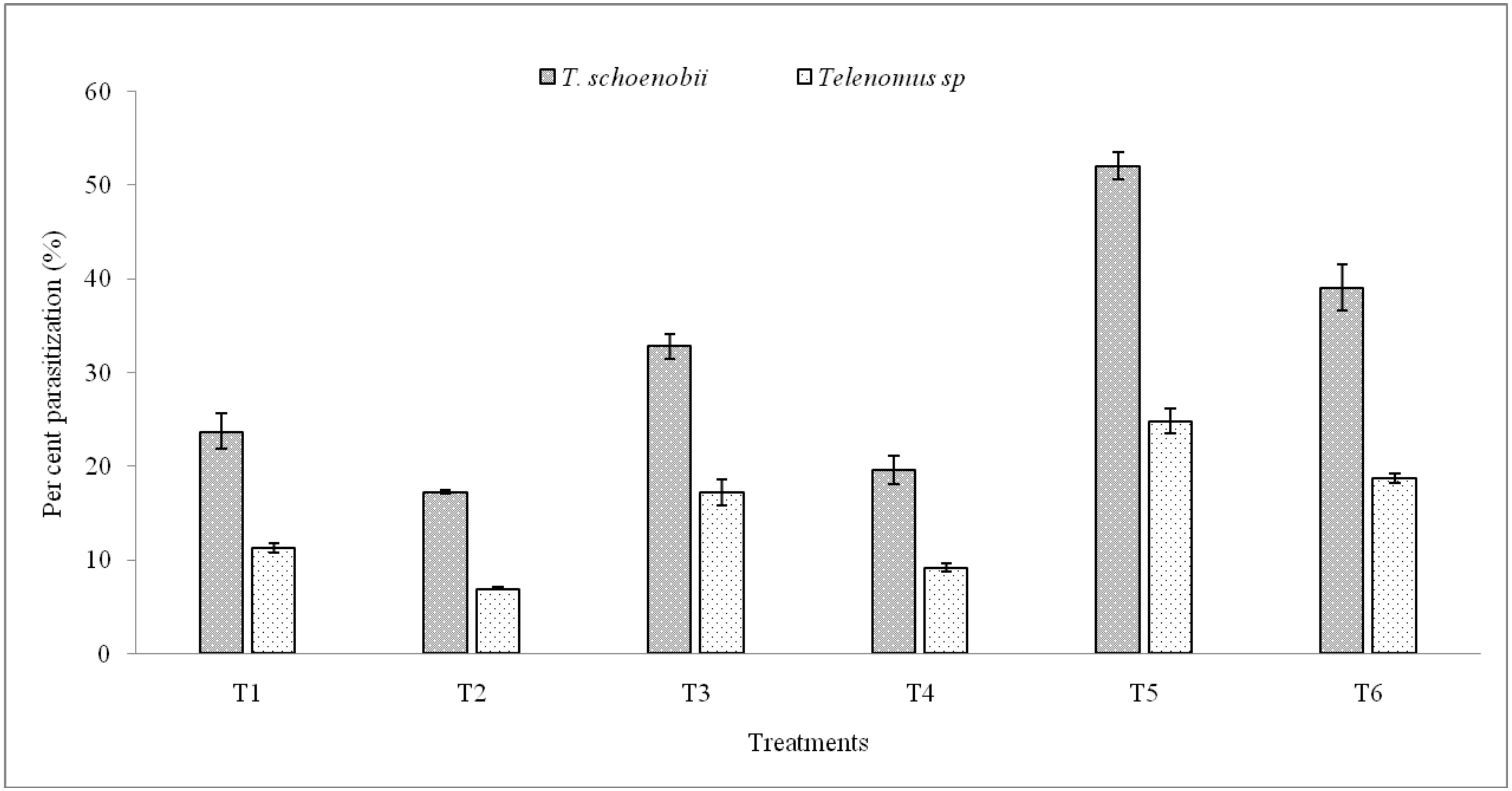

Plate.1 The egg parasitoids of *S. incertulas.*

A. *Tetrastichus schoenobii*

B. *Telenomus* sp

Earlier reports also suggest that flubendiamide was less toxic to beneficial arthropods in rice ecosystem (Tohnishi *et al.*, 2005; Kubendran *et al.*, 2006 and Thilagam *et al.*, 2006). Now it is realized that LAB, especially *Lactobacillus*, are an indispensable component of sustainable agriculture production, controlling pests, attracting the natural enemies, stimulate plant growth and conditioning soils (Paulsen *et al.*, 2009). It may be concluded that *S. incertulas* can be managed more effectively by spraying flubendiamide 20 WG @ 25 or 50 g a.i. ha^{-1} in combination with formulated LAB ferments at 2.5 % which is comparatively safer to egg parasitoids, *T. schoenobii* and *Telenomus*.

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