Research Article

Evaluation of Newer Molecule Insecticides for the Management of *Rhyzopertha dominica* (F.) (Bostrichidae: Coleoptera) and their Effect on Seed Quality in Stored Maize

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Abstract

A storage experiment was conducted to study the relative efficacy of newer insecticide molecules in combating the *R. dominica* on storability of Hema hybrid maize seeds under ambient storage condition from June 2014 to March 2015. The observations were recorded on per cent seed damage (natural infestation), presence of live adults of *R. dominica***,** germination percentage, moisture content and vigour indices at tri-monthly interval up to nine months of storage period. Three months after treatment imposition no insect damage and live adults was noticed in any of the treatments. The treatments of spinosad 45 SC @2 ppm and emamectin benzoate 5 SG @ 2 ppm were found free from the seed damage and presence of live adults at six months of treatment imposition and both were differed significantly from remaining treatments. Nine months after treatment imposition significant differences were observed among treatments. The least level of insect damage (0.50 %), and live (1.00 adult) insects was observed in spinosad 45 SC @ 2 ppm which was on par with the emamectin benzoate 5 SG @ 2 ppm (0.75 % seed damage) and live (1.33 adult) treated seeds and both differed significantly with remaining treatments. Present studies clearly revealed that many of the new insecticides tested were found effective in reducing seed damage without affecting the seed quality parameters.

Keywords: Spinosad, Emamectin benzoate, Maize, *R. dominica*, Seed damage and Seed quality

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Introduction

Maize or Corn (*Zea mays* L.) is a versatile cereal crop grown over a range of agro climatic zones. Globally, maize is known as queen of cereals because, it has the highest genetic yield potential among the cereals. It is not only an important human nutrient, but also a basic element of animal feed and raw material for manufacture of many industrial products like corn starch, corn oil, corn syrup and bio-fuel. It is cultivating on nearly 150 m ha in about 160 countries that contributes 36% (782 m t) in the global grain production [1]. India has 5 per cent of maize acreage and contributes 2.5 per cent of world production. During 2015, it was cultivated on about 9.5 million hectares; producing 23.29 million tons of grain with 2451 kg/hectare yields [2].

During postharvest storage, maize grains are vulnerable to many insects. Among those, the lesser grain borer *Rhyzopertha dominica*, Weevils complex *Sitophlilus* spp., Angoumois grain moth *Sitotroga cerealella* (Olivier), Khapra beetle *Trogoderma granarium* Everts and Red flour beetle *Tribolium castaneum* (Herbst) are important [3]. It is estimated that 5 to 10 per cent of world's grain production is lost due to ravages of insect pests. These losses reach to 50 per cent in tropical countries where temperature and humidity run high during summer season [4]. Estimates of post-harvest losses of cereal grains ranged between 5 to 35 per cent in the world [5]. In India, up to 12 per cent of post-harvest losses were caused by insect pests [6]. This reflects on the magnitude of pest problem in storage.

The lesser grain borer is a serious and primary pest that feeds internally on stored commodities such as paddy, wheat, maize and sorghum including pulses [7, 8]. The beetle has been reported to be highly polyphagous and cosmopolitan in tropical and subtropical regions of the world, but it has also been found in warm and temperate regions [7, 9]. Relative to other stored grain insect pests, *R. dominica* is the most difficult insect pest to control with insecticide grain protectants, because many of the currently approved grain protectants are either not effective against the insect, or the insect has developed resistance to them. For instance, *R. dominica* is resistant to methoprene [10];

several pyrethroid-based grain protectants [11] and to all approved organo phosphorus insecticides [8]. Though fumigation by phosphine has been effective in the control of *R. dominica* [12], its resistance to phosphine is of major global concern internationally [13].

Insecticides are one of the most effective weapons for disinfesting and protecting stored products from infestation. There is also need to find the chemicals that can effectively prevent the storage losses, easily available, affordable, safer and least detrimental to environment. It is well established that a lot of efforts are put for the production of "every single grain" but this is of no use if the produced grains are not saved, which recalls the proverb "a grain saved is a grain grown". This adage depends mainly on how best we protect the quality of grains during storage. Since, lesser grain borer is a major insect pest of stored maize causing severe damage, preventing long term storage, the present investigation was undertaken to study the management of *R. dominica* by using newer molecule insecticides.

Experimental Methods

A storage experiment was conducted in Entomological laboratory at All India Coordinated Research Project on Seed Technology, National Seed Project, University of Agricultural Sciences, Gandhi Krishi Vignan Kendra, Bengaluru during June 2014 to March 2015, to study the effect of newer molecule insecticides for effective control of *R. dominica* on maize. Freshly harvested certified seeds of Hema hybrid maize were taken from NSP. Recommended quantity of insecticides was diluted in five ml water to treat one kg of seed for proper coating. After treatment, seeds were dried in shade and packed in two kg capacity gunny bags and kept for storage under ambient condition. Similarly, control was maintained without any treatment for comparison. The experiment was conducted in completely randomized design (CRD) with nine treatments and three replications.

Observations were made includes per cent seed damage, germination of undamaged seeds, moisture content of seeds, vigor index and the number of live insects in representative sample.

Per cent seed damage

Four hundred seeds were randomly drawn from each treatment and replication; number of damaged seeds were counted and expressed as per cent seed damage.

Adult insect survival

Number of live insects was counted in all the treatments by taking 400 maize seeds randomly.

Germination of undamaged seeds

The germination test was conducted by between paper methods as prescribed by the International Seed Testing Association [14]. A total of 100 maize seeds of each replication in each of the treatment were selected and uniformly placed on a germination paper and the rolled towels were placed vertically in the germination cabinet maintained at 25 °C, with 85 per cent relative humidity. Germination counts were taken on 8th day after incubation to work out per cent germination.

Seed moisture content

Moisture content of seed was estimated by oven dry method. Five grams of maize seeds were taken from each replication of each treatment and by taking the initial weight, the seeds were ground and kept in an oven for 4 h at 130 °C and the final weight was recorded. The moisture content of the seed was calculated by using following formula.

$$\text{Moisture content (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where: W_1= Weight of empty cup with lid (g), W_2= weight of cup with seed sample before drying (g), W_3= weight of cup with seed sample after drying (g)

Vigour index

Measurements of root and shoot length was recorded in 10 randomly selected seedlings from germination test, from each treatment and replication. The mean seedling length was measured and vigour index-I was calculated by using following formula.

$$\text{Vigour Index-I} = \text{Germination (\%)} \times \text{Mean seedling length (cm)}$$

Ten seedlings selected for seedling measurement were dried in hot air oven maintained at 80±2º C for 24 h, then dry weight was recorded and computed the vigour index- II by using following formula.

$$\text{Vigour index-II} = \text{Germination (\%)} \times \text{Mean dry weight of seedling (g)}$$

Statistical analysis

The data after suitable transformations (wherever required) were subjected to statistical analysis following analysis of variance (ANOVA) technique for completely randomized design (CRD) to draw inference at 5 % level of significance.

Results and Discussion

Relative efficacy of insecticides against *R. dominica* in stored maize

Seed damage (%)

Zero seed damage was recorded in all the treatments at three months after storage. At six months after treatment imposition, zero seed damage was in seeds treated with spinosad 45 SC @ 2ppm and emamectin benzoate 5 SG @ 2 ppm. The least seed damage (0.25 %) was observed in rynaxypyr 20 SC @ 2ppm, indoxacarb 14.5 SC @ 2ppm and deltamethrin 2.8 EC @ 1ppm. The highest insect damage (2.50 %) was in untreated control. The results at nine months after treatment imposition revealed that, the least seed damage (0.50 %) was in spinosad 45 SC @ 2 ppm, closely followed by emamectin benzoate 5 SG @ 2 ppm (0.75 %) both of which differed significantly with all other treatments. The highest seed damage (10.25 %) was in untreated control (**Table 1**). Thus the present study revealed that among the insecticides evaluated spinosad 45 SC @ 2 ppm and emamectin benzoate 5 SG @ 2 ppm were superior in reducing the insect damage. This is supported by the observations of [15] and [16] who reported that seed damage was not evident in spinosad (0.5, 1.0 or 2.0 mg a.i./ka) treated maize seeds, and spinosad at 1 or 2 mg/kg provided complete or near complete suppression of kernel damage after 49 days. Emamectin benzoate as well as spinosad treated seeds were free from the seed damage after 12 months of storage in pearl millet [17].

Table 1 Effect of insecticide seed treatment on seed damage and presence of live *R. dominica* adults in maize at different storage period

Treatments		Seed damage (%)			Presence of live *R. dominica* adults/400 seeds		
		3 MAT	6 MAT	9 MAT	3 MAT	6 MAT	9 MAT
T_1	Emamectin benzoate 5 SG @ 2 ppm	0.00(0.00)	0.00(0.00)^{a}	0.75(4.92)^{a}	0.00(0.00)	0.00(0.00)^{a}	1.33(6.53)^{a}
T_2	Spinosad 45 SC @ 2 ppm	0.00(0.00)	0.00(0.00)^{a}	0.50(4.05)^{a}	0.00(0.00)	0.00(0.00)^{a}	1.00(5.74)^{b}
T_3	Indoxacarb 14.5 SC @ 2 ppm	0.00(0.00)	0.25(2.86)^{a}	2.00 (8.13)^{c}	0.00(0.00)	1.00(5.74)^{b}	3.67(11.01)^{d}
T_4	Rynaxypyr 20 SC @ 2 ppm	0.00(0.00)	0.25(2.86)^{a}	1.75(7.56)^{c}	0.00(0.00)	1.00(5.74)^{b}	2.33 (8.74)^{b}
T_5	Chlorfenapyr 10 EC @ 2 ppm	0.00(0.00)	0.50(4.05)^{b}	3.25(10.38)^{d}	0.00(0.00)	1.67(7.33)^{c}	3.33(10.49)^{cd}
T_6	Profenofos 50 EC @ 2 ppm	0.00(0.00)	1.00(5.74)^{c}	4.00(11.53)^{e}	0.00(0.00)	2.00(8.13)^{cd}	6.33(14.56)^{ef}
T_7	Novaluron 10 EC @ 2 ppm	0.00(0.00)	1.25(6.40)^{d}	5.25(13.24)^{f}	0.00(0.00)	3.00(9.17)^{d}	7.00(15.34)^{f}
T_8	Deltamethrin 2.8 EC @ 1 ppm	0.00(0.00)	0.25(2.86)^{a}	1.75(7.59)^{c}	0.00(0.00)	2.33(8.74)^{d}	3.67(11.01)^{d}
T_9	Untreated control	0.00(0.00)	3.00(9.97)^{e}	10.25(18.66)^{g}	0.00(0.00)	6.33(14.56)^{e}	11.00(19.05)^{g}
	SEm±	NA	0.12	0.29	NA	0.36	0.48
	CD (P = 0.05)		0.37	0.85		1.07	1.43
	CV (%)		5.59	5.18		9.31	7.30

Figures in parentheses are Arc sine transformed values; Means followed by same alphabet in a column do not differ significantly; MAT: Months after treatment; NA: not analyzed

Presence of live adults

With respect to presence of live adults, no population was recorded in any treatment at three months after treatment imposition. Observations recorded at six months after treatment imposition revealed spinosad 45 SC @ 2 ppm and emamectin benzoate 5 SG @ 2 ppm were free from live adults. Indoxacarb 14.5 SC @ 2 ppm and rynaxypyr 20 SC @ 2 ppm recorded least live adults (1.00 adult each). Untreated control recorded the highest number (6.33 adult/400 seeds). At nine months of treatment imposition spinosad 45 SC @ 2 ppm (1.00 adult) recorded least number of live adults and untreated control recorded highest (11.00 adult/400 seeds) **(Table 1)**. Among the insecticides evaluated, spinosad 45 SC @ 2 ppm and emamectin benzoate 5 SG @ 2 ppm proved better in controlling the attack of *R. dominica*. The present results were in close agreement with [15] who reported that spinosad at the rate of 1.0 mg and 2.0 a.i./kg seeds registered 100 per cent mortality even after four months. Spinosad applied at 0.5 to 1 mg per kg was completely effective for nine months, with 100 per cent adult mortality of *R. domnica* after 14 days of exposure to treated seeds and no live F1 adults produced [18].

Effect of insecticidal treatment on maize seed quality parameters

Seed moisture content (%)

Significant differences were observed between the treatments with respect to seed moisture content observed three, six and nine months after treatment imposition. Least seed moisture content was documented due to spinosad 45 SC @ 2 ppm (10.09 %) treatment and highest in untreated control (10.20 %) at three months after treatment imposition. At six months, least moisture content was observed in spinosad 45 SC @ 2 ppm (10.51 %) and emamectin benzoate 5 SG @ 2 ppm (10.61 %) and untreated control (11.39 %) with the highest moisture content. Same trend was observed at nine months after of treatment, spinosad 45 SC @ 2 ppm (11.18 %) and emamectin benzoate 5 SG @ 2 ppm recoded least (11.24 %) and untreated control with highest (12.56 %) seed moisture content (**Table 2**). These variations between the treatments may be related to effect of per cent seed damage, as damaged seeds absorb more moisture from external environment than normal undamaged seeds with the increase in storage period.

Table 2 Effect of insecticide seed treatment on moisture content and germination of maize at different storage period

	Treatments	**Moisture content (%)**			**Germination (%)**		
		3 MAT	**6 MAT**	**9 MAT**	**3 MAT**	**6 MAT**	**9 MAT**
T_1	Emamectin benzoate 5 SG @ 2 ppm	10.12^{ab}	10.61^{a}	11.24^{a}	94.67^{ab}	92.67^{a}	86.00^{b}
T_2	Spinosad 45 SC @ 2 ppm	10.09^{a}	10.51^{a}	11.18^{a}	95.33^{a}	93.00^{a}	88.00^{a}
T_3	Indoxacarb 14.5 SC @ 2 ppm	10.17^{bc}	10.87^{b}	11.37^{b}	94.00^{ab}	88.67^{c}	83.00^{cd}
T_4	Rynaxypyr 20 SC @ 2 ppm	10.14^{abc}	10.90^{b}	11.47^{bc}	94.33^{ab}	89.00^{c}	84.33^{bc}
T_5	Chlorfenapyr 10 EC @ 2 ppm	10.19^{c}	11.14^{cd}	11.50^{c}	93.33^{bc}	87.00^{d}	81.33^{de}
T_6	Profenofos 50 EC @ 2 ppm	10.18^{bc}	10.93^{bc}	11.63^{d}	94.00^{ab}	86.33^{de}	80.00^{ef}
T_7	Novaluron 10 EC @ 2 ppm	10.16^{bc}	11.25^{de}	11.65^{d}	93.33^{bc}	85.00^{e}	78.33^{f}
T_8	Deltamethrin 2.8 EC @ 1 ppm	10.15^{abc}	10.92^{b}	11.54^{cd}	94.33^{ab}	91.00^{b}	84.00^{c}
T_9	Untreated control	10.20^{c}	11.39^{e}	12.56^{e}	92.00^{c}	81.00^{f}	64.00^{g}
	SEm±	0.02	0.08	0.04	0.47	0.54	0.58
	CD (P = 0.05)	0.06	0.22	0.11	1.40	1.61	1.72
	CV (%)	0.37	1.19	0.55	0.86	1.06	1.23

Means followed by same alphabet in a column do not differ significantly; MAT: Months after treatment.

Seed germination (%)

In all the storage periods (three, six and nine months) spinosad 45 SC @ 2 ppm, closely followed by emamectin benzoate 5 SG @ 2 ppm produced the highest seed germination. The results indicated that, most of the new insecticide molecules did not affect the seed germination at different storage periods, this clearly indicating the effectiveness of these molecules except novaluron 10 EC @ 2 ppm in managing the *R. dominica* up to nine months after treatment imposition. However, novaluron 10 EC @ 2 ppm also maintained more than 80 per cent seed germination percentage up to six months of storage. The reduction in seed germination was observed only in untreated control, however more than 80 per cent seed germination percentage was maintained up to six months of storage **(Table 2)**. The present results were in confirmation with the results obtained by [19] and [20], who revealed the germination of deltamethrin treated seeds was not affected up to 15 months and 12 months of storage in wheat and maize, respectively. As demonstrated by [16] that spinosad at 1 or 2 mg per kg seeds provided significantly higher germination in maize after 49 days. Findings of [17] closely supported the obtained results, that emamectin benzoate treated pearl millet seeds had the highest germination (87.50 %) over the control (77.75 %) even after 12 months of storage.

Vigour indices-I and II

Both vigour indices I and II was affected at three, six and nine months after treatment imposition. Spinosad 45 SC @ 2 ppm recorded the highest mean vigour index-I (2491, 2289 and 2124) and least in untreated control (2112, 1669 and 1065), similarly with respect to vigour index-II highest (66.57, 54.50 and 37.05) was recorded in spinosad 45 SC @ 2 ppm and least (47.16, 32.75 and 16.59) in untreated control (**Table 3**). During all the three different storage period higher germination was documented in spinosad 45 SC @ 2 ppm closely followed by the emamectin benzoate 5 SG @ 2 ppm treated seeds. These results are supported by the findings of [20] that the physiological quality of maize seeds was effectively preserved by the addition of chemical insecticides for 12 months under normal environmental conditions. In the seed testing experiment conducted by [21], they observed that the root and shoot lengths (cm) were highest in deltamethrin treated seeds followed by malathion-treated seeds in stored maize. Higher vigour indices in insecticide treated seeds are related to the per cent seed damage. Because of higher seed damage, untreated control had minimum and poor seed quality parameters. The variation among the insecticide treated seeds may be due to the variation with respect to extent of seed damage and respective seed moisture content percentages. As seed damage and moisture content varied in different insecticide treatments, the germination percentage also varied accordingly and thereby differences were observed with respect to vigour indices over a different storage periods.

Table 3 Effect of insecticide seed treatment on Vigour index-I and II of maize at different storage period

Treatments		Vigour index-I			Vigour index-II		
		3 MAT	**6 MAT**	**9 MAT**	**3 MAT**	**6 MAT**	**9 MAT**
T_1	Emamectin benzoate 5 SG @ 2 ppm	2484^{a}	2276^{a}	1970^{b}	65.86^{ab}	54.48^{a}	35.49^{ab}
T_2	Spinosad 45 SC @ 2 ppm	2491^{a}	2289^{a}	2124^{a}	66.37^{a}	54.50^{a}	37.05^{a}
T_3	Indoxacarb 14.5 SC @ 2 ppm	2386^{bc}	2132^{c}	1788^{cd}	64.13^{b}	51.83^{b}	32.71^{c}
T_4	Rynaxypyr 20 SC @ 2 ppm	2425^{b}	2166^{bc}	1856^{c}	65.24^{abc}	49.88^{c}	34.40^{bc}
T_5	Chlorfenapyr 10 EC @ 2 ppm	2353^{de}	2020^{b}	1727^{d}	63.60^{c}	48.58^{cd}	30.18^{d}
T_6	Profenofos 50 EC @ 2 ppm	2379^{bc}	2004^{d}	1592^{e}	65.19^{abc}	47.37^{d}	28.18^{d}
T_7	Novaluron 10 EC @ 2 ppm	2308^{d}	1910^{e}	1432^{f}	59.13^{d}	42.12^{f}	24.29^{e}
T_8	Deltamethrin 2.8 EC @ 1 ppm	2422^{bc}	2234^{ab}	1837^{c}	66.14^{ab}	53.01^{b}	34.35^{bc}
T_9	Untreated control	2212^{e}	1669^{f}	1065^{g}	47.16^{e}	32.75^{e}	16.59^{f}
	SEm±	17.12	23.94	24.62	0.68	0.47	0.43
	CD (P = 0.05)	51.00	70.00	73.00	2.03	1.38	2.48
	CV (%)	1.24	1.96	2.49	1.90	1.67	1.29

Means followed by same alphabet in a column do not differ significantly; MAT: Months after treatment.

Conclusion

In the evaluation of insecticide molecules against the *R. domonica*, many of the insecticides (spinosad 45 SC @ 2 ppm, emamectin benzoate 5 SG @ 2 ppm deltamethrin 2.8 EC at 1 ppm, indoxacarb 14.5 SC @ 2 ppm, rynaxypyr 20 SC @ 2 ppm, chlorfenapyr 10 EC @ 2 ppm and deltamethrin 2.8 EC @ 1 ppm) were found effective in reducing seed damage without affecting the germination, moisture content and vigour indices. Any of the above mentioned newer insecticides can used for seed treatment to manage the *R. dominica* effectively and to maintain the seed quality above the minimum standards.

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