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Bioefficacy of insect growth regulators (IGRs) as seed protectant against lesser grain borer, *Rhyzopertha dominica* (Fab.) on wheat

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Abstract
The present was conducted to evaluate Bioefficacy of insect growth regulators (IGRs) as seed protectant against lesser grain borer, Rhyzopertha dominica (Fab.) on wheat at Jobner Jaipur Rajasthan in the year 2016-17. The insect growth regulators, *viz*. diflubenzuron, novaluron, lufenuron, pyriproxyfen and buprofezin (in four dosage levels, *viz*. 1,5,10, and 15 ppm) and neem oil (in three dosage levels 0.1,0.5 and 1.0%) and neem seed kernel extract (at three dosage levels 1.0%, 2.5% and 5.0%) were evaluated. A standard check of deltamethrin 2.8 EC @ 2 ppm and an untreated control was maintained for comparison. These treatments were evaluated on the basis of adult emergence, grain damage, weight loss and developmental period at 24 hours, 30, 60, 90, 120, 150 days after storage.
Among these treatments, neem oil 1.0% and NSKE 5.0% exhibited nil emergences of adults, grain damage, weight loss and developmental period upto 150 days of storage. These treatments were followed by pyriproxyfen 15 ppm (0.00-2.00 F_1 adults, 0.00-3.33 percent grain damage, 0.00-4.00 percent weight loss) and lufenuron (0.00-3.00 F_1 adults, 0.00-5.00 percent grain damage, 0.00-4.67 percent weight loss). The developmental period was prolonged in pyriproxyfen 15 ppm (56.33-61.33 days) which was followed by buprofezin 15 ppm (55.33-59.67 days), however, all the treatments proved significantly superior over untreated check.

Keywords: Insect growth regulators, *Rhyzopertha dominica* (Fab.). wheat etc

1. Introduction

Wheat grain is the chief commodity stored in ware houses, farmers' and traders' godowns. In storage, it is heavily infested by a number of insect pests, *viz*. lesser grain borer, *Rhyzopertha dominica* (Fab.); khapra beetle, *Trogoderma granarium* Everts; red rust flour beetle, *Tribolium castaneum* (Herbst.) and rice weevil, *Sitophilus oryzae* (L.). Among them, the lesser grain borer, *R. dominica* (Bostrichidae: Coleoptera) causes considerable damage to stored grains[3]. The original home of this borer is said to be India[9], has wide occurrence feeding on a variety of stored products, like cereals, pulses, groundnut kernels, other edible commodities and grocery stores. It not only causes post harvest losses in terms of quantity but also affects the quality through depletion of specific nutrients and contamination with uric acid and excreta.

The lesser grain borer, *R. dominica* can be readily distinguished from other grain beetles by its cylindrical form and small size. It is polished dark brown with some what roughened surface. The beetle has the head turned down under thorax and armed with powerful jaws with which they can cut directly into wood or other tough vegetable material. Both beetles and larvae cause serious damage in warm climate. Females lay eggs on the exterior of the wheat kernel. The first instar grubs hatch and bore into the kernel, feed and develop inside the kernel and upon reaching the adult stage, bore out of the kernel creating a large exit hole. Two or three grubs are generally seen feeding in a grain. They cause weight loss, diminish germination potential and market value of the grain. It has been reported that the larvae remain in hibernation during December to February but with favourable conditions regain activity. In Uttar Pradesh its peak period of occurrence is August only while in Rajasthan and *Tarai* parts of Uttar Pradesh, the first week of September is peak period of infestation [8].

Because, the development occurs inside the kernel, the population of *R. dominica* is difficult to kill with contact insecticides applied directly to stored wheat. High non target toxicity and persistence and a wide spectrum activity are characterstics, which led to withdrawal of many conventional insecticides in recent years.

Highly persistant compounds were found to accumulate in food chains affecting wide range of wild life. The wide spread use of conventional insecticides has also led to the development of resistance amongst some insect species. Consequently, there is a need to introduce alternative compounds which are less persistent and more pest specific. Of those currently identified substances which act on biochemical processes of insects, the insect growth regulators were found to appear to be suitable and effective replacement of insecticides. To be compatible with the existing strategies in an integrated pest management (IPM) programme, each component of the programme should have a characteristic selectivity to the target species. Emphasis on selective insect pest control practices markedly impacted the approaches of chemical industries to adopt developing novel insecticides. Pesticide regulation, Environmental protection agency emphasized the discovery and synthesis of insect growth regulators (IGRs) that are specific to the target species and do not adversely or minimally affect beneficial and non-target species.

A meagre work has been done in India on the efficacy of the IGRs against stored grain pests.

2. Material and Methods

2.1 Treatments: Three chitin synthesis inhibitors (diflubenzuron, novaluron and lufenuron), two juvenile hormones mimics (pyriproxyfen and buprofezin), two botanicals neem oil and neem seed kernel extract and one synthetic pyrethroid as standard check (deltamethrin) in different dosages were evaluated (Table-1) against lesser grain borer, *R. dominica* in wheat. An untreated control was maintained for comparision.

2.2 Treatment of grain: Sterilized and conditioned wheat grains (200 g) was treated with different dosages of insect growth regulators which was treated as treated grain lot.

2.3 Release of insects in treated grain samples: After 24 hours, 15 g from treated lot of each growth regulator was taken in glass vials (10 x 2.5 cm). Two pairs of newly emerged beetles equal sex (0 to 24 hours old) were released in each glass vial. Three replications of each treatment were maintained. The experiment was repeated after 30, 60, 90, 120 and 150 days after treatment.

2.4 Method for recording observations: The observations on grain damage, F_1 adult emergence, weight loss and total developmental period was recorded. The total developmental period from adult to adult was recorded by averaging out the period.

2.4.1 Adult emergence (Progeny development): The observation on progeny development was recorded by sieving the grains and counting the total number of adult beetles in the grain after 30, 60, 90, 120 and 150 days of treatment. The damage caused by one generation (F_1) was recorded by visual count. The adults emerged were recorded at an alternate day upto one generation. The adults emerged were discarded while taking observations to check the egg laying.

2.4.2 Grain damage: Before estimating the damaged grains, the grains were thoroughly mixed and samples of 100 grains were drawn from each sample. The damaged grains in 100 grains were counted from each sample to work out the percent grain damage.

2.4.3 Weight loss: The weight loss due to insect damage was recorded as per the methodology suggested [4]. The frass material was excluded and the weight of grain was taken with a metler electronic balance.

Table 1: Dosages of insect growth regulators as seed protectant against lesser grain borer, *Rhyzopertha dominica*

S. No.	IGR	Formulation	Dosage			
1	Diflubenzuron	25 WP	1 ppm	5ppm	10ppm	15 ppm
2	Novaluron	10 EC	1 ppm	5ppm	10ppm	15 ppm
3	Lufenuron	5 EC	1 ppm	5 ppm	10 ppm	15 ppm
4	Pyriproxyfen	10.8 EC	1 ppm	5 ppm	10 ppm	15 ppm
5	Buprofezin	25 EC	1 ppm	5 ppm	10 ppm	15 ppm
6	Neem oil	-	0.1%	0.5%	1.0%	-
7	NSKE	-	1.0%	2.5%	5.0%	-
8	Deltamethrin	2.8 EC	2 ppm	-	-	-
9	Control (Untreated)		-	-	-	-

2.5 Statistical analysis: The percent data on grain damage, weight loss and germination were transformed into angular values (arc sine √percentage) and number of adult emergence into √X+0.5 values for analysis of variance.

3. Results and Discussion

3.1 Adult Emergence:-In the present investigation, The F_1 adults emerged in the neem products (neem oil 1.0% and NSKE 5.0%) treatment was nil up to 150 days of storage (Table 1). In pyriproxyfen, lufenuron, buprofezin, diflubenzuron and novaluron 15 ppm each, the F_1 adults emerged was nil upto 60 days of storage, however, after 90 days of storage adult emerged in these treatments were in range of 0.67-3.00. These treatments were followed by pyroproxyfen 10 ppm (0.00-3.33 F_1 adults) and lufenuron 10 ppm (0.00-4.00 F_1 adults). However, all the treatments resulted in significantly lower F_1 adult emergence over the untreated. The other treatments resulted in the middle order of efficacy.

Among the different treatments, neem products followed by pyriproxyfen emerged as effective grain protactant. Neem has been most widely evaluated and used pesticidal plant. It acts as deterrent for feeding and oviposition, antifeedent for young insects, reduces fecundity and also act as insecticide. It contains a number of compounds having pesticidal properties, *viz.*, salannin, meliantriol and azadirachtin [8]. Pyriproxyfen is an insect growth regulator. It mimics natural insect hormones that stop young insects from maturing into adults. Pyriproxyfen can affect an insect if it is touched or eaten. However, pyriproxyfen is rarely toxic to adult insects. Instead, it disturbs egg laying and egg-hatch and keeps young insects from growing into adult forms. This prevents target insects from multiplying.the finding also get evident from the finding of same entomologist [6] that reported that lufenuron and pyriproxyfen in the case of *R. dominica* completely suppressed progeny production (100%) when they were applied to stored grain which corroborate the present findings. the residual activity of an ethanolic neem kernel extract containing azadirachtin in the laboratory against *R. dominica* on wheat stored for upto 48 weeks were evaluated and reported the persistency of this emulsifiable neem formulation and the potential for field evaluation as a grain protectant [10]. This partially supports the present findings.

3.2 Total developmental period:- No developmental period was observed in neem oil 1.0% and NSKE 5.0% upto 150 days of storage while highest developmental period was observed in pyriproxyfen 15 ppm (56.33-61.33 days) followed by buprofezin 15 ppm (55.33-59.67) (Table 2). These findings are in agreement with the results obtained by Singh *et al.* (1996) [11] who reported that seed treatment with different plant oils/ extracts normally delayed the development of *R. dominica.* Pyriproxyfen gave effective residual control of primary stored-product insect species by inhibiting development of exposed larvae [1] which is in close conformity with the present findings.

3.3 Grain Damage:-The grain damage observed after 24 hrs after seed treatment was in the range of 0.00-11.33 percent (Table 3). The grain damage was nil after 150 days of treatment in neem oil 1.0 percent and NSKE 5.0 percent treated grain. These treatments were found significantly superior over rest of the treatments. The next effective treatments were pyriproxyfen 15 ppm (0.00-3.33% damage), lufenuron 15 ppm (0.00-5.00% damage), diflubenzuron 15 ppm (0.00-5.33% damage) and novaluron 15 ppm (0.00-7.33% damage). The rest of the treatments resulted in the lower order of effectivity but significantly superior over the untreated. pyriproxyfen gave effective residual control of primary stored product insect species by inhibiting adult emergence of exposed larvae [1]. Results showed that it can be a useful addition for pest management programmes in mills, ware houses and food storage facilities.

3.4 Weight loss:- The weight loss is nil in neem oil 1.0 percent and NSKE 5.0 percent upto 150 days of storage, however, it was minimum in pyriproxyfen 15 ppm (0.00-4.00%), lufenuron 15 ppm (0.00-4.67), buprofezin 15 ppm (0.00-5.33%) and diflubenzuron (0.00-6.67%) (Table 3) which was significantly superior over the other treatments. The other treatments were found at lower order of efficacy, however, differed significantly over the untreated. all the IGRs were very effective (>88.5% suppression of progeny) against the tested species (*Prostephanus truncatus* and *R. dominica*) at doses of ≥5 ppm which support the present findings [6].

3.5 Effect of insect growth regulators on germination of wheat seed treatment with insect growth regulators: It is utmost important to know the effect of IGRs on the viability of seed. The germination test of the treated seeds revealed that the germination percent ranged from 82.00-85.67 (table no- 4) which was statistically at par. Therefore, it could be inferred that the insect growth regulators did not impair the viability of the seeds. These results corroborate fully with the results obtained by Kadam *et al*. (2013) [5] and Babu *et al* (1991) [2].

Table 2: Adult emergence and total developmental period (Days) of *Rhyzopertha domonica* (Fab.) as influenced by insect growth regulator (IGR) treated wheat seed after certain period of storage

		Adult Emergence*						Total Developmental Period*					
Insect Growth Regulator	**Dose**	**24 hours**	**30 days**	**60 days**	**90days**	**120 days**	**150 days**	**24 hours**	**30 days**	**60 days**	**90 days**	**120 days**	**150 days**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Diflubenzuron	1 ppm	4.67	7.33	9.33	10.67	13.33	17.33	54.00	52.67	51.00	50.33	49.67	47.00
		(2.27)	(2.80)	(3.14)	(3.34)	(3.72)	(4.22)	(7.38)	(7.29)	(7.18)	(7.13)	(7.08)	(6.89)
	5 ppm	2.00	3.00	6.00	8.33	10.33	12.67	55.67	54.67	54.00	52.00	51.67	49.00
		(1.58)	(1.87)	(2.55)	(2.97)	(3.29)	(3.63)	(7.49)	(7.43)	(7.38)	(7.25)	(7.22)	(7.04)
	10 ppm	0.00	0.67	1.67	3.67	5.00	6.33	0.00	57.00	56.33	55.33	54.67	51.33
		(0.71)	(1.08)	(1.47)	(2.04)	(2.35)	(2.61)	(0.71)	(7.58)	(7.54)	(7.47)	(7.43)	(7.20)
	15ppm	0.00	0.00	0.00	2.00	3.33	4.00	0.00	0.00	0.00	58.00	57.33	55.33
		(0.71)	(0.71)	(0.71)	(1.58)	(1.96)	(2.12)	(0.71)	(0.71)	(0.71)	(7.65)	(7.60)	(7.47)
Novaluron	1 ppm	5.33	8.00	10.67	11.33	14.67	18.33	53.33	52.00	51.33	50.00	49.33	46.67
		(2.41)	(2.92)	(3.34)	(3.44)	(3.89)	(4.34)	(7.34)	(7.25)	(7.20)	(7.11)	(7.06)	(6.87)
	5 ppm	2.00	3.33	6.67	9.33	12.67	14.33	56.33	55.33	54.67	53.33	52.67	50.00
		(1.58)	(1.96)	(2.68)	(3.14)	(3.63)	(3.85)	(7.54)	(7.47)	(7.43)	(7.34)	(7.29)	(7.11)
	10 ppm	0.33	0.67	2.33	4.33	6.33	8.67	0.00	57.33	56.33	54.67	53.00	51.00
		(0.91)	(1.08)	(1.68)	(2.20)	(2.61)	(3.03)	(0.71)	(7.60)	(7.54)	(7.43)	(7.31)	(7.18)
	15ppm	0.00	0.00	0.00	2.67	4.00	5.33	0.00	0.00	0.00	57.33	56.67	54.33
		(0.71)	(0.71)	(0.71)	(1.78)	(2.12)	(2.41)	(0.71)	(0.71)	(0.71)	(7.60)	(7.56)	(7.40)
Lufenuron	1 ppm	1.33	2.00	2.67	5.33	7.67	9.00	55.00	53.67	52.00	51.33	50.67	47.33
		(1.35)	(1.58)	(1.78)	(2.41)	(2.86)	(3.08)	(7.45)	(7.36)	(7.25)	(7.20)	(7.15)	(6.92)
	5 ppm	0.33	1.00	2.00	4.00	6.33	7.33	56.33	54.33	53.67	52.33	51.33	48.67
		(0.91)	(1.22)	(1.58)	(2.12)	(2.61)	(2.80)	(7.54)	(7.40)	(7.36)	(7.27)	(7.20)	(7.01)
	10 ppm	0.00	0.00	1.00	2.00	3.33	4.00	0.00	0.00	58.33	56.33	54.67	52.00
		(0.71)	(0.71)	(1.22)	(1.58)	(1.96)	(2.12)	(0.71)	(0.71)	(7.67)	(7.54)	(7.43)	(7.25)
	15ppm	0.00	0.00	0.00	1.33	2.00	3.00	0.00	0.00	0.00	57.33	55.67	53.33
		(0.71)	(0.71)	(0.71)	(1.35)	(1.58)	(1.87)	(0.71)	(0.71)	(0.71)	(7.60)	(7.49)	(7.34)
Pyriproxyfen	1 ppm	1.00	1.67	2.33	4.00	6.33	7.67	58.33	56.67	55.00	53.67	52.33	50.67
		(1.22)	(1.47)	(1.68)	(2.12)	(2.61)	(2.86)	(7.67)	(7.56)	(7.45)	(7.36)	(7.27)	(7.34)
	5 ppm	0.33	1.00	1.67	3.33	4.67	5.33	60.67	58.67	56.67	54.33	53.67	51.00
		(0.91)	(1.22)	(1.47)	(1.96)	(2.27)	(2.41)	(7.82)	(7.69)	(7.56)	(7.40)	(7.36)	(7.18)

	10 ppm	0.00	0.00	0.33	1.00	2.00	3.33	0.00	0.00	59.67	58.33	55.67	52.33
		(0.71)	(0.71)	(0.91)	(1.22)	(1.58)	(1.96)	(0.71)	(0.71)	(7.76)	(7.67)	(7.49)	(7.27)
	15ppm	0.00	0.00	0.00	0.67	1.67	2.00	0.00	0.00	0.00	61.33	59.33	56.33
		(0.71)	(0.71)	(0.71)	(1.08)	(1.47)	(1.58)	(0.71)	(0.71)	(0.71)	(7.86)	(7.73)	(7.54)
Buprofezin	1 ppm	2.67	3.67	4.67	8.33	10.67	13.00	57.67	55.00	54.33	52.33	51.67	49.00
		(1.78)	(2.04)	(2.27)	(2.97)	(3.34)	(3.67)	(7.63)	(7.45)	(7.40)	(7.27)	(7.22)	(7.04)
	5 ppm	1.33	2.00	3.67	6.67	9.00	11.67	59.67	58.00	55.33	53.67	52.33	50.33
		(1.35)	(1.58)	(2.04)	(2.68)	(3.08)	(3.49)	(7.76)	(7.65)	(7.47)	(7.36)	(7.27)	(7.13)
	10 ppm	0.67	1.00	2.67	5.00	7.33	9.33	60.33	58.67	56.67	55.00	54.00	51.33
		(1.08)	(1.22)	(1.78)	(2.35)	(2.80)	(3.14)	(7.80)	(7.69)	(7.56)	(7.45)	(7.38)	(7.20)
	15ppm	0.00	0.00	0.00	3.00	4.67	5.00	0.00	0.00	0.00	59.67	57.67	55.33
		(0.71)	(0.71)	(0.71)	(1.87)	(2.27)	(2.35)	(0.71)	(0.71)	(0.71)	(7.76)	(7.63)	(7.47)
Neem oil	0.1%	2.00	2.67	3.67	7.00	9.67	12.33	56.67	54.67	53.67	52.33	51.33	48.33
		(1.58)	(1.78)	(2.04)	(2.74)	(3.19)	(3.58)	(7.56)	(7.43)	(7.36)	(7.27)	(7.20)	(6.99)
	0.5%	1.00	1.33	2.00	4.67	7.67	10.33	58.33	56.67	55.33	53.67	52.00	50.00
		(1.22)	(1.35)	(1.58)	(2.27)	(2.86)	(3.29)	(7.67)	(7.56)	(7.47)	(7.36)	(7.25)	(7.11)
	1%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)
NSKE	1%	2.33	3.33	4.67	8.33	10.33	14.67	55.33	53.67	53.00	52.67	51.00	48.00
		(1.68)	(1.96)	(2.27)	(2.97)	(3.29)	(3.89)	(7.47)	(7.36)	(7.31)	(7.29)	(7.18)	(6.96)
	2.5%	1.33	1.67	3.33	6.00	8.33	11.00	57.00	55.33	54.67	53.33	51.67	49.33
		(1.35)	(1.47)	(1.96)	(2.55)	(2.97)	(3.39)	(7.58)	(7.47)	(7.43)	(7.34)	(7.22)	(7.06)
	5.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)
Deltamethrin	2 ppm	1.00	1.33	2.00	3.33	4.67	6.33	52.67	51.33	50.00	49.33	48.33	47.00
		(1.22)	(1.35)	(1.58)	(1.96)	(2.27)	(2.61)	(7.29)	(7.20)	(7.11)	(7.06)	(6.99)	(6.89)
Control (Untreated)		24.67	26.33	27.00	28.33	29.33	31.66	51.00	49.33	48.67	47.33	46.00	45.67
		(5.02)	(5.18)	(5.24)	(5.37)	(5.46)	(5.67)	(7.18)	(7.06)	7.01	(6.92)	(6.82)	(6.79)
S.Em.+		0.10	0.13	0.17	0.28	0.14	0.15	0.46	0.55	0.59	0.66	0.76	0.62
CD (P=0.05)		0.29	0.37	0.49	0.79	0.39	0.41	1.32	1.57	1.68	1.87	2.14	1.74

*Figures in the parenthesis are √(X+ 0.5) values

Table 3: Damaged grains (%) and Weight loss (%) due to F_1 of *Rhyzopertha dominica* (Fab.) in insect growth regulator (IGR) treated wheat seed after certain period of storage

		Grain Damage**						**Weight Loss Percent****					
Insect Growth Regulator	**Dose**	**24 hours**	**30 days**	**60 days**	**90days**	**120 days**	**150 days**	**24 hours**	**30 days**	**60 days**	**90 days**	**120 days**	**150 days**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Diflubenzuron	1 ppm	10.67	14.00	16.33	17.67	21.33	23.33	5.67	6.33	8.73	11.33	13.67	17.00
		(19.07)	(21.97)	(23.83)	(24.86)	(27.51)	(28.88)	(13.78)	(14.57)	(17.19)	(19.67)	(21.70)	(24.35)
	5 ppm	9.67	11.67	14.33	16.33	18.33	19.67	4.00	4.27	5.02	7.66	9.33	10.67
		(18.12)	(19.98)	(22.24)	(23.83)	(25.35)	(26.33)	(11.54)	(11.93)	(12.95)	(16.07)	(17.79)	(19.07)
	10 ppm	2.00	3.33	3.33	5.33	6.33	7.67	1.00	1.67	2.33	5.00	7.67	9.33
		(8.13)	(10.51)	(10.51)	(13.35)	(14.57)	(16.08)	(5.74)	(7.43)	(8.78)	(12.92)	(16.08)	(17.79)
	15ppm	0.00	0.00	0.00	3.33	4.33	5.33	0.00	0.00	0.00	1.67	4.33	6.67
		(0.00)	(0.00)	(0.00)	(10.51)	(12.01)	(13.35)	(0.00)	(0.00)	(0.00)	(7.43)	(12.01)	(14.97)
Novaluron	1 ppm	11.33	15.67	18.33	21.33	23.33	25.67	6.99	9.67	11.03	13.33	16.33	18.33
		(19.67)	(23.32)	(25.35)	(27.51)	(28.88)	(30.44)	(15.33)	(18.12)	(19.40)	(21.41)	(23.83)	(25.35)
	5 ppm	10.33	12.33	17.33	19.00	23.00	24.67	4.33	5.00	5.71	7.67	9.33	11.67
		(18.75)	(20.56)	(24.60)	(25.84)	(28.66)	(29.43)	(12.01)	(12.92)	(13.82)	(16.08)	(17.79)	(19.98)
	10 ppm	3.00	4.00	4.67	6.00	7.33	9.00	1.67	2.00	2.67	5.33	8.33	10.00
		(9.97)	(11.54)	(12.48)	(14.18)	(15.71)	(17.46)	(7.43)	(8.13)	(9.40)	(13.35)	(16.78)	(18.43)
	15ppm	0.00	0.00	0.00	4.67	5.67	7.33	0.00	0.00	0.00	2.33	5.00	7.00
		(0.00)	(0.00)	(0.00)	(12.48)	(13.78)	(15.71)	(0.00)	(0.00)	(0.00)	(8.78)	(12.92)	(15.34)
Lufenuron	1 ppm	5.00	6.00	7.33	9.33	10.33	12.33	3.33	4.33	5.67	8.00	10.33	11.67
		(12.92)	(14.18)	(15.71)	(17.79)	(18.75)	(20.56)	(10.51)	(12.01)	(13.78)	(16.43)	(18.75)	(19.98)
	5 ppm	3.33	3.67	4.67	6.33	7.67	9.33	2.00	2.67	3.33	5.33	7.67	9.33
		(10.51)	(11.04)	(12.48)	(14.57)	(16.08)	(17.79)	(8.13)	(9.40)	(10.51)	(13.35)	(16.08)	(17.79)
	10 ppm	1.33	2.66	3.33	4.67	5.67	6.33	0.67	1.33	2.33	4.67	6.33	7.00
		(6.62)	(9.39)	(10.51)	(12.48)	(13.78)	(14.57)	(4.70)	(6.62)	(8.78)	(12.48)	(14.57)	(15.34)
	15ppm	0.00	0.00	0.00	2.00	3.67	5.00	0.00	0.00	0.00	2.00	3.67	4.67
		(0.00)	(0.00)	(0.00)	(8.13)	(11.04)	(12.92)	(0.00)	(0.00)	(0.00)	(8.13)	(11.04)	(12.48)
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pyriproxyfen	1 ppm	4.33	4.67	6.00	8.33	9.67	11.00	2.67	3.33	4.67	6.33	8.67	10.33
		(12.01)	(12.48)	(14.18)	(16.78)	(18.12)	(19.37)	(9.40)	(10.51)	(12.48)	(14.57)	(17.12)	(18.75)
	5 ppm	2.67	3.33	3.67	4.33	5.33	6.33	1.00	1.67	2.33	4.67	6.67	8.00
		(9.40)	(10.51)	(11.04)	(12.01)	(13.35)	(14.57)	(5.74)	(7.43)	(8.78)	(12.48)	(14.97)	(16.43)
	10 ppm	1.00	2.00	3.00	3.67	4.33	5.00	0.33	1.00	1.67	3.33	5.00	6.33
		(5.74)	(8.13)	(9.97)	(11.04)	(12.01)	(12.92)	(3.29)	(5.74)	(7.43)	(10.51)	(12.92)	(14.57)
	15ppm	0.00	0.00	0.00	1.33	2.33	3.33	0.00	0.00	0.00	1.33	3.33	4.00
		(0.00)	(0.00)	(0.00)	(6.62)	(8.78)	(10.51)	(0.00)	(0.00)	(0.00)	(6.62)	(10.51)	(11.54)
Buprofezin	1 ppm	8.33	9.33	11.33	12.33	14.67	18.00	5.33	6.67	7.33	10.67	13.00	16.33
		(16.78)	(17.79)	(19.67)	(20.56)	(22.52)	(25.10)	(13.35)	(14.97)	(15.71)	(19.07)	(21.13)	(23.83)
	5 ppm	5.67	7.00	8.67	9.33	10.67	12.67	4.00	4.67	5.00	8.33	10.00	13.00
		(13.78)	(15.34)	(17.12)	(17.79)	(19.07)	(20.85)	(11.54)	(12.48)	(12.92)	(16.78)	(18.43)	(21.13)

	10 ppm	3.33	4.67	5.33	6.67	8.67	10.33	1.67	2.33	2.67	6.00	8.67	10.67
		(10.51)	(12.48)	(13.35)	(14.97)	(17.12)	(18.75)	(7.43)	(8.78)	(9.40)	(14.18)	(17.12)	(19.07)
	15ppm	0.00	0.00	0.00	5.00	6.33	8.00	0.00	0.00	0.00	3.33	5.00	5.33
		(0.00)	(0.00)	(0.00)	(12.92)	(14.57)	(16.43)	(0.00)	(0.00)	(0.00)	(10.51)	(12.92)	(13.35)
Neem oil	0.1%	6.33	7.33	8.67	10.33	12.67	14.67	4.33	5.33	6.00	8.67	10.67	13.33
		(14.57)	(15.71)	(17.12)	(18.75)	(20.85)	(22.52)	(12.01)	(13.35)	(14.18)	(17.12)	(19.07)	(21.41)
	0.5%	3.67	5.00	5.67	7.67	8.33	10.33	3.33	4.00	4.33	6.67	8.33	10.33
		(11.04)	(12.92)	(13.78)	(16.08)	(16.78)	(18.75)	(10.51)	(11.54)	(12.01)	(14.97)	(16.78)	(18.75)
	1%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
NSKE	1%	7.67	8.00	9.33	11.00	13.33	16.67	5.00	6.00	6.67	9.33	12.33	15.33
		(16.08)	(16.43)	(17.79)	(19.37)	(21.41)	(24.10)	(12.920	(14.18)	(14.97)	(17.79)	(20.56)	(23.05)
	2.5%	4.33	6.67	7.00	8.33	9.67	11.33	3.67	4.33	4.67	7.33	9.00	11.67
		(12.01)	(14.97)	(15.34)	(16.78)	(18.12)	(19.67)	(11.04)	(12.01)	(12.48)	(15.71)	(17.46)	(19.98)
	5.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Deltamethrin	2 ppm	1.67	3.33	4.00	5.33	6.67	8.00	1.33	1.60	4.02	6.33	8.00	9.33
		(7.43)	(10.51)	(11.54)	(13.35)	(14.97)	(16.43)	(6.62)	(7.27)	(11.57)	(14.57)	(16.43)	(17.79)
Control(Untreated)		65.99	66.33	66.67	67.33	68.67	70.00	22.00	24.33	25.00	26.67	29.33	30.00
		(54.33)	(54.53)	(54.74)	(55.14)	(55.35)	(56.79)	(27.97)	(29.55)	(30.00)	(31.09)	(32.79)	(33.21)
S.Em.±		0.25	0.22	0.25	0.28	0.24	0.26	0.08	0.09	0.11	0.14	0.21	0.23
CD (P=0.05)		0.70	0.63	0.71	0.79	0.69	0.74	0.23	0.24	0.31	0.41	0.59	0.64

**Figures in the parenthesis are arc sine √ percentage values

Table 4: Effect of insect growth regulator treatment on the germination of wheat seed after 150 days of treatment

S. No.	Treatment	Dosage	Germination (%)
1	2	3	4
1	Diflubenzuron	1 ppm	85.00 (9.25)
		5 ppm	84.33 (9.21)
		10 ppm	83.33 (9.16)
		15ppm	84.67 (9.23)
2	Novaluron	1 ppm	84.33 (9.21)
		5 ppm	84.00 (9.19)
		10 ppm	83.33 (9.16)
		15ppm	83.33 (9.16)
3	Lufenuron	1 ppm	85.00 (9.25)
		5 ppm	84.33 (9.21)
		10 ppm	84.67 (9.23)
		15ppm	83.00 (9.14)
4	Pyriproxyfen	1 ppm	83.00 (9.14)
		5 ppm	83.00 (9.14)
		10 ppm	84.33 (9.21)
		15ppm	85.00 (9.25)
5	Buprofezin	1 ppm	84.33 (9.21)
		5 ppm	84.00 (9.19)
		10 ppm	83.00 (9.14)
		15ppm	84.33 (9.21)
6	Neem oil	0.1%	85.33 (9.26)
		0.5%	84.67 (9.23)
		1%	84.33 (9.21)
7	NSKE	1%	84.67 (9.23)
		2.5%	85.33 (9.26)
		5.0%	82.00 (9.10)
8	Deltamethrin	2 ppm	85.00 (9.25)
9	Control (Untreated)		85.67 (9.28)
	SEm±		1.21
	CD (P=0.05)		NS

*NS = Non-significant

Figures in the parenthesis are arc sine √ percentage values

4. Conclusion

Insect growth regulators can be a useful addition for pest management programmes in mills, ware houses and food storage facilities. The insect growth regulators (IGRs), *viz*. diflubenzuron, novaluron, lufenuron, pyriproxyfen and buprofezin and *neem* products (*neem* oil and NSKE) were evaluated against lesser grain borer, *R. dominica* as seed protactant. Out of these, *neem* oil 1.0 percent, NSKE 5.0% were most effective, revealed no adult emergence of *R. dominica*, damaged grains and weight loss. These treatments were followed by pyriproxyfen, lufenuron, diflubenzuron and novaluron 15 ppm each. No development could take place in the neem oil 1.0 percent and NSKE 5.0 percent upto 150 days of storage. These were followed by pyriproxyfen, buprofezin, diflubenzuron, lufenuron and novaluron 15 ppm each. It is also revealed that there is no adverse effects of tested IGRs were evident on the germination of seeds upto 150 days of treatment.

5. References

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