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EVALUATION OF SELECTED INSECTICIDES AS SEED PROTECTANTS AGAINST THE MAIZE WEEVIL (*Sitophilus zeamais* M.)

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ABSTRACT: An investigation was carried out to evaluate the relative toxicity of selected newer insecticides *viz*., deltamethrin, spinosad, abamectin and emamectin benzoate in comparision with the organophosporus insecticide malathion to the maize weevil, *Sitophilus zeamais* Motschulsky, in an attempt to find out a safer and effective seed protectant. The LC_{50} values based on bioassay studies indicated that among the test insecticides, deltamethrin exhibited greater toxicity both at 24 and 48 hours of exposure. The relative toxicity of deltamethrin, abamectin, spinosad, and emamectin benzoate were 1.06, 1.005, 0.07 and 0.01 at 24 hours and 1.18, 1.08, 0.11 and 0.02 at 48 hours of exposure compared to check malathion.

Keywords: Maize**,** *Sitophilus zeamais***,** relative toxicity, seed protectants

INTRODUCTION

Maize (*Zea mays* L.) one of the most important cereal crops of India is subjected to both quantitative and qualitative losses due to infestation by a number of insect species in field as well as in storage. In India, maize occupies third position next to rice and wheat with an area of 7.89 m ha under cultivation producing 15.09 mt, with an average productivity of 1904 kg ha^{-1} (CMIE, 2010). Of late, the importance of maize has rapidly increased as maize is being used as food and fuel for human beings, feed for livestock, poultry and as an industrial raw material. Hence, keeping in mind the future demand of maize, it is very essential to achieve sustainable production and to preserve the produce for increasing future needs. There are some major threats to the harvested produce from stored grain pests like *Sitophilus oryzae* Linnaeus, *Sitophilus zeamais* Motschulsky, *Tribolium castaneum* Herbst and *Rhyzopertha dominica* Fabricius *etc*. Among these pests, maize weevil**,** *S. zeamais* (Motschulsky) is one of the major pests in field and storage. The maize weevil causes extensive damage to maize in storage, especially in tropical and subtropical regions (Throne, 1994), causing serious losses to many poor farmers who store grains on farm for use as food and seed without any chemical protectants. The huge post harvest losses and quality deterioration caused by this pest is a major obstacle for achieving food security in developing countries (Rouanet, 1992). Initial infestations of maize grain occur in the field just before harvest and insect pests are carried to the store where the population builds up rapidly (Adedire and Lajide, 2003).

Damage to grain caused by this weevil includes reduction in nutritional value, germination, weight and commercial value (Yuya *et al*., 2009). Therefore, considering the extent of losses caused by the maize weevil, the present investigation has been undertaken to assess relative toxicity of various seed protectants, to identify an effective and safer seed protectant against the maize weevil, *Sitophilus zeamais.*

MATERIALS AND METHODS

The culture required was obtained from Agriculture Research Station, Rajendranagar and the experiment was conducted at Department of Entomology, Hyderabad. The study on relative toxicity of test insecticides was carried out by dry film residue method. In this method 1ml of test solution of a concentration was taken and spread uniformly to the bottom and lid of petriplate in a thin layer. The petriplate was allowed to dry at room temperature and then 10 adult insects were released into the petriplate. Similarly the procedure was repeated for all concentrations and for all insecticides. Initially mortality was assessed for a wide range of concentrations for each insecticide and on its basis, narrow range was selected.

Table 1.List of particulars of seed protectants

S.No.	Name of seed protectant	Trade name	Concentration
1	Deltamethrin 2.8EC	Decis	1ppm
2	Emamectin benzoate- 5SP	Missile	2ppm
3	Spinosad - 45SC	Tracer	2ppm
4	Abamectin -1.9EC	Dynamite	2ppm
5	Malathion -50EC	Hilmala	0.05%

Mortality was assessed after 24 and 48 hours and the LC_{50} values were calculated by Probit analysis method. The mortality count of insects in three replications of each concentration was recorded and the average per cent mortality in each concentration was calculated. The per cent mortality in the control, if any, was corrected using Abbot's formula (1925).

$$\text{Corrected Mortality (\%)} = \frac{\text{Test mortality (\%)} - \text{Control mortality (\%)}}{100 - \text{Control mortality (\%)}} \times 100$$

The dose mortality regressions were computed by Probit analysis (Finney, 1971) using Biostat 2009 (5.8.00 version) software. The relative toxicity of test insecticides was calculated by taking malathion as standard check.

$$\text{Relative toxicity of newer insecticides} = \frac{LC_{50}\text{ of malathion (check)}}{LC_{50}\text{ of newer insecticide}}$$

RESULTS AND DISCUSSION

24 hours after exposure

The results of mortality response and relative toxicity of selected novel test insecticides *viz*., deltamethrin, emamectin benzoate, spinosad, abamectin and the check malathion against *S. zeamais* (Table 2 and 3) reveal highest mortality (90.00%) for deltamethrin at 20 ppm and emamectin benzoate at 5000 ppm concentration. Mortality of 100.00 per cent was observed for spinosad at 700 ppm concentration and 90.00 per cent for abamectin at 22.5 and malathion at 16 ppm concentration.

Comparing the toxicity of all insecticides, it was evident that all insecticides were toxic to maize weevil, *S. zeamais* adults. The LC_{50} values after 24 hours period of exposure revealed that deltamethrin had low LC_{50} value of 6.85 followed by abamectin (7.26) and malathion (7.30) indicating their high toxicity. Emamectin benzoate has 404.60 followed by spinosad with 100.12 as LC_{50} values that were found less toxic. Similar observation was made by Kljajic *et al*. (2004) recording high toxicity of deltamethrin to maize weevil. The calculated χ^2 values in all the insecticides tested were less than that of table value (12.592) suggesting that the adult population was homogeneous.

Table 2. Mortality response of selected novel insecticides against *Sitophilus zeamais* 24 hrs after exposure

Deltamethrin		Emamectin benzoate		Spinosad		Abamectin		Malathion	
Concentration (ppm)	% Mortality	Concentration (ppm)	% Mortality	Concentration (ppm)	% Mortality	Concentration (ppm)	% Mortality	Concentration (ppm)	% Mortality
3.5	20	70	**30**	**10**	**13.33**	**5**	**36.66**	**6**	**33.33**
4.5	33.33	100	**33.33**	**30**	**20**	**7.5**	**53.33**	**7**	**50**
6.5	43.33	300	**36.66**	**50**	**23.33**	**10**	**63.33**	**8**	**60**
7.5	56.66	500	**40**	**70**	**30**	**12.5**	**66.66**	**9**	**63.33**
10	70	700	**56.66**	**100**	**43.33**	**15**	**70**	**10**	**70**
15	80	1000	**70**	**300**	**70**	**17.5**	**76.66**	**12**	**73.33**
17.5	86.66	3000	**80**	**500**	**96.66**	**20**	**80**	**14**	**83.33**
20	90	5000	**90**	**700**	**100**	**22.5**	**90**	**16**	**90**
control	0	control	**0**	**control**	**0**	**control**	**0**	**control**	**0**

Table 3.Relative toxicity of selected novel insecticides against *Sitophilus zeamais* 24 hrs after exposure

Insecticide	Heterogeneity ($\chi 2$)	Regression Equation	LC_{50} (ppm) [95 % FL]	Relative toxicity	Order of toxicity	LC_{90} (ppm) [95 % FL]	Slope ± SE (b)
Deltamethrin	0.276	Y = 2.727 + 2.719 x	6.85 (7.9536-5.7422)	1.06	1	20.29	2.719 ± 0.036
Emamectin benzoate	2.545	Y = 2.536 + 0.945x	404.6 (611.5056-252.9939)	0.01	5	9187.64	0.945 ± 0.097
Spinosad	7.904	Y = 1.562 + 1.718x	100.12 (170.4283-58.5609)	0.07	4	557.67	1.718 ± 0.094
Abamectin	0.271	Y = 3.225 + 2.060x	7.26 (8.9674-6.0805)	1.005	2	30.4	2.060 ± 0.067
Malathion	0.423	Y = 1.934 + 3.551x	7.3 (8.224-6.0212)	1	3	16.76	3.551 ± 0.034

With respect to LC_{50} values, the relative toxicity of these insecticides were arranged in the following order: deltamethrin (1.06) > abamectin (1.005) > malathion (1.00) > spinosad (0.07) > emamectin benzoate (0.01) after taking the toxicity of the check malathion as unity (Figure1). The LC_{90} value of the insecticides *viz*., deltamethrin, emamectin benzoate, spinosad, abamectin and malathion were 20.290, 9187.64, 557.67, 30.40 and 16.76 ppm, respectively.

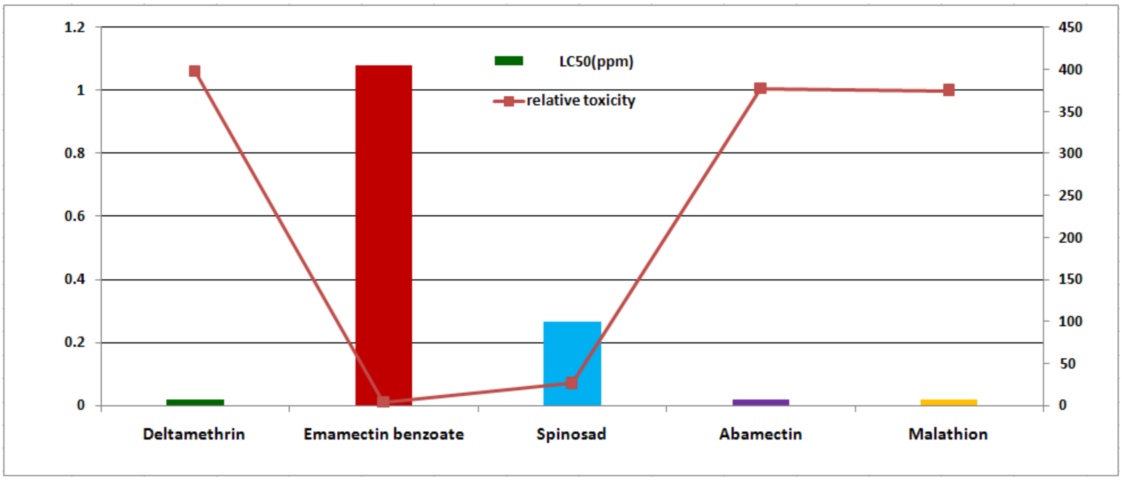

Figure 1. Relative toxicity of test insecticides against *Sitophilus zeamais* 24 hrs after exposure

The results revealed that deltamethrin had the maximum toxicity against *S. zeamais* ($LC_{50} =$ 6.85 ppm) at 24 hrs after exposure. These results corroborate the previous reports wherein deltamethrin was more toxic (0.687 ppm) against *S. zeamais* that has exhibited superior toxicity over malathion (Pathak and Jha, 1999). Rao and Rao (1988) determined the toxicity of deltamethrin and malathion to adults of *S. oryzae* on maize seed and found their LC_{50} values to be 0.0055258 and 0.00691313 respectively.

Subsequently, abamectin, a novel insecticide belonging to avermectin group was found highly toxic against the test insect with LC_{50} value of 7.26ppm. Abamectin, a member of avermectin class of compounds is a potent broad spectrum acaricide and narrow spectrum insecticide, although abamectin has shown differential toxicity to lepidopterans (Lasota and Dybas, 1991). Malathion was the next best chemical in reducing *S. zeamais* population. In contrast to our findings, malathion was reported to be less effective against *S. zeamais* by Pathak and Jha (1999) with LC_{50} value of 4.913 ppm. The reason underlying might be its comparison with new insecticides like spinosad and emamectin benzoate in the present study.

The efficacy of spinosad in the present investigation was in tune with the findings of Subramanyam *et al.* (2006) who reported mortality of more than 98% within 12 days when seed was treated with spinosad @ 1 or 2 mg/kg. As spinosad was toxic to insects by ingestion or contact, and its action on the insect nervous system was at the nicotinic acetylcholine and gamma-aminobutyric acid (GABA) receptor sites (Sparks *et al.,* 2001), it might need maximum time to cause 50 per cent mortality. Emamectin benzoate was found less effective with high LC_{50} value of 404.60 ppm by recording lower reduction of *S. zeamais.* Kelly *et al.* (1996) reported that emamectin benzoate was taken up by the insects via ingestion and contact, albeit ingestion was the primary route of intoxication that needed much exposure period. This was further confirmed by Lasota *et al*. (1996) who recorded greater emamectin toxicity in ingestion versus residual contact bioassay method.

48 hours after exposure

The adult mortality increased marginally at 48 hrs after exposure. Deltamethrin and spinosad exhibited 100.00 per cent mortality at concentrations of 20 and 700 ppm respectively. Mortality of 96.66 per cent was observed in abamectin and malathion at 22.5 and 16 ppm concentrations respectively and 93.33 per cent at 5000 ppm in emamectin benzoate (Table 4). The LC_{50} values were 5.35, 225.75, 55.46, 5.85 and 6.33 ppm for deltamethrin, emamectin benzoate, spinosad, abamectin and malathion, respectively. Deltamethrin exhibited highest toxicity followed by abamectin (Figure 2).

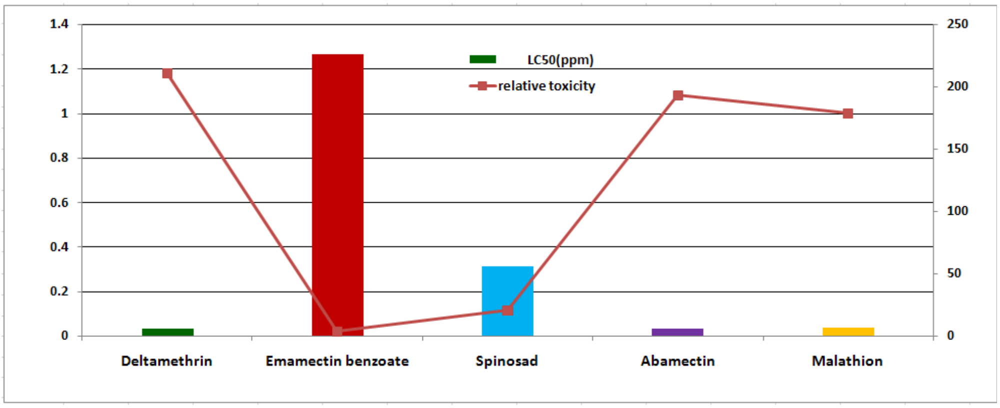

Figure 2. Relative toxicity of test insecticides against *Sitophilus zeamais* 48 hrs after exposure

Table 4. Mortality response of selected novel insecticides against *Sitophilus zeamais* 24 hrs after exposure

Deltamethrin		Emamectin benzoate		Spinosad		Abamectin		Malathion	
Concentration (ppm)	% Mortality	Concentration (ppm)	% Mortality	Concentration (ppm)	% Mortality	Concentration (ppm)	% Mortality	Concentration (ppm)	% Mortality
3.5	33.33	70	36.66	10	23.33	5	50	6	46.66
4.5	46.66	100	40	30	33.33	7.5	60	7	60
6.5	53.33	300	43.33	50	40	10	66.66	8	66.66
7.5	66.66	500	56.66	70	43.33	12.5	70	9	70
10	70	700	70	100	63.33	15	76.66	10	76.66
15	83.33	1000	76.66	300	83.33	17.5	83.33	12	83.33
20	100	5000	93.33	700	100	22.5	96.66	16	96.66
control	0	control	0	control	0	control	0	control	0

The relative toxicity values were 1.18, 0.02, 0.11, 1.08 and 1.00 for deltamethrin, emamectin benzoate, spinosad, abamectin and malathion respectively, (Table 5). The data clearly indicates the superior performance of deltamethrin over others. The calculated χ^2 values indicated that the adult population used in this study was homogenous.On the basis of LC_{90} values, the order of toxicity of the insecticides remained the same as in LC_{50} values. The LC_{90} values were found to be 16.07, 4647.49, 364.78, 21.74 and 13.21 ppm for deltamethrin, emamectin benzoate, spinosad, abamectin and malathion, respectively.

Table 5. Relative toxicity of selected novel insecticides against *Sitophilus zeamais* 48 hrs after exposure

Insecticide	Heterogeneity ($\chi 2$)	Regression Equation	LC_{50} (ppm) [95 % FL]	Relative toxicity	Order of toxicity	LC_{90} (ppm) [95 % FL]	Slope ± SE (b)
Deltamethrin	0.749	Y = 3.041 + 2.686x	5.35 (6.3141-4.2818)	1.18	1	16.07	2.686 ± 0.043
Emamectin benzoate	1.41	Y = 2.703 + 0.975x	225.75 (342.4749-27.8378)	0.02	5	4647.49	0.975 ± 0.109
Spinosad	4.513	Y = 2.267 + 1.566x	55.46 (72.898-40.6369)	0.114	4	364.78	1.566 ± 0.064
Abamectin	0.828	Y = 3.274 + 2.249x	5.85 (7.4486-3.6978)	1.08	2	21.74	2.249 ± 0.077
Malathion	0.169	Y = 1.778 + 4.017x	6.33 (7.2076-5.0447)	1	3	13.21	4.017 ± 0.039

Deltamethrin remained the most toxic insecticide (LC_{50}=5.35ppm) even after 48 hours of exposure. This was further confirmed by Jansson *et al.* (1996) indicating its primary route of toxicity being through ingestion than contact. Abamectin (LC_{50}=5.85ppm), malathion (LC_{50}=6.33ppm) and spinosad (LC_{50}=55.46ppm) were intermediary in toxicity while, emamectin benzoate was the least toxic (LC_{50}-225.75) against the test insect. Srinivasacharyulu and Yadav (1997) also reported that deltamethrin (LC_{95}) was the most toxic insecticide to *S. zeamais* while malathion was the least toxic insecticide. This differential toxicity might be due to the quick knock down effect causing rapid paralysis in insect where malathion was less toxic to *S. zeamais* (Kljajic *et al* .,2004). Thus, the results on relative toxicity obtained 48 hours after exposure in this study indicated that there has been a marginal increase in the mortality of insects as time elapsed, there by the LC_{50} values reduced numerically as compared to 24 hours after exposure.

Thus at both 24 and 48 hours, the most toxic insecticide was deltamethrin followed by abamectin > malathion > spinosad > emamectin benzoate Since there is a chance of development of resistance to malathion and deltamethrin due to its continuous use in storage godowns for reducing the infestation of maize weevil, *S. zeamais*, there is a need to identify a safer seed protectant. Both abamectin and spinosad being derivatives of bacterium can be a more practical alternative to malathion and deltamethrin. Though abamectin is highly toxic to weevils, it has low mammalian toxicity and when ingested can be rapidly eliminated from the body within two days. Similar is the case with spinosad which shows low toxicity when ingested by mammals and has no adverse effects from chronic exposure. So, in future these two insecticides can be considered as viable replacements to malathion and deltamethrin in control of maize weevil, *S. zeamais*. However, there is a need for further studies with the two biopesticides abamectin and spinosad on their biodegradability in terms of residues after a definite period of storage on different commodities in a large scale.

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