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Efficacy of spinetoram and flupyradifurone against bruchid on blackgram (*Vigna mungo*) under storage conditions

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Blackgram [*Vigna mungo* (L.) Hepper] is an important pulse crop plays an important role in the Indian diet since it is high in vegetable protein and serves as a cereal-based diet. However, it faces severe pest problems by bruchids which causes massive post-harvest losses during long-term storage conditions. Several methods including cultural, physical, biological and chemical control measures have been implemented, but none of these has been successful in controlling the *Callosobruchus* species, due to bruchids insect resistance against the commercially available insecticides and these chemicals not confirming the acceptable residue standards in controlling the bruchid infestation hence losing their efficacy in controlling the bruchid infestation (Mishra *et al*. 2018). The new molecules such as Spinetoram and Flupyradifurone affect nicotinic acetylcholine and γ-aminobutyric acid (GABA) receptors in insect nervous systems thereby causing abnormal neural transmission (Thomas *et al.* 2012, Yasutaka *et al*. 2012, Nauen *et al.* 2015). In fact, due to their potential ability, many conventional insecticides have been replaced by these novel insecticides as they are effective at low doses, have high selectivity, improved specificity for target pests, and low toxicity to non-target species and the environment.

An experiment was conducted during 2020–21 at the University of Agricultural Sciences, Bengaluru, Karnataka to evaluate the effectiveness of new molecules Spinetoram and Flupyradifurone against bruchid and their influence on the seed quality of blackgram during storage. The experiment comprised of 9 treatments (Table 1) including an untreated check and replicated thrice. Freshly harvested blackgram (cv. LBG-971) seeds were procured from the AICRP on NSP (Crops), University of Agricultural Sciences, Gandhi Krishi Vigyana Kendra, Bengaluru, Karnataka and treated with new insecticides and stored under ambient conditions for 9 months (Table 1).

Observations on quality parameters were recorded bimonthly up to 6 months and then monthly observations up to 9 months of seed storage (July 2020 to April 2021) were conducted. Whereas, total dehydrogenase activity (A_{480}), total soluble sugar (µg/ml) and protein (%) were recorded once in 3 months of storage. These observations were taken by sampling of 400 seeds from each treatment. The data obtained from the experiment were statistically analysed by using appropriate ANOVA with the suitable transformation wherever necessary.

$$\text{Bruchid infestation (\%)} = \frac{\text{Number of seeds damaged}}{\text{Total number of seeds counted}} \times 100$$

Effectiveness of new molecules on bruchid management: In the study, the treatment with spinetoram 11.7% SC at 25.6 mg/kg of seeds demonstrated the lowest bruchid infestation, recording an infestation rate of 1.42%. Following closely was the treatment with emamectin benzoate 5 SG at 2 ppm (40 mg/kg seeds), which exhibited an infestation of 1.67% and also recorded the least bruchid population (Fig. 1).

Table 1 Treatments details

Treatment	Details	Quantity of formulation mg or ml/kg seeds
T_1	Spinetoram 11.7 SC	8.5 mg/kg
T_2	Spinetoram 11.7 SC	17 mg/kg
T_3	Spinetoram 11.7 SC	25.6 mg/kg
T_4	Flupyradifurone 200 SL	0.01 ml/kg
T_5	Flupyradifurone 200 SL	0.02 ml/kg
T_6	Flupyradifurone 200 SL	0.04 ml/kg
T_7	Emamectin Benzoate 5 SG	2 ppm (40 mg/kg)
T_8	Deltamethrin 2.8 EC	1.0 ppm (0.04 ml/kg)
T_9	Control	-

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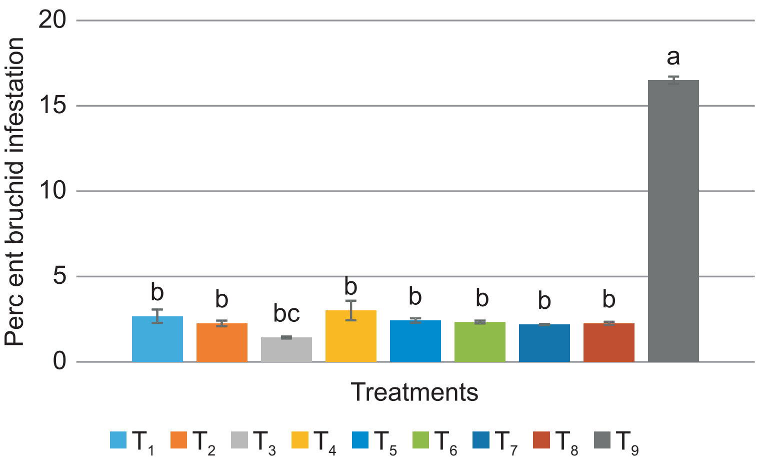

Fig. 1 Effect of different insecticides on bruchid infestation in blackgram after 9 months of storage.

(Fig. 2). Furthermore, the mean seedling length was recorded at 24.57 cm, and the mean dry weight of seedling was notably high at 47.67 mg. The seedling vigour index I and II, calculated at 2014 and 3910 respectively, reflected the robustness of the seedlings resulting from this treatment. Additionally, the seeds treated with spinetoram showcased a total dehydrogenase activity of 1.41, indicating a high level of metabolic activity within the seeds. The total soluble sugars content was substantial, measuring at 92.44 µg/ml. Furthermore, the treated seeds displayed a remarkably low seed moisture content of 9.64%, underscoring the efficacy of spinetoram in preserving the quality of blackgram seeds during the storage period. These outcomes align with previous studies conducted by Amruta *et al.* (2015) in blackgram, Chaithra (2016) in cowpea and Namashya *et al.* (2018) in greengram and blackgram, which also reported positive effects on seed parameters, emphasizing the consistency and reliability of spinetoram in enhancing seed quality across various leguminous crops.

It was noticed that new molecule treatments were beneficial in the maintenance of seed quality parameters which was on par with standard chemical check and significantly higher than untreated seeds. As the storage period progresses, the quality parameters steadily decreased. This is due to higher bruchid infestation, seed deterioration, aging of seeds, accumulation of toxic metabolites. New molecule treated seeds recorded higher seeds quality parameters over untreated seeds because of their anti-feeding property, neurotoxic mode of action, relatively effective at lower dosages in controlling bruchid population (Satpathy *et al.* 2017, Anil Kumar *et al.* 2023)

The seed treatment with new molecules significantly influenced the seed quality parameters and controlled the bruchid population and recorded the highest B:C ratio in blackgram during storage. The seed treatment with spinetoram recorded the lowest seed moisture content and bruchid infestation. Whereas, the highest seed quality parameters, viz. seed germination, mean seedling length, mean seedling dry weight, seedling vigour index I and II (2014 and 3910), total dehydrogenase activity, total soluble sugars and highest B:C ratio were recorded. Between the new molecules the treatment with spinetoram was found most effective by recording highest seed quality parameters, lowest seed infestation and highest B:C ratio as compared to other treatments. However, all the treatments outperformed the control (Table 2).

Conversely, untreated seeds showed the highest seed damage at 16.50% after 9 months of storage. These results align with findings from Raghu (2014) in cowpea, indicating an increase in seed damage percentage over time. The escalation in seed damages, such as exit holes, can be attributed to the rising bruchid population levels, particularly under favourable temperature conditions. This phenomenon may also be linked to the diminishing effectiveness of insecticides when exposed to the storage environment. Notably, the new insecticide-treated treatments demonstrated potent insecticidal action, resulting in lower infestation rates compared to untreated seeds, as observed by Naveen *et al.* (2022). Similar outcomes were reported by Rajput *et al.* (2013) in cowpea and Dissanayaka *et al.* (2020) in improved rice varieties. The collective evidence suggests the efficacy of these insecticide treatments in mitigating bruchid infestations and minimizing seed damage during storage.

Effectiveness of new molecules on seed quality during storage: The outcomes of the study unveiled that blackgram seeds treated with spinetoram 11.7% SC at 25.6 mg/kg of seeds exhibited remarkable characteristics after 9 months of storage. Notably, these treated seeds demonstrated the highest seed germination rate, reaching an impressive 84%

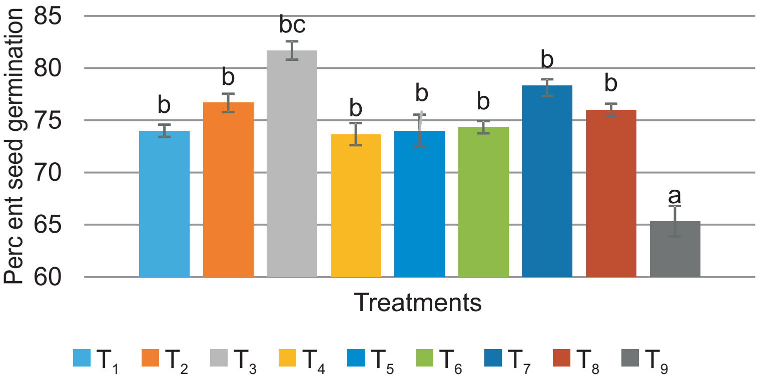

Fig. 2 Effect of different insecticides on seed germination in blackgram after 9 months of storage.

Benefit cost (B:C) ratio: The treatment with spinetoram 11.7 SC at 25.6 mg/kg seeds demonstrated a noteworthy economic impact, as evidenced by the highest benefit-cost (B:C) ratio recorded at an impressive 1:7.22. Following closely was the treatment with deltamethrin 2.8

Table 2 Effect of new molecules on seed quality parameters in blackgram cv. LBG-791 after 9 months of storage

Treatment	Seed moisture (%)	Seed germination (%)	Mean seedling length (cm)	Mean seedling dry weight (mg)	Seedling vigour index I	Seedling vigour index II	Total dehydrogenase activity (OD value)	Total soluble sugars (µg/ml)	Bruchid infestation (%)	B:C
T_1	10.71^{b}	74^{b}	21.80^{b}	45.87^{b}	1613^{b}	3394^{b}	1.30^{b}	98.21^{b}	2.67^{b} (9.39)	1: 5.01
T_2	10.48^{b}	77^{b}	22.27^{b}	46.07^{b}	1707^{b}	3532^{b}	1.33^{b}	95.24^{b}	2.25^{b} (8.62)	1: 5.51
T_3	9.64^{bc}	82^{bc}	24.57^{bc}	47.67^{bc}	2014^{bc}	3910^{bc}	1.41^{bc}	92.44^{bc}	1.42^{bc} (6.83)	1: 7.22
T_4	11.03^{b}	74^{b}	20.23^{b}	45.33^{b}	1498^{b}	3355^{b}	1.27^{b}	101.87^{b}	3.00^{b} (9.97)	1: 4.67
T_6	10.63^{b}	75^{b}	21.77^{b}	46.17^{b}	1625^{b}	3447^{b}	1.30^{b}	98.07^{b}	2.33^{b} (8.78)	1: 5.56
T_7	10.40^{b}	78^{b}	23.50^{b}	46.83^{b}	1825^{b}	3637^{b}	1.40^{b}	93.44^{b}	2.17^{b} (8.62)	1: 5.52
T_8	10.91^{b}	76^{b}	21.30^{b}	45.83^{b}	1612^{b}	3468^{b}	1.35^{b}	101.58^{b}	2.25^{b} (8.62)	1: 5.90
T_9	12.11^{a}	65^{a}	18.40^{a}	43.03^{a}	1203^{a}	2812^{a}	1.18^{a}	151.87^{a}	16.50^{a} (23.96)	--
Mean	10.75	75.0	21.61	45.85	1625.2	3438.8	1.31	103.65	3.89	--
SEM±	0.14	0.7	0.59	0.59	48.7	59.9	0.01	0.61	0.20	--
CD (P=0.05)	0.41	2.1	1.74	1.75	144.8	177.9	0.04	1.82	0.60	
CV %	2.2	1.64	4.70	2.23	5.19	3.02	1.71	2.38	3.31	

Refer to the methodology for treatment details.

EC at 1.0 ppm (0.04 ml/kg seeds), which also exhibited a substantial B:C ratio of 1:5.90. In stark contrast, untreated seeds incurred significant economic losses when compared to the other treatments. This economic advantage observed in treated seeds aligns with findings from a study by Thirumalaraju and Jyothi (2016) in cowpea, where similar positive economic outcomes were reported.

SUMMARY

The effectiveness of various molecules, including spinetoram 11.7 SC and flupyradifurone 200 SL, along with chemical checks like emamectin benzoate 5 SG and deltamethrin 2.8 EC, was investigated for controlling bruchid infestation and preserving seed quality during ambient storage at University of Agricultural Sciences, Bengaluru, Karnataka (2021–22). After 9 months, spinetoram 11.7 SC at 25.6 mg/kg seeds (T_3) demonstrated outstanding results compared to the control (T_9). Treatment T_3 exhibited the highest 100-seed weight (5.28 g), lowest seed moisture (9.64%), and the highest germination rate (82%). Additionally, treatment T_3 showed maximum shoot length, root length, mean seedling length, and mean seedling dry weight. The electrical conductivity (EC) of seed leachate was significantly lower in T_3 (834 µS/cm) treatment, highlighting its superiority. Spinetoram 11.7 SC also excelled in dehydrogenase activity, protein content and total soluble sugars, indicating its positive impact on seed quality.

Bruchid infestation significantly reduced in treatment T_3 (1.42%), while untreated seeds exhibited the highest seed damage (16.50%). Teatment T_3 recorded the fewest live and dead bruchids per 400 seeds, as well as the lowest seed infection. Compared to other treatments, spinetoram 11.7 SC at 25.6 mg/kg seeds emerged as the most effective in controlling bruchids and maintaining superior seed quality, as reflected in its highest B:C ratio. Overall, this research suggests that spinetoram can be a highly effective solution for bruchid control and seed quality preservation in blackgram during storage.

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