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Laboratory studies and field evaluation of new generation insecticides against banana pseudostem borer, *Odoiporus longicollis* (Olivier)

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ABSTRACT: Banana pseudostem borer, *Odoiporus longicollis* (Olivier) is a serious pest of banana; especially in India. The pest can cause complete crop destruction in endemic areas where conditions are favorable. Laboratory studies were conducted to evaluate the efficacy of certain new molecules of insecticides *viz.*, chlorantraniliprole, thiamethoxam, emamectin benzoate, indoxacarb and cartap hydrochloride against *O. longicollis* adults and grubs. After 36 hours of treatment with insecticides, thiamethoxam, emamectin benzoate, indoxacarb and cartap hydrochloride recorded complete mortality of grubs while thiamethoxam, emamectin benzoate and cartap hydrochloride recorded the same mortality against adult weevils. Among them, based on the bio efficacy and cost of chemical, two insecticides were selected and tested in banana field. Six different application methods were evaluated in the field and all thiamethoxam application methods except swabbing were on par in giving maximum yield. Laboratory studies and field evaluation studies clearly indicated thiamethoxam 25WDG @0.01% as the best pesticide molecule for management of *O. longicollis* in banana.

Keywords: *Odoiporus*, thiamethoxam, bio-assay, banana, pesticides

INTRODUCTION

Banana, even though it is a profitable fruit crop, its production is threatened by a plethora of pests and diseases including sigatoka leaf spot disease, bunchy top disease, *Fusarium* wilt, *Xanthomonas* wilt, nematodes, weevils and borers and many more with regional significance (Uma, 2007). The banana pseudostem borer, *Odoiporus longicollis* (Olivier) emerged as a major pest of banana and has the potential of causing complete crop failure in farms where efficient pest management is not adopted (Padmanaban and Sathiamoorthy, 2001). The female weevil lays eggs inside the air chamber of the outer sheath of pseudostem; emerging grubs are yellowish white and apodous and feed on leaf sheath and may reach up to peduncle (Padmanaban *et al*., 2001). Grubs pupate inside the pseudostem in a cocoon weaved from banana fiber. Total development period may vary from 40 to 90 days (Anitha, 2000; Thippaiah *et al.,* 2011). Various insecticides have been tested against *O. longicollis*. Earlier, soil treatments with organochlorine insecticides endrin and aldrin was found futile but treatment of infested plants with Celphos tablet @ 0.5 g x3 tablets plant^{-1} could control all stages of the pest inside the stem (Dutt and Maiti, 1972). Phytotoxicity of Celphos was observed when treated during vegetative phase, as death of central immature rolled leaf; nevertheless it could recover within four weeks after treatment. Endosulfan 35EC at 0.1% or carbaryl 50WP at 0.1% spray solution by drenching in the leaf whorls and leaf sheaths from top to lower pseudostem at monthly interval gave effective control of *O. longicollis* infestation (Isahaque, 1978). Studies by Reghunath *et al.* (1992) in Kerala showed that spraying either aldrin (0.1% a.i.) or HCH (0.3% a.i.) was effective in controlling *O. longicollis*. Swabbing of chlorpyrifos (0.05%) at monthly intervals from fourth month after planting until shooting, resulted in complete protection against *O. longicollis*. The same level of control was also obtained with swabbing of carbaryl (0.2%) and injection with chlorpyrifos (0.2%), quinalphos (0.4%) and cypermethrin (200 ppm) (Mathew *et al.*, 1997).

In some of the earlier attempts, different application techniques were also tested using conventional insecticides. Injection of insecticides monocrotophos and dimethoate in 1:5 ratio with water at 60 cm and 150 cm height were found effective against the pest (Justin *et al.,* 2006). Similar observations with monocrotophos were obtained by Irulandi *et al.* (2012). They recorded 96.15% mortality and increased fruit yield with monocrotophos stem injection @ 4 ml plant^{-1}. As many of the conventional organochlorine and organophosphorous insecticides are either being phased out or not preferred owing to their persistent toxicity in the environment, there is a need to explore the new generation insecticides with different modes of action as well as low mammalian toxicity. Present studies were conducted in laboratory and field to check the efficacy of certain new molecules against grubs and adults of *O. longicollis*.

MATERIALS AND METHODS

The bio-efficacy of different chemicals was tested in laboratory at the Department of Agricultural Entomology, College of Agriculture, Vellayani, Thiruvananthapuram during 2013-14. Effective insecticides were further evaluated for their field efficacy using different application methods at banana plot maintained by Instructional Farm, Kerala Agricultural University, Vellayani during 2014-15.

Laboratory studies

Grubs and adults of *O. longicollis* for the experiment were reared on 'Nendran' psueodostem pieces as described by Sivakumar *et al.* (2017). The design followed was completely randomized design (CRD) with three replications. Each replication consisted of ten adults and ten grubs. The experiment was carried out at 27±3^{0}C and 75 to 85% RH. A set of treatment with sterile water acted as control.

Mortality of adults

One week old adult weevils were collected and used for the study. One ml each of the test solutions prepared at the desired concentrations were poured into a nine cm diameter Petri plate and made to dry film. After air drying, five adults were released into each Petri plate. Two such plates served as one replication. A control was also kept using sterile water as dry film. After one hour, banana pseudostem pieces of size 4x4 cm were provided as food.

Mortality of grubs

Third instar grubs were collected from the stock culture and used for the experiment. One ml each of the test solutions prepared in the desired concentration was poured into a nine cm diameter Petri plate and prepared a dry film. Control plate was treated with sterile water. The grubs were allowed to move on the dry film at the rate of two grubs per plate after which they were transferred to pesticide free pseudo stem pieces of 'Nendran' variety.

Mortality of both adults and grubs was observed at 12 hour intervals. The per cent mortality was calculated using Abotts' (1925) formula.

Field evaluation of insecticides using different application methods

Two chemicals which were found to be effective in laboratory studies and were cost effective were selected for field evaluation. Six different application methods for each insecticide as detailed below were tested. Recommended Package of Practices for 'Nendran' banana (KAU, 2016) was followed except pesticide application. Cutting of old leaf and leaf sheaths were followed as cultural control measure in all plants. Five plants were taken as one replication and each treatment was replicated twice under randomised block design (RBD). The treatments (Table-3) were given at fifth and sixth month after planting.

Leaf axil filling was done from outermost leaf axil, all leaf axils except two adjacent leaf axils to the pipe leaf were filled with the test solution. Kwazer Orion® Sprayer with extensible lance was used to apply the solution into the leaf axil. For treating each plant, 200 ml solution was used. The desired concentration of insecticides were prepared in water and mixed with water soluble starch powder @10 g l^{-1} for swabbing on the stem. A four inch hair brush was used to swab the test solution all around the pseudostem from soil level to the base of the existing oldest live leaf axil. Aqueous solutions of insecticides were prepared with liquid starch as sticker @ 5ml l^{-1} and sprayed on the pseudostem from soil level to the base of the existing oldest live leaf axil. Stem injection was carried out using three times the concentration of insecticides and botanicals used for spraying was used for injection. A special injection needle (1.2 mm diameter and 38 mm length) was made with closed tip and holes were made on the needle shaft. This facilitated delivery of injection liquid to different sheaths in pseudostem and prevented clogging of needle holes by fibre. This needle was attached to a 12 ml syringe. A total of 10 ml of solution was injected per plant, at four points @2.5 ml insecticide solution per injection point, diagonally opposite to each other at 60, 90, 120 and 150 cm from the ground level. The needle was inserted into the stem at 30^0 angle to the stem to avoid any possible injury to developing inner core.

Damage on banana by pseudostem borer was recorded according to the damage score index developed by Anitha (2000).

RESULTS

Mortality of adults of *O. logicollis* at different time intervals when treated with different insecticides is given in table 1. On twelve hours after treatment with the chemicals, adult mortality ranged between zero to

100 per cent. Nereistoxin analogue insecticide, cartap hydrochloride 0.05% showed cent percent mortality which was statistically superior to all other treatments followed by emamectin benzoate 0.002% (86.67%) and thiamethoxam 0.01% (43.33%).

One day after the treatment, emamectin benzoate 0.002% recorded 100% mortality as in the case of cartap hydrochloride 0.05%. Mortality of adults treated with thiamethoxam 0.01% increased from 43.33% to 70.00% at 12HAT while indoxacarb 0.01% and chlorantraniliprole 0.0075% treated adults showed no mortality and were alive. Adults treated with thiomethaxam 0.01% showed 100% mortality after thirty six hours of treatment which was on par with cartap hydrochloride 0.05% and emamectin benzoate 0.002%. Chlorantraniliprole 0.0075% treated adults registered mortality only after 36 hours of treatment (36.67%). No further mortality was recorded as time progressed in chlorantraniliprole treated weevils. So at the end of 72HAT, thiamethoxam 0.01%, cartap hydrochloride 0.05% and emamectin benzoate 0.002% treated adults showed same and maximum mortality rate (100 per cent) followed by chlorantraniliprole 0.0075% (36.67%). Adults kept on control and indoxacarb 0.01% did not record any mortality during this period, and significantly differed from all other treatments.

O. longicollis grubs showed higher mortality than adults when treated with same insecticides as depicted in table 2. Immediate maximum mortality (86.67%) was registered with emamectin benzoate 0.002% followed by cartap hydrochloride 0.05% (83.33%), indoxacarb 0.01% (66.67%) and thiamethoxam 0.01% (43.33%). All treatments except chlorantraniliprole 0.0075% which didn't record any mortality differed significantly from control on 12HAT. A day after treatment, emamectin benzoate and thiamethoxam yielded maximum mortality (100%) that was statistically on par with cartap hydrochloride (93.33%). Test insecticides, excluding chlorantraniliprole recorded complete mortality after two days of treatment and drastically differed from control. The same trend was continued till 72HAT.

Yield data (Table 3.) analysis revealed that maximum yield was obtained from plants treated with thiamethoxam 0.01% leaf axil filling (LAF). Combination of methods such as spraying and LAF found having a synergistic effect. Statistically eight methods were equally good in yield. All application methods of thiamethoxam expect swabbing alone were equally effective.

DISCUSSION

The insecticides *viz.*, thiamethoxam 0.01%, indoxacarb 0.01%, emamectin benzoate 0.002% and cartap hydrochloride 0.05% registered 100.00% mortality of *O. longicollis* grubs at 36 HAT, while thiamethoxam 0.01%, cartap hydrochloride 0.05%, and emamectin benzoate 0.002% were equally effective in causing 100.00% adult mortality at 36 HAT. Thiamethoxam, emamectin benzoate and cartap hydrochloride were found equally effective against damaging stages of *O. longicollis* at 0.01, 0.002 and 0.1%, respectively. All these chemicals have different modes of action. Thiamethoxam act as agonist to nicotinic acetylcholine receptor site, emamectin benzoate activates chloride channels in nerve cells and nereis toxin analogue, cartap hydrochloride blocks the nicotinic acetylcholine receptor on the nerve cells. Indoxacarb blocks voltage dependent sodium channel in neurons and chlorantraniliprole acts at rynodine receptors located in muscle tissue (IRAC, 2015). This difference in action sites may be attributed to the variation in inducing mortality both in adults and grubs. The economic advantages as well as effectiveness of thiamethoxam against *O. longicollis* proved in this study are in corroboration with laboratory and field studies conducted on other insects and crops with thiamethoxam (Maienfisch *et al*., 2001a; Vastrad, 2003; Karibasavaraja *et al*., 2005; Sujay *et al*., 2013 and Patel *et al*., 2016). Efficacy of emamectin benzoate under laboratory conditions on borer pests of vegetables has been already reported Vijayasree, 2013). As thiamethoxam 0.01% proved effective against both grubs and adults of *O. longicollis in vitro* and economically viable, it was chosen as best insecticide against *O. longicollis*. Cartap hydrochloride 0.05% also showed its efficacy against the pest and stood second in cost incurred. So both these chemicals were selected for the field evaluation against *O. longicollis.*

Calculating the cost of required chemicals showed that thiamethoxam 0.01% had advantageous over other chemicals. Thiamethoxam 0.01% was more cost effective (Rs. 16 for making 10 l of spray solution) when compared to cartap hydrochloride 0.05% and emamectin benzoate 0.002%. The insecticides cartap hydrochloride 0.05% and emamectin benzoate 0.002% incurred a cost of 11.55 and 46.20 rupees, respectively. Considering the mammalian toxicity, thiamethoxam has low mammalian toxicity (Maienfisch *et al*., 2001b) when compared to other insecticides in the study. All except thiamethoxam have yellow label and coming under toxic category of insecticides. Blue label of thiamethoxam makes it fit for a good choice against *O. longicollis* with low toxic effects on man and environment. Indoxacarb showed distinguished difference in effecting mortality in adults and grubs. Cent per cent mortality of grubs with indoxacarb was recorded at 36 HAT whereas no mortality

Table 1. Effect of new generation insecticides on *O. longicollis* adults under laboratory conditions

Treatment	Concentration (%)	Mortality of weevils (%)					
		12 HAT	24 HAT	36HAT	48 HAT	60 HAT	72 HAT
Chlorantraniliprole 0.0075%	0.0075	0.0 (0.91)	0.0 (0.91)	36.67 (36.15)	36.67 (36.15)	36.67 (36.15)	36.67 (36.15)
Thiamethoxam 0.01%	0.01	43.33 (41.15)	70.0 (56.99)	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)
Indoxacarb 0.01%	0.01	0.0 (0.91)	0.0 (0.91)	0.0 (0.91)	0.0 (0.91)	0.0 (0.91)	0.0 (0.91)
Cartap hydrochloride 0.05%	0.05	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)
Emamectin benzoate 0.002%	0.002	86.67 (68.85)	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)	100.00 (89.09)
Control	0.0	0.0 (0.91)	0.0 (0.91)	0.0 (0.91)	0.0 (0.91)	0.0 (0.91)	0.0 (0.91)
CD(p = 0.05)		4.183	4.609	11.908	11.908	11.908	12.529

Figures in parenthesis are arc sine transformed values HAT- Hours after treatment

Table 2. Effect of new generation insecticides on *O. longicollis* grubs under laboratory conditions

Treatment	Mortality of grubs (%)					
	12 HAT	24 HAT	36HAT	48 HAT	60 HAT	72 HAT
Chlorantraniliprole 0.0075%	0.0 [d] (0.909)	0.0 [c] (0.909)	6.67 [b] (12.599)	6.67 [b] (12.599)	6.67 [b] (12.599)	10.0 [b] (15.309)
Thiamethoxam 0.01%	43.33 [c] (41.073)	100.0 [a] (89.090)	100.0 [a] (89.090)	100.0 [a] (89.090)	100.0 [a] (89.090)	100.0 [a] (89.090)
Indoxacarb 0.01%	66.67 [b] (54.996)	83.33 [b] (66.149)	100.0 [a] (89.090)	100.0 [a] (89.090)	100.0 [a] (89.090)	100.0 [a] (89.090)
Cartap hydrochloride 0.05%	83.33 [a] (66.149)	93.33 [a] (80.540)	100.0 [a] (89.090)	100.0 [a] (89.090)	100.0 [a] (89.090)	100.0 [a] (89.090)
Emamectin benzoate 0.002%	86.67 [a] (68.85)	100.0 [a] (89.090)	100.0 [a] (89.090)	100.0 [a] (89.090)	100.0 [a] (89.090)	100.0 [a] (89.090)
Control	0.0 [d] (0.909)	0.0 [c] (0.909)	0.0 [c] (0.909)	0.0 [c] (0.909)	0.0 [c] (0.909)	0.0 [c] (0.909)
CD (p=0.05)	9.662	11.283	7.357	7.357	7.357	9.526

Figures in parenthesis are arc sine transformed values HAT- Hours after treatment

Table 3. Effect of different application methods of insecticides on yield under field conditions conditions

Treatment	Yield (kg $plant^{-1}$)
T_1 Thiamethoxam 0.01% swabbing at 5&6MAP	7.38
T_2 Thiamethoxam 0.01% leaf axil filling at 5&6MAP	10.98
T_3 Thiamethoxam 0.03% stem injection at 5&6MAP	8.85
T_4 Thiamethoxam 0.01% spraying at 5&6MAP	10.88
T_5 Thiamethoxam 0.01% swabbing at 5MAP + leaf axil filling at 6MAP	10.83
T_6 Thiamethoxam 0.01% spraying at 5MAP + leaf axil filling at 6MAP	10.85
T_7 Cartap hydrochloride 0.05% swabbing at 5&6MAP	7.75
T_8 Cartap hydrochloride 0.05% leaf axil filling at 5&6MAP	9.70
T_9 Cartap hydrochloride 0.15% stem injection at 5&6MAP	8.18
T_{10} Cartap hydrochloride 0.05% spraying at 5&6MAP	7.70
T_{11} Cartap hydrochloride 0.05% swabbing at 5MAP + leaf axil filling at 6MAP	9.23
T_{12} Cartap hydrochloride 0.05% spraying at 5MAP + leaf axil filling at 6MAP	10.50
T_{13} Control	1.70
CD(p = 0.05)	2.293

MAP= Months After Planting

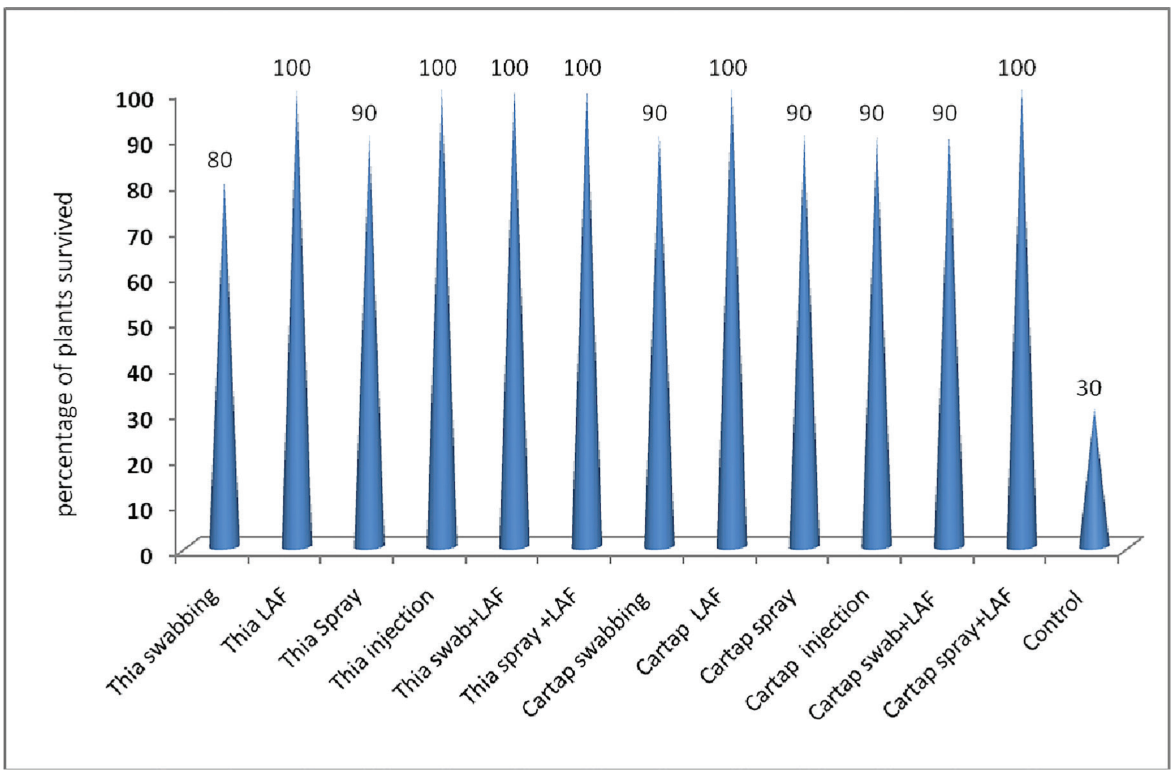

Fig. 1. Survival per cent of weevil with different treatments

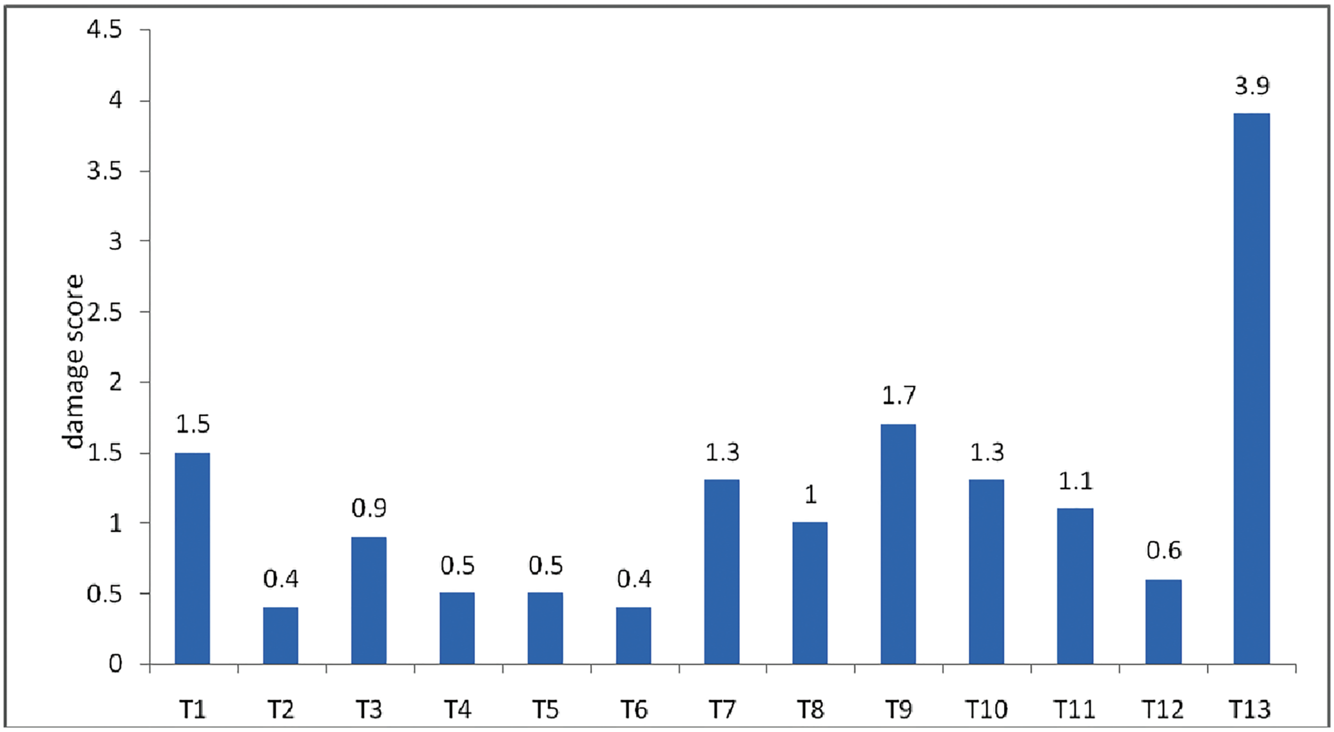

Fig. 2. Damage score of plants under different treatment

recorded on adults even after 72 HAT. Indoxacarb is a broad spectrum insecticide acting as sodium channel blockers in nerve cells. Indoxacarb is a pro insecticide and the rate of bio-activation may differ in different species or life stages as proposed (Gour and Sridevi, 2012) may be the reason. Chlorantraniliprole 0.0075% which was effective against lepidopteran larvae found causing only 10% mortality of *O. longicollis* grubs. This indicated the difference in action of chlorantraniliprole on coleopteran grubs. Earlier studies also showed less effectiveness of chlorantraniliprole on coleopteran grubs (Reding and Persad (2009); Hoffmaan *et al*., 2009 and Karar *et al*. 2017).

Thiamethoxam, being a systemic insecticide, was more effective than cartap hydrochloride in field application. Spraying + LAF of cartap hydrochloride 0.05% yielded maximum among the different application methods of cartap hydrochloride. Swabbing on the outer sheath didn't offer much pest effectiveness for both thiamethoxam and cartap hydrochloride. This may be due to the non persistence of chemical on the highly hydrophobic outer sheath and non absorption of chemical through this layer. Dead adult weevils were collected from outer sheaths of LAF of thiamethoxam and cartap hydrochloride. LAF with thiamethoxam 0.01% offered protection by both contact as well as systemic action. It caused death of adult weevils hiding in between leaf sheaths and young grubs feeding inside the leaf sheath. Thiamethoxam was effective against other coleopteran pests under different eco systems (Maienfisch *et al.* 2001).

The survival percentage of plants received various treatments in field also supported the yield data. The treatments T2, T4, T5, T6, T8 and T12 had 100% survival rate of plants (Fig. 1). Treatments involving application of thiamethoxam once or twice as leaf axil filling @0.01% and injection @ 0.03% recorded maximum survival. Among the different treatments with cartap hydrochloride, leaf axil filling at five and six months after planting and spraying at five month after planting followed by leaf axil filling at six month recorded 100 % survival of plants. Survival percentage of all treatments was higher than that of control plants (30%). Damage score was the lowest for thiamethoxam application methods, except swabbing (Fig. 2). Lowest index indicated the minimum pest infestation on the plants.

Cartap hydrochloride 0.05%, emamectin benzoate 0.002% and thiamethoxam 0.01% were found effective against adults and grubs of *O. longicollis* in the laboratory studies. Further studies on various application methods of thiamethoxam and cartap hydrochloride revealed the field effectiveness of thiamethoxam 0.01% leaf axil filling at five and six months after planting. Apart from the bio efficacy of thiamethoxam against potential damaging stages of *O. longicollis*, it was found cost effective as well as safe to persons applying the chemical.

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