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Efficacy of insecticides against pod borer complex of pigeonpea

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Abstract
The present investigation, entitled “Efficacy of Insecticides against Pod Borer Complex of Pigeonpea,” was conducted during the kharif season of 2024-2025 at the experimental field of the Pulse Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The study was designed to evaluate the effectiveness of selected insecticidal modules against the major pod borer pests infesting pigeonpea, which are known to cause significant yield losses in the crop. The effectiveness of these modules was assessed based on multiple parameters, including larval population density, extent of pod and grain damage, and final grain yield per hectare.
Considering the effectiveness of various insecticide modules in recording lowest larval population of *H. armigera and E. atomosa* (0.15 and 0.23 larva per plant respectively) and percent pod damage (4.88%) and grain damage (3.10%) due to lepidopteran borer (*H. armigera and E. atomosa*) was registered in module M_5 which was found at par with module M_1, while in the case of pod fly, module M_5 recorded the lowest larval population (0.08 larvae/25 pods) and lowest percent pod damage (5.55%) and grain damage(3.70%), followed by module M_1, which were mostly found at par with each other. At the time of harvest lowest percent pod damage (4.26%) and grain damage (3.64%) due to pod borer complex was registered in module M_5, which was found at par with module M_1.

Keywords: Pigeonpea, pod borer complex, *Helicoverpa armigera*, *Exelastis atomosa*, *Melanagromyza obtusa*, larval population, pod damage, grain damage

1. Introduction

Pigeonpea is cultivated by many small-scale farmers in developing countries. Economically, pigeonpea is the second most important pulse crop in India, after chickpea, contributing significantly to the nation's agricultural output (Sharma *et al*., 2010) [18]. It is one of the most important legume crops of the tropics and subtropics of Asia and Africa. Pigeonpea, also known by names such as red gram, arhar, and tur in India, offers nutritional security due to its richness in protein (21%), carbohydrates (57.2%), calcium (9.1%), phosphorus (0.26%) along with mineral supplements such as iron and iodine (Singh *et al*., 2005) [17].

Pigeonpea (*Cajanus cajan*) ranks sixth in global grain legume production, with 6.03 million hectares under cultivation, producing approximately 5.32 million tonnes and yielding 882 kg ha^{-1} (FAO, 2022) [1]. India has the highest annual pigeonpea production of 4.2 million tonnes, followed by Malawi (0.44 million tonnes), Myanmar (0.32 million tonnes), the United Republic of Tanzania (0.16 million tonnes), and Kenya (0.083 million tonnes) respectively (FAO, 2022) [1]. In Maharashtra, pigeonpea is primarily cultivated as an intercrop with soybeans, cotton, and mungbeans under rainfed conditions. The area under pigeonpea is 11.11 lakh ha with a production of 9.82 lakh tonnes and a productivity of 884 kg/ha in 2023-24. (MoAF&W Third advance estimate 2023-24).

Various constraints are responsible for the consistently low yields of pigeonpea, among which insect pests pose a major threat, causing significant economic losses. Although several insect pests attack pigeonpea from the seedling stage, the majority of the damage is inflicted during the flowering and pod formation stages. The pod borer complex, comprising *Helicoverpa armigera*, *Exelastis atomosa* (tur plume moth), and *Melanagromyza obtusa* (tur pod fly), is considered the most destructive, often leading to grain yield losses ranging from 30% to 100% depending on pest severity and crop management practices (Muchhadiya *et al*., 2024) [8]. Recent studies have estimated that *H. armigera* alone can cause yield losses up to

57%, while *M. obtusa* and *E. atomosa* contribute to losses of about 24% and 6%, respectively (Patoliya *et al*., 2024) [14]. Overall, the annual loss of pulse production due to insect pest infestation is estimated at 15-40% in India (FAO, 2023) [2]. These alarming figures underscore the urgent need for integrated pest management strategies in pigeonpea cultivation to minimize yield losses and ensure food security.

2. Materials and Methods

The present investigation was carried out regarding the "Efficacy of insecticides against the pod borer complex of pigeonpea". The field experiment was systematically conducted during the Kharif season of 2024-25 at the Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth (PDKV), Akola. The experimental layout followed a Randomized Block Design (RBD) comprising seven treatments, including an untreated control, with three replications to ensure statistical reliability and minimize experimental error.

The treatment modules included different combinations and sequences of insecticides aimed at targeting the major pod borer species observed in pigeonpea. These modules were as follows: Module M1 comprised Deltamethrin 2.80% EC @ 10 ml per 10 litres of water followed by Indoxacarb 15.80% EC @ 7 ml per 10 litres; Module M_2 involved Emamectin benzoate 1.90% EC @ 7.5 ml per 10 litres followed by Deltamethrin 2.80% EC @ 10 ml per 10 litres; Module M_3 consisted of Monocrotophos 36% SL @ 12.5 ml per 10 litres followed by Emamectin benzoate 1.90% EC @ 7.5 ml per 10 litres; Module M_4 included Lufenuron 5.40% EC @ 12 ml per 10 litres followed by Lambda-cyhalothrin 5% EC @ 10 ml per 10 litres; Module M5 involved Indoxacarb 15.80% EC @ 7 ml per 10 litres followed by Lufenuron 5.40% EC @ 12 ml per 10 litres; and Module M_6 comprised Lambda-cyhalothrin 5% EC @ 10 ml per 10 litres followed by Monocrotophos 36% SL @ 12.5 ml per 10 litres. Module M_7 was maintained as the untreated control for comparative evaluation.

The first spray was administered at the 50% pod formation stage, which is considered an economically important phase for pod borer infestation, while the second spray was applied at a 15-day interval thereafter. Both sprays were applied using a knapsack sprayer, ensuring uniform coverage across all plots. Pre-treatment observations of the pest population were recorded one day before each spray, while post-treatment observations were conducted at 3, 7, and 14 days after each application to monitor the efficacy and persistence of the insecticides.

The primary pests targeted in this study included the pod borer complex, notably *Helicoverpa armigera* (Gram pod borer), *Exelastis atomosa* (Plume moth), and *Melanogromyza obtusa* (pod fly). To evaluate the pest population dynamics, five randomly selected and permanently tagged pigeonpea plants per plot were observed. Pest counts were manually recorded to quantify the incidence and severity of infestation.

At harvest, Pod damage and grain damage due to pigeonpea pod borer complex were calculated. Percent pod damage and grain damage were calculated by using the following formulas.

$$\text{Percent pod damage} = \frac{\text{No. of damaged pods}}{\text{Total no. of pods}} \times 100$$

$$\text{Percent grain damage} = \frac{\text{No. of damaged grains}}{\text{Total no. of grains}} \times 100$$

3. Results and Discussion

3.1 Effect of different insecticide modules on larval population of *H. armigera*, *E. atomosa*, and *M. obtusa*.

3.1.1 Effect of different insecticide modules on larval population of *H. armigera*.

The efficacy of various insecticidal modules was evaluated based on the mean larval population of *Helicoverpa armigera* recorded at regular intervals from 3 to 48 days after treatment (DAT), as presented in Table 1. The results revealed that all treatment modules significantly reduced the larval population compared to the untreated control. Among them, Module M_5 comprising Indoxacarb 15.80% EC at 7 ml per 10 L applied at 50% pod formation, followed by Lufenuron 5.40% EC at 12 ml per 10 L at 15 days after the initial spray recorded the lowest mean larval density (0.15 larvae plant^{-1}), and was found to be statistically on par with Module M_1 (0.23 larvae plant^{-1}) and Module M_4 (0.27 larvae plant^{-1}).

The next most effective group included Module M_6 (0.52 larvae plant^{-1}), which was statistically comparable to Module M_2 (0.68 larvae plant^{-1}) and Module M_3 (0.69 larvae plant^{-1}). In contrast, the untreated control (Module M_7) recorded the highest larval incidence, with a mean population of 1.70 larvae plant^{-1}, thereby confirming the efficacy of all tested insecticidal modules over the control.

The present findings are in close agreement with those of Jakhar *et al*. (2015) [6], who reported that three sprays of indoxacarb 15.8 EC @ 0.5 ml/litre of water provided excellent control of pod borers (10.17%) and pod flies (5.84%), and resulted in the highest grain yield of 2144.17 kg/ha. Similarly, Sambathkumar *et al*. (2015) [23] found that indoxacarb 15.8 EC @ 75 g a.i./ha recorded the lowest larval population of *Helicoverpa armigera* (1.03 larvae/plants) and the maximum grain yield of 892.2 kg/ha among the newer insecticides tested. Rana *et al*. (2008) [15] also reported that lambda-cyhalothrin 5% EC @ 500 ml/ha was highly effective in suppressing *H. armigera* infestation in pigeonpea.

3.1.2 Effect of different insecticide modules on larval population of *E. atomosa*.

The data on the larval population of *Exelastis atomosa* in pigeonpea revealed that all the insecticidal modules evaluated were significantly more effective than the untreated control (Table 1). Among the treatments, Module M_5—consisting of Indoxacarb 15.80% EC at 7 ml per 10 L applied at 50% pod formation, followed by Lufenuron 5.40% EC at 12 ml per 10 L at 15 days after the first spray—recorded the lowest mean larval population (0.07 larvae plant^{-1}). This treatment was found to be statistically at par with Module M_1 (0.12 larvae plant^{-1}), Module M_4 (0.15 larvae plant^{-1}), and Module M_6 (0.23 larvae plant^{-1}).

Module M_3 also showed considerable efficacy, recording a larval population of 0.50 larvae plant^{-1}, and was found statistically at par with Module M_2, which recorded 0.57 larvae plant^{-1}. In contrast, the untreated control (Module M_7) registered the highest infestation with 0.76 larvae plant^{-1}, highlighting the relative effectiveness of all tested modules in reducing *E. atomosa* infestation in pigeonpea.

The present findings are in agreement with the results reported by Wadaskar *et al*. (2012) [21], who evaluated a three-spray insecticidal module under field conditions. In this module, the first spray consisted of Profenophos 50 EC @ 25 ml per 10 litres of water applied at the bud initiation stage, followed by a second spray of Flubendiamide 20 WDG @ 5 g per 10 litres of water at 50 percent flowering. The third spray involved Indoxacarb 15.8 EC @ 5 ml per 10 litres of water, applied 15 days after 50 percent flowering. This treatment schedule proved highly effective, resulting in a significantly reduced larval population of *E. atomosa*, with only 0.45 larvae per plant, and recorded the highest grain yield of 21.03 q/ha. These findings confirm the synergistic effect of well-timed sequential insecticide applications in minimizing plume moth infestation and enhancing pigeonpea productivity.

3.1.2 Effect of different insecticide modules on larval population of *M. obtusa*.

The effect of various insecticidal modules on the larval population of *M. obtusa* was evaluated based on the mean larval counts recorded from 3 to 48 days after treatment, and the results are presented in Table 1. The data indicated that all the tested modules were significantly more effective than the untreated control in suppressing larval incidence. Among them, Module M_5 comprising Indoxacarb 15.80% EC at 7 ml per 10 L applied at 50% pod formation, followed by Lufenuron 5.40% EC at 12 ml per 10 L applied 15 days after the initial spray registered the lowest mean larval population (0.08 larvae pod^{-1}). This treatment was statistically at par with Module M_1 (0.09 larvae pod^{-1}), Module M_4 (0.11 larvae pod^{-1}), and Module M_6 (0.13 larvae pod^{-1}).

The next effective group of modules was Module M_3, which recorded a larval population of 0.19 larvae pod^{-1}, which was statistically comparable with Module M_2 (0.20 larvae pod^{-1}). In contrast, the untreated control (Module M_7) exhibited the highest larval incidence, with a mean of 0.74 larvae pod^{-1}, confirming the superior efficacy of all treated modules in managing *M. obtusa* infestation in pigeonpea.

The effectiveness of Lufenuron and Indoxacarb in controlling *Melanagromyza obtusa* (pod fly) in pigeonpea has been well-documented in recent field studies. Prajapati *et al*. (2021) [13] reported that the application of Lufenuron 5.4% EC @ 12 ml/10 L of water significantly reduced the larval population, recording a minimum of 0.70 maggots per plant, along with a reduction in pod (23.3%) and grain (11.9%) damage compared to the untreated control. Further, Ramkumar (2021) [16] reported that Indoxacarb 15.8% EC @ 50 g a.i./ha was among the most effective, reducing pod fly infestation to approximately 1.37 maggots/plant. Additionally, Verma (2006) [20] showed that lambda-cyhalothrin 5% EC @ 500 ml/ha reduced pod fly damage to below 6.2**%**, contributing to substantial control of larval infestation.

Table 1: Effect of different insecticide modules on larval population of pod borer complex.

Tr. No. (Module)	Module details	Average No. of *H. armigera* larvae/plant		Average No. *E. atomosa* larvae/plant		Average No. *M. obtusa* larvae/pods per plant	
		1 DBS	Mean of two sprays	1 DBS	Mean of two sprays	1 DBS	Mean of two sprays
M_1	Deltamethrin 02.80% EC @10ml/10L fb Indoxacarb 15.80% EC @ 7 ml/10 L	0.93 (0.97)	0.23 (0.74)	0.80 (0.89)	0.12 (0.72)	0.48 (0.69)	0.09 (0.29)
M_2	Emamectin benzoate 1.90% EC @7.5ml/10L fb Deltamethrin 02.80% EC @ 10 ml/10 L	1.13 (1.06)	0.68 (1.00)	0.73 (0.86)	0.57 (0.99)	0.33 (0.57)	0.20 (0.48)
M_3	Monocrotophos 36% SL @ 12.5 ml/10 L fb Emamectin benzoate 1.90% EC @ 7.5 ml/10 L	1.07 (1.03)	0.69 (1.01)	0.87 (0.93)	0.50 (0.96)	0.38 (0.62)	0.19 (0.43)
M_4	Lufenuron 5.40% EC @ 12 ml/10 L fb Lambda-cyhalothrin 5% EC @ 10 ml/10 L	1.00 (1.00)	0.27 (0.77)	0.80 (0.89)	0.15 (0.75)	0.44 (0.66)	0.11 (0.33)
M_5	Indoxacarb 15.80% EC @ 7 ml/10 L fb Lufenuron 5.40% EC @ 12 ml/10 L	1.27 (1.13)	0.15 (0.69)	0.93 (0.97)	0.07 (0.69)	0.36 (0.60)	0.08 (0.28)
M_6	Lambda-cyhalothrin 5%EC @10ml/10 L fb Monocrotophos 36% SL @ 12.5 ml/10 L fb	1.33 (1.15)	0.52 (0.91)	0.53 (0.73)	0.23 (0.80)	0.37 (0.61)	0.13 (0.35)
M_7	Untreated control	1.40 (1.18)	1.70 (1.42)	0.73 (0.86)	0.76 (1.08)	0.65 (0.80)	0.74 (0.86)
	'F' test	NS	Sig.	NS	Sig.	NS	Sig.
	SE (m)±	0.06	0.05	0.05	0.04	0.03	0.02
	CD at 5%	0.19	0.16	0.16	0.15	0.11	0.07
	CV (%)	9.92	9.32	10.29	10.16	9.87	9.94

(Figures in parentheses are the corresponding square root transformed values, DBS = Days before spraying)

3.2 Effect of different insecticide modules on percent pod damage to green pods by pod borer complex of pigeonpea.

3.2.1 Effect of different insecticide modules on percent pod damage to green pods by lepidopteran pod borers (*Helicoverpa armigera* and *Exelastis atomosa*)

The percent pod damage caused by lepidopteran pod borers (*Helicoverpa armigera* and *Exelastis atomosa*) was assessed from 3 to 48 days after treatment to evaluate the efficacy of different insecticidal modules. The data (Table 2) indicated that all tested modules were significantly more effective in reducing pod damage compared to the untreated control. The untreated check (Module M_7) recorded the highest pod damage (11.77%), demonstrating the extent of damage in the absence of control measures. In contrast, Module M_5, comprising Indoxacarb 15.80% EC @ 7 ml per 10 L applied at 50% pod formation, followed by Lufenuron 5.40% EC @ 12 ml per 10 L applied 15 days later, recorded the lowest pod damage (4.88%). This module was found significantly superior and statistically at par with Module M_1 (5.33%), Module M_4 (5.77%), and Module M_6 (6.66%).

the next most effective group of modules were Module M_3 and M_2, recording 8.88% and 10.00% pod damage, respectively, and were statistically at par with each other.

These findings highlight the considerable reduction in pod damage achieved by all insecticidal treatments, with Module M_5 emerging as the most effective in managing the lepidopteran pod borer complex.

These results are further supported by previous field studies. Jadhav *et al*. (2005) [4] tested chitin synthesis inhibitors and reported that Lufenuron 0.006% recorded the lowest pod damage (11.9%) and highest grain yield (20.64 q/ha) in chickpea, indicating its strong larvicidal activity. Supporting these results, Thilagam *et al*. (2024) [19] found that Lufenuron 5.4% EC @ 30 g a.i./ha reduced pod damage to 10.21%, with performance comparable to other modern molecules like flubendiamide and emamectin benzoate. In addition, Priyadarshini (2012) [11] reported that Lambda-cyhalothrin 5% EC @ 25 g a.i./ha reduced pod borer damage to 8.00% and resulted in a favorable ICBR of 1:7.54. Prasad *et al*. (2012) [9] also documented the effectiveness of Lambda-cyhalothrin 5% EC, which limited lepidopteran pod damage to 6.20% and 8.00%, respectively, confirming its role as an effective component in integrated pest management modules.

3.2.1 Effect of different insecticide modules on percent pod damage to green pods by *M. obtusa*.

The percent pod damage caused by *Melanagromyza obtusa* was assessed from 3 to 48 days after treatment to evaluate the impact of different insecticidal modules. The data (Table 2) clearly demonstrated that all modules tested were significantly more effective in reducing pod damage compared to the untreated control. The untreated check (Module M_7) recorded the highest pod damage (20.22%), highlighting the severe impact of pod fly in the absence of control measures. In contrast, Module M_5, comprising Indoxacarb 15.80% EC @ 7 ml per 10 L applied at 50% pod formation followed by Lufenuron 5.40% EC @ 12 ml per 10 L applied 15 days later, recorded the lowest pod damage (5.55%). This treatment was significantly superior and statistically at par with Module M_1 (6.22%), Module M_4 (7.11%), and Module M_6 (8.22%).

Modules M_3 and M_2, recording 10.00% and 10.66% pod damage, respectively, formed the next effective group and were statistically at par with each other. These results clearly show the substantial reduction in pod damage achieved by all insecticidal treatments, especially M5, as compared to the untreated control.

Findings from previous field studies further support the effectiveness of modern insecticides in managing *M. obtusa*. Indrasen *et al*. (2017) [3] reported that Indoxacarb 15.8% EC @ 73 g a.i./ha was among the most effective treatments on the pigeonpea variety ‘Bahar’, reducing pod fly damage to 20.33%. This suggests that Indoxacarb possesses both ovicidal and larvicidal properties, which contribute to its high efficacy. Similarly, Thilagam *et al*. (2024) [19] evaluated newer insecticides and observed that Lufenuron 5.4% EC @ 30 g a.i./ha resulted in a significant reduction in pod damage (10.21%), with performance statistically similar to other advanced insecticides such as flubendiamide and emamectin benzoate. These results highlight the potential of Lufenuron, an insect growth regulator, in disrupting pod fly development and reducing its field population. In another notable study, Pathade *et al*. (2015) [12] demonstrated the enhanced effectiveness of a tank mix of Deltamethrin 1% EC and Triazophos, which significantly reduced infestation of both green and mature pods. This combination of a contact pyrethroid and systemic organophosphate provided effective coverage against various life stages of *M. obtusa*, further supporting its use in integrated pest management strategies.

Table 2: Effect of different insecticide modules on percent pod damage to green pods by pod borer complex.

Tr. No. (Module)	Module details	Percent pod damage			
		Lepidopteran borer		*M.obtusa*	
		1 DBS	Mean of two sprays	1 DBS	Mean of two sprays
M_1	Deltamethrin 02.80% EC @10ml/10L fb Indoxacarb 15.80% EC @ 7 ml/10 L	9.33 (3.06)	5.33 (2.29)	16.00 (4.00)	6.22 (2.47)
M_2	Emamectin benzoate 1.90% EC @7.5ml/10L fb Deltamethrin 02.80% EC @ 10 ml/10 L	13.33 (3.65)	10.00 (3.15)	17.33 (4.16)	10.66 (3.25)
M_3	Monocrotophos 36% SL @ 12.5 ml/10 L fb Emamectin benzoate 1.90% EC @ 7.5 ml/10 L	12.00 (3.46)	8.88 (2.97)	18.67 (4.32)	10.00 (3.13)
M_4	Lufenuron 5.40% EC @ 12 ml/10 L fb Lambda-cyhalothrin 5% EC @ 10 ml/10 L	9.33 (3.06)	5.77 (2.39)	14.67 (3.83)	7.11 (2.63)
M_5	Indoxacarb 15.80% EC @ 7 ml/10 L fb Lufenuron 5.40% EC @ 12 ml/10 L	10.67 (3.27)	4.88 (2.20)	18.67 (4.32)	5.55 (2.33)
M_6	Lambda-cyhalothrin 5%EC @10ml/10 L fb Monocrotophos 36% SL @ 12.5 ml/10 L fb	10.67 (3.27)	6.66 (2.56)	17.33 (4.16)	8.22 (2.85)
M_7	Untreated control	12.00 (3.46)	11.77 (3.42)	21.33 (4.62)	20.22 (4.49)
	‘F’ test	NS	Sig.	NS	Sig.
	SE (m)±	0.23	0.19	0.24	0.16
	CD at 5%	0.70	0.60	0.75	0.54
	CV (%)	11.92	12.47	10.05	10.20

(Figures in parentheses are the corresponding square root transformed values, DBS= Days before spraying)

3.3 Effect of different insecticide modules on percent grain damage to green grains by the pod borer complex.

3.3.1 Effect of different insecticide modules on percent grain damage to green grains by lepidopteran borers (*Helicoverpa armigera* and *Exelastis atomosa*).

The evaluation of insecticidal modules revealed that all treatments were significantly superior to the untreated control in reducing grain damage caused by lepidopteran borers (*Helicoverpa armigera* and *Exelastis atomosa*). The untreated control (Module M_7) recorded the highest grain damage of 9.18%, underscoring the need for effective chemical intervention. Among the treatments, Module M_5 (comprising Indoxacarb 15.80% EC @ 7 ml per 10 L at 50% pod formation, followed by Lufenuron 5.40% EC @ 12 ml per 10 L at 15 days after the first spray) recorded the lowest grain damage (3.10%). This treatment was found to be significantly superior and statistically at par with Module M_1 (3.18%), Module M_4 (3.62%), and Module M_6 which recorded 4.51% grain damage.

Modules M_3 and M_2 recorded slightly higher grain damage at 5.25% and 5.70%, respectively, and were statistically at par with each other and formed the next effective group. These findings demonstrate that all insecticidal modules considerably reduced grain damage compared to the untreated control, with Module M_5 emerging as the most effective in managing the lepidopteran borer complex.

These observations are supported by earlier studies. Yadav and Verma (2007) [22] found that Emamectin benzoate, Spinosad, Indoxacarb, and Fenvalerate significantly reduced pod damage, with recorded values of 11.75%, 12.02%, 14.01%, and 14.73%, respectively—each markedly lower than the untreated control. Similarly, Priyadarshini (2012) demonstrated that Lambda-cyhalothrin 5% EC @ 25 g a.i./ha resulted in minimal grain damage (3.37%), which was superior to Beta-cyfluthrin (6.37%) and significantly lower than several other treatments. These studies support the present findings, underscoring the effectiveness of selective insecticides such as Indoxacarb, Lufenuron, and Lambda-cyhalothrin in reducing damage from lepidopteran borers in pigeonpea.

3.3.2 Effect of different insecticide modules on percent grain damage to green grains by *M. obtusa*.

The effectiveness of various insecticidal modules in reducing grain damage caused by the pod fly (*Melanagromyza obtusa*) was evaluated based on the mean percent grain damage recorded between 3 and 48 days after treatment. The results revealed that all modules tested were significantly superior to the untreated control, which recorded the highest grain damage (13.03%). Among the treatments, Module M_5 (Indoxacarb 15.80% EC @ 7 ml per 10 L applied at 50% pod formation, followed by Lufenuron 5.40% EC @ 12 ml per 10 L at 15 days after the first spray) recorded the lowest grain damage (3.70%) and was found to be statistically superior. This treatment was statistically at par with Module M_1 (4.66%), Module M_4 (4.96%), and Module M_6 (5.85%).

Modules M_3 and M_2 recorded grain damage of 7.40% and 7.92%, respectively, and were statistically comparable, forming the next effective group. In contrast, the untreated control (Module M_7) showed the highest level of grain damage (13.03%), clearly demonstrating the necessity of effective chemical control strategies against the pod fly.

These findings align with earlier studies highlighting the efficacy of newer insecticidal molecules. Jadhav *et al*. (2005) [4] demonstrated the potential of insect growth regulators like Lufenuron in reducing grain damage, reporting 11.9% pod damage and 20.64 q/ha yield in chickpea. Similarly, Prasad *et al*. (2012) [9] found Lambda-cyhalothrin 5% EC @ 25 g a.i./ha effective in minimizing lepidopteran grain damage under field conditions. These studies support the present findings, particularly the superior performance of modules combining Indoxacarb and Lufenuron in effectively managing pod fly and minimizing grain losses.

Table 3: Effect of different insecticide modules on percent grain damage to green grains by pod borer complex.

Tr. No. (Module)	Module details	Percent grain damage			
		Lepidopteran borer		*M. obtusa*	
		1 DBS	Mean of two sprays	1 DBS	Mean of two sprays
M_1	Deltamethrin 02.80% EC @10ml/10L fb Indoxacarb 15.80% EC @ 7 ml/10 L	8.00 (2.83)	3.18 (1.74)	12.44 (3.53)	4.66 (2.13)
M_2	Emamectin benzoate 1.90% EC @7.5ml/10L fb Deltamethrin 02.80% EC @ 10 ml/10 L	7.56 (2.75)	5.70 (2.36)	13.33 (3.65)	7.92 (2.81)
M_3	Monocrotophos 36% SL @ 12.5 ml/10 L fb Emamectin benzoate 1.90% EC @ 7.5 ml/10 L	7.55 (2.75)	5.25 (2.27)	15.56 (3.94)	7.40 (2.71)
M_4	Lufenuron 5.40% EC @ 12 ml/10 L fb Lambda-cyhalothrin 5% EC @ 10 ml/10 L	8.42 (2.90)	3.62 (1.84)	13.78 (3.71)	4.96 (2.20)
M_5	Indoxacarb 15.80% EC @ 7 ml/10 L fb Lufenuron 5.40% EC @ 12 ml/10 L	7.54 (2.75)	3.10 (1.73)	15.56 (3.94)	3.70 (1.91)
M_6	Lambda-cyhalothrin 5%EC @10ml/10 L fb Monocrotophos 36% SL @ 12.5 ml/10 L fb	8.43 (2.90)	4.51 (2.09)	13.78 (3.71)	5.85 (2.34)
M_7	Untreated control	7.56 (2.75)	9.18 (3.02)	16.00 (4.00)	13.03 (3.60)
	'F' test	NS	Sig.	NS	Sig.
	SE (m)±	0.13	0.11	0.26	0.14
	CD at 5%	0.41	0.36	0.79	0.43
	CV (%)	8.25	9.47	11.86	9.61

(Figures in parentheses are the corresponding square root transformed values, DBS= Days before spraying)

3.4. Effect of different insecticide modules on percent pod and grain damage by pod borer complex at harvest.

3.4.1 Effect of different insecticide modules on percent pod damage by pod borer complex at harvest.

The efficacy of various insecticide modules in managing pod damage caused by *Helicoverpa armigera*, *Exelastis atomosa*, and *Melanagromyza obtusa* in pigeonpea is summarized in Table 4. The results revealed that all insecticide modules significantly reduced pod damage compared to the untreated control. Among the treatments, Module M_5 (Indoxacarb 15.80% EC @ 7 ml/10 L at 50% pod formation followed by Lufenuron 5.40% EC @ 12 ml/10 L at 15 days after the first spray) recorded the lowest pod damage across all pest categories i.e. 4.12% from lepidopteran pod borers, 4.40% from *M. obtusa*, and 4.26% from the pod borer complex, emerging as the most effective module. Module M_5 was found statistically at par with Module M_1 and Module M_4, which recorded 4.26% and

4.53% pod damage from lepidopterans, 4.77% and 4.94% pod damage from *M. obtusa*, and 4.60% and 4.65% pod damage from the overall pod borer complex, respectively.

The next group of effective modules included M_6, M_2, and M_3, which recorded 6.31%, 7.51%, and 7.13% pod damage, respectively, from lepidopteran borers; 6.25%, 7.51%, and 8.29% from *M. obtusa*; and 6.28%, 7.51%, and 7.71% overall pod damage from the pod borer complex. Although statistically inferior to M_5, M_1, and M_4, these modules still performed significantly better than the untreated control. The untreated control (M_7) consistently exhibited the highest pod damage, recording 7.90% from lepidopteran borers, 8.29% from *M. obtusa*, and 8.10% from the pod borer complex. These findings indicate that all tested insecticide modules were significantly effective in reducing pod damage, with the combination of Indoxacarb and Lufenuron (M_5) showing the most promising results against the pod borer complex in pigeonpea under field conditions.

3.4.2 Effect of different insecticide modules on percent grain damage by pod borer complex at harvest.

The efficacy of insecticide modules on percent grain damage caused by lepidopteran pod borers (*Helicoverpa armigera* and *Exelastis atomosa*) and the pod fly (*Melanagromyza obtusa*) in pigeonpea was assessed, and the results are presented in Table 4. All insecticidal treatments significantly reduced grain damage compared to the untreated control. Among the tested treatments, Module M_5 (Indoxacarb 15.80% EC @ 7 ml/10 L at 50% pod formation, followed by Lufenuron 5.40% EC @ 12 ml/10 L at 15 days after the first spray) consistently recorded the lowest grain damage across pest categories. Specifically, it resulted in 3.40% grain damage due to lepidopteran pod borers, 3.89% due to *M. obtusa*, and 3.64% due to the overall pod borer complex. This module was found to be significantly superior to all others and statistically at par with Modules M_1, M_4, and M_6, which recorded 3.87%, 3.65%, and 3.99% grain damage by lepidopteran borers, and 3.92%, 4.06%, and 5.04% grain damage by *M. obtusa*, respectively. Grain damage by the overall pod borer complex in these modules was also low, at 3.89%, 3.85%, and 4.51%, confirming their effectiveness and statistical similarity to Module M_5.

The next group of effective treatments included Module M_2 and Module M_3, which recorded 5.25% and 6.04% grain damage by lepidopteran borers, 6.14% and 6.93% damage by *M. obtusa*, and 6.09% and 6.13% grain damage by the pod borer complex, respectively. Although slightly less effective than the top-performing modules, these treatments still performed significantly better than the untreated control. The untreated control (M_7) consistently showed the highest grain damage, recording 8.13% from lepidopteran borers, 7.91% from *M. obtusa*, and 8.02% from the pod borer complex, thereby confirming the critical role of timely and effective insecticidal interventions in mitigating yield losses in pigeonpea caused by these pests.

Table 4: Effect of different insecticide modules on percent pod and grain damage by pod borer complex at harvest.

Tr. No. (Module)	Module details	Percent pod damage at harvest			Percent grain damage at harvest		
		Lepidopteran borer	*M. obtusa*	Pod borer complex	Lepidopteran borer	*M. obtusa*	Pod borer complex
M_1	Deltamethrin 02.80% EC @10ml/10L fb Indoxacarb 15.80% EC @ 7 ml/10 L	4.26 (2.06)	4.77 (2.18)	4.60 (2.15)	3.87 (1.97)	3.92 (1.98)	3.89 (1.97)
M_2	Emamectin benzoate 1.90% EC @7.5ml/10L fb Deltamethrin 02.80% EC @ 10 ml/10 L	7.51 (2.74)	7.51 (2.74)	7.51 (2.74)	6.04 (2.46)	6.14 (2.48)	6.09 (2.47)
M_3	Monocrotophos 36% SL @ 12.5 ml/10 L fb Emamectin benzoate 1.90% EC @ 7.5 ml/10 L	7.13 (2.67)	8.29 (2.88)	7.71 (2.78)	5.25 (2.29)	6.93 (2.63)	6.13 (2.48)
M_4	Lufenuron 5.40% EC @ 12 ml/10 L fb Lambda-cyhalothrin 5% EC @ 10 ml/10 L	4.53 (2.13)	4.94 (2.22)	4.65 (2.16)	3.65 (1.91)	4.06 (2.02)	3.85 (1.96)
M_5	Indoxacarb 15.80% EC @ 7 ml/10 L fb Lufenuron 5.40% EC @ 12 ml/10 L	4.12 (2.03)	4.40 (2.10)	4.26 (2.06)	3.40 (1.84)	3.89 (1.97)	3.64(1.91)
M_6	Lambda-cyhalothrin 5%EC @10ml/10 L fb Monocrotophos 36% SL @ 12.5 ml/10 L fb	6.31 (2.51)	6.25 (2.50)	6.28 (2.51)	3.99 (2.00)	5.04 (2.24)	4.51 (2.12)
M_7	Untreated control	7.90 (2.81)	8.29 (2.88)	8.10 (2.85)	8.13 (2.85)	7.91 (2.81)	8.02 (2.83)
	'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
	SE (m)±	0.13	0.13	0.12	0.12	0.14	0.13
	CD at 5%	0.41	0.40	0.38	0.37	0.44	0.39
	CV (%)	9.56	8.99	8.80	9.40	10.69	9.69

(Figures in parentheses are the corresponding square root transformed values, DBS = Days before spraying)

4. Conclusion

Modules M5 and M1 were found to be the most effective treatments for managing the pod borer complex in pigeonpea. Module M5 (Indoxacarb 15.80% EC @ 7 ml/10 L at 50% pod formation followed by Lufenuron 5.40% EC @ 12 ml/10 L at 15 days after the first spray) gave the highest grain yield and excellent pest control, while Module M1 (Deltamethrin 2.80% EC @ 10 ml/10 L at 50% pod formation followed by Indoxacarb 15.80% EC @ 7 ml/10 L at 15 days after the first spray) showed superior cost-effectiveness with the highest ICBR. Both modules significantly reduced pod and grain damage. Hence, they are recommended for sustainable and profitable pigeonpea cultivation.

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6. References

1. FAO. Food and Agriculture Organization of the United Nations. Rome: FAO; 2022.

2. FAO. Pulse production and pest challenges in Asia. Rome: Food and Agriculture Organization of the United Nations; 2023.
3. Indrasen R, Mishra VK, Kumar R. Efficacy of some newer insecticides against insect pests in pigeonpea ecosystem. J Exp Zool India. 2017;20(1):245-248.
4. Jadhav SV, Mohite PB, Kharbade SB. Relative efficacy of chitin synthesis inhibitor against *Helicoverpa armigera* (Hub.). Ann Plant Prot J. 2005;13(1):11-13.
5. Jadhav LD, Wankhade SG. Evaluation of chitin synthesis inhibitors against *Helicoverpa armigera* in chickpea. Indian J Plant Prot. 2005;33(1):45-48.
6. Jakhar BL, Kumar S, Ravindrababu Y. Efficacy of different newer insecticides against legume pod borer, *Maruca vitrata* (Geyer) on pigeonpea. Res Crops. 2016;17(1):134-136.
7. Ministry of Agriculture & Farmers Welfare (MoAF&W). Third advance estimate 2023-24. New Delhi: MoAF&W; 2024.
8. Muchhadiya DV, Patel JJ, Patel DR, Patel RB. Estimation of yield losses caused by insect pests on pigeonpea (*Cajanus cajan* L.). Int J Plant Soil Sci. 2024;36(3):410-414.
9. Prasad G. Bio-efficacy and dissipation of selective insecticides against pod borer complex in pigeonpea [MSc thesis]. Hyderabad: Acharya N.G. Ranga Agricultural University; 2012.
10. Prasad TV, Reddy SM, Rao PV. Bioefficacy of newer insecticides against pod borer complex in pigeonpea. Pest Manag Hortic Ecosyst. 2012;18(1):80-84.
11. Priyadarshini G. Bioefficacy and dissipation of selective insecticides against pod borer complex in pigeonpea [MSc thesis]. Hyderabad: ANGRAU; 2012.
12. Pathade MP, Salunk PB, Borkar SL. Evaluation of some insecticides against pigeonpea pod fly, *Melanagromyza obtusa* Mall. Indian J Agric Res. 2015;49(5):460-463.
13. Prajapati KK, Tiwari GN, Singh RK. Evaluation of some insecticides against major insect pests on pigeonpea (*Cajanus cajan* L.) [MSc thesis]. Varanasi: Banaras Hindu University; 2021.
14. Patoliya BV, Ghelani YH, Kachhadiya NM, Ghelani MK, Godhani HS. Estimation of yield losses due to infestation of pod borer *Helicoverpa armigera* in pigeonpea. Int J Adv Biochem Res. 2024;8(2):361-363.
15. Rana NS, Rana DK, Gupta A, Shukla BC, Sharma RN. Study of population dynamics of insect pests of pigeonpea. In: Proceedings of the national conference on pest management strategies for food security; 2008 May 2-3; Raipur, India. College of Agriculture, IGKV.
16. Ramkumar. Bioefficacy of some insecticides against the pod pest complex on pigeonpea [MSc thesis]. Varanasi: Banaras Hindu University; 2021.
17. Singh SS, Yadav SK. Bioefficacy of modern insecticides, biopesticides, and their combinations against pod borers in pigeonpea. Indian J Entomol. 2005;67(2):133-136.
18. Sharma OP, Gopali JB, Yelshetty S, Bambawale OM, Garg DK, Bhosle BB, *et al*. Pests of pigeonpea and their management. New Delhi: NCIPM, IARI Campus; 2010.
19. Thilagam P, Gopali JB, Kenganal M. Field bio-efficacy of insect growth regulators and insecticides against pod fly, *Melanagromyza obtusa* in pigeonpea. J Entomol Zool Stud. 2024;12(2):44-47.
20. Verma SK. Population dynamics, yield losses and efficacy of different insecticides against pod borer complex in pigeonpea [MSc thesis]. Raipur: Indira Gandhi Krishi Vishwavidyalaya; 2006.
21. Wadaskar RM, Bhalkare SK, Patil AN. Field efficacy of newer insecticides against the pod borer complex of pigeonpea. J Food Legumes. 2012;26(1-2):62-66.
22. Yadav JB, Verma RA. Efficacy of certain synthetic insecticides and biopesticides used as foliar application against gram pod borer *Helicoverpa armigera* (Hub). J Ent Res. 2007;31(4):327-329.
23. Sambathkumar S, Durairaj C, Ganapathy N, Mohankumar S. Field evaluation of newer insecticide molecules and botanicals against pod borers of Red gram. Legume Research-An International Journal. 2015;38(2):260-267.