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Efficacy of insecticides against pod borer complex in pigeonpea (*Cajanus cajan* (L.) Millsp.)

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Abstract
Background: Pigeonpea is one of the most widely grown pulse crop in India, and farmers should use recommended pesticides to harvest good yield instead of using ineffective and unknown agrochemicals.
Methods: A field trial was conducted at RLBCAU, Jhansi, (India), to study efficacy of *Beauveria bassiana*, chlorantraniliprole, cypermethrin, emmamectin benzoate, indoxacarb, profenophose, quinalphos, and spinosad against leaf webber, (*Maruca vitrata* Geyer), pod borer, (*Helicoverpa armigera*), and pod fly, (*Melanagromyza obtuse*) affecting pigeonpea crop during Kharif season 2020.
Result: Spinosad had the most extended residual effect on pigeonpea against all the insects, thus been able to save more than 90% of the pod and grain from insect damage, as well as reduce larval populations by 90%. The spinosad treated plots provided the higher benefit cost ratio and grain yield.

Keywords: efficacy, *Helicoverpa armigera*, Insecticides, *Maruca vitrata*, *Melanagromyza obtuse*

Introduction
Pulses are the world's most popular food, with India producing about 25% of global production, consuming 27%, and using 34% (Shukla and Mishra, 2020) [19]. Pigeonpea, the second important pulse crop after chickpea, is often grown in semi-arid and tropical regions of India (Sarkar *et al.*, 2020) [13]. In India, about 150 species of insects attack pulse crops (Seetharamu *et al.*, 2020). There are 38 species of Lepidopteran insects those damage pigeonpea crops worldwide (Shanower *et al.*, 1999) [15]. Pigeonpea crop is damaged severely by the gram pod borer, (*Helicoverpa armigera* Hubner); leaf webber, (*Maruca vitrata* Geyer), pod fly, (*Melanagromyza obtusa* Malloch), plume moth, (*Exelastis atomosa* Walsingham), and pod bugs. Under affirmative conduction, *Helicoverpa armigera* dislodged 60-90% of the grain yield, and *Melanagromyza obtusa* ranged from 10 to 90% (Durairaj, 2006) [4]. According to Randhawa and Verma (2011) [11], 26-28% of flower damage in pigeonpea was caused by *M. vitrata* whereas Singh and Singh (1990) reported that a variety of Hemipteran insects caused average 50% yield loss in pigeonpea. Management stratagies were chalked out based on the economic threshold level for *Maruca vitrata* (4.19 webs/plant), Manohar and Kumar, 2017); *Helicoverpa armigera* (2-4% pod infestation), Goyal *et al.*, 1990) [5], and *Melanagromyza obtusa* (4.60% pod damage), (Chiranjeevi and Patange, 2017) [3]. A pod borer was recognized during the 44th and 45th standard weeks of the Kharif season (Yadav *et al.*, 2021) [6]. Farmers successfully implement crop protection strategies proposed by scientists but farmers usually think that insect pest can be managed by only chemicals. Weeds, insect pests, fungi, bacteria, viruses, and nematodes are among the biotic stresses curbing pigeonpea productivity (Singh *et al.*, 2020) [21]. The farmscape approach is an adequate and reliable eco-friendly superintendence artifice (Sujayanand *et al.*, 2021) [18]. In pigeonpea crude protein and soluble sugar content were used to identify pod infestations where fat, phenol, and tannin content were also associated with insect pest resistance (Jat *et al.*, 2021) [6]. Therefore, a study was conducted in Bundelkhand to recommend insecticides those can be used by farmers to protect pigeonpea crops from insect pests infestation. The excessive use of insecticides may result in insecticidal resistance (Kranthi *et al.*, 2002) [8] and the resurgence of secondary insect pests, leading to yield losses may be seen.

Materials and Methods
Study location
The experiment was carried during Kharif 2020 at the Rani Lakshmi Bai Central Agricultural

University (RLBCAU), Jhansi (India), located at the latitude and longitude coordinates 25.4484° N, 78.5685° E. Average annual rainfall is 850 mm. Following randomized block design eight insecticides *viz.*, *Beauveria bassiana* 10%SC @ 100 gm *a.i.*/hectare (ha), chlorantraniliprole 18.5SC @ 30 gm *a.i.*/ha, cypermethrin 25EC @ 50 gm *a.i.*/ha, emmamectin benzoate 5SG @ 11 gm *a.i.*/ha, indoxacarb 58.8EC @ 50 gm *a.i.*/ha, profenophose 50EC @ 500 gm *a.i.*/ha, quinalphos 25EC @ 350 gm *a.i.*/ha, and spinosad 48SC @ 70 gm *a.i.*/ha *a.i.*/ha were evaluated in 3 x 3 m^2 plots size with 3 replications on pigeonpea cultivar 'Pusa Arhar-16' which was sown on last week of 21 June, 2020. The insecticides were applied twice i.e. first time with a high-volume, power-operated knapsack sprayer at 50 percent flowering and the second at 15th days later.

Larval population of *M. vitrata* and *H. armigera*, was counted randomly from five randomly tagged plants one day before and 3rd, 7th and 10th days after each spray. Webber larvae were collected from leaf webs. Pod fly population count of maggots per 10 pods was made from five tagged plants plot one day before and after the 14th day of spraying.

Insecticide efficacy (E) was assessed following the formula:

$$\text{Insecticide efficacy (E)} = \frac{(\text{T}-\text{t})}{\text{T}} \text{x}100$$

where, T is the mean number of alive larvae on control treatment, and t is the mean number of alive larvae on each insecticide treatment.

A sample of 100 mature pods was randomly picked from five tagged plants from each treatment after the second spray and the data carried out during harvest time. Using the Naresh and Singh (1984) [9] formula, the percent pod and grain damaged were worked out on laboratory.

$$\text{Per cent pod/grain damage} = \frac{\text{Number of infected pods/grains}}{\text{Total number of pods/grains}} \text{x}100$$

Data were analyzed ($\sqrt{x+0.5}$) using ANOVA after transformation (Taylor's Power Law, 1984).

The yield data for each treatment was kept separately during threshing. Based on the current market price, the benefit cost ratio was calculated.

Result and Discussion

Insecticidal efficacy against *M. vitrata*

All the insecticides significantly increased leaf webber larval mortality compared to the untreated control (Table 1). The larval population of leaf webber was reduced by 87.2% with spinosad. After three days, no significant differences were found among spinosad, indoxacarb and profenophose while at 7th and 10th days after spraying, spinosad and indoxacarb showed no significant differences in toxicity. After the first spray, the mortality rate in the larval population of *M. vitrata* was 39.1, 48.1, 48.8, 54.9, 65.4, 72.2, 78.9, and 87.2% following a second spray, it was 47.4, 63.4, 66.8, 74.3, 80.6, 84.6, 91.4, and 94.9% from *Beauveria bassiana*, cypermethrin, emmamectin benzoate, chlorantraniliprole, quinalphos, profenophose, indoxacarb, and spinosad treated plots, respectively. The spinosad was the most efficient way wherein webber larval numbers in the field significantly diminished with long-term residual effects on a crop. Rangawa and Saini (2015) [12] also observed that spinosad was the most effective insecticide against *M. vitrata*, followed closely by indoxacarb and cypermethrin.

Insecticidal efficacy against pod borer

Before spraying, there was no significant difference in larval populations (Table 2). However, after the first and second sprays, spinosad was continued declared to be superior in reducing the pod borer incidence (91.1% and 96.8%). After the first spray, the larval mortality rate did 82.3, 76.6, 76.0, 63.9, 60.2, 56.4, 54.5 percent from the treatments, indoxacarb 58.8EC, profenophose 50EC, quinalphos 25EC, chlorantraniliprole 18.5SC, emmamectin benzoate 5SG, cypermethrin 25EC, and *Beauveria bassiana* 10%SC, while after the second shower, it was 95.2, 89.5, 82.7, 78.2, 72.6, 69.8, 62.9 percent, respectively. Based on statistical analysis, spinosad 48SC was at par on the 3rd and 7th day after the first spray. At 7th and 10th days, it was at par with indoxacarb 58.8EC and emmamectin benzoate 5SG. The bio-efficacy of spinosad 45SC against *Helicoverpa armigera* in sorghum exhibited reduction in larval populations by 72.0% (Gandhi *et al.*, 2013).

Insecticidal efficacy against pod fly, *Melanagromyza obtusa*

On the day before spray, there was no significant difference in the larval population of pod fly (Table 3). Spinosad 48SC @ 70g a.i./ha was determined to be the best treatment that reduced the number of maggots present in damaged pods. It was the most effective at reducing maggot population (93.2%) followed by indoxacarb 58.8EC (89.0), emmamectin benzoate 5SG (83.0), profenophos 50EC (81.3), quinalphos 25EC (73.7), cypermethrin 25EC (71.2), chlorantraniliprole 18.5SC (71.2) and *Beauveria bassiana* 10SC. Niraj *et al.*, (2008) [10] finding also supports our conclusions.

Insecticidal efficacy against pod damage

Results (Table 4) showed that pod damage ranged from 7.0 to 85.3 pods with a pod damage reduction of 32.8 to 91.8 percent with different insecticidal treatments compared with an untreated control suffering 85.3 percent pod infestation. Spinosad, indoxacarb, emmamectin benzoate, and profenophos showed no significant difference in terms of reducing in maggot populations from a statistical point of view. The most effective insecticide treatment was spinosad 48SC, which reduced pod infestation by 91.8%, the corresponding significance as Indoxacarb 15.8EC. Earlier Keval *et al.*, (2016) [77], also reported the lowest pod damage when spinosad 45% SC @ 73 g a.i./ha was used.

Insecticidal efficacy against grain damage

Among the various chemicals tested that spinosad 48SG determined to be the most effective in reducing grain infestations caused by both pod borer and pod fly (Fig. 1). Spinosad 48SG was the most effective chemical tested against pigeonpea grain infestations caused by pod borer and pod fly. Spinosad, indoxacarb, profenophos, quinalphos, and chlorantraniliprole were all comparable with no significant differences. Distinct insecticides against pod bugs have been assessed for their efficacy. There were no significant differences between Indoxacarb 15.8EC, Spinosad 48SG and Emamectin benzoate 5SG. The results showed that the test insecticides reduced grain infestation significantly in comparison to the control. Spinosad 48SG, Indoxacarb 15.8EC were at par in reducing grain infestation and did not differ significantly. Reductions in grain infestation were arranged in decreasing order by percentage 92.1, 87.1, 72.1, 61.9, 58.9, 50.4 58.3, and 34.9 from spinosad 48SG, indoxacarb 15.8EC, profenophos 50EC, emmamectin benzoate 5SG, chlorantraniliprole 18.5SC, quinalphos 25EC, cypermethrin 25EC and *Beauveria bassiana* 10SC, respectively. Among the tested plots, Keval *et al.*, (2016) [7] noted the lowest grain damage to last recorded for spinosad 45% SC applied at 73 grams of a.i./ha. The present findings are in agreement with the ones by Sreekanth *et al*., (2014) [17] and Vikrant *et al.*, (2020) [21].

Grain yield and economics

Application of insecticides exhibited significant increase in grain yield of pigeonpea from 71.5 kg/ha to 266.5 kg/ha compared with the untreated plots (513 kg/ha). The maximum increased grain yield (266.6 kg/ha), and benefit cost ratio (3.1) was obtained from spinosad treated plots, followed by indoxacarb. The present findings are in agreement with the ones by Agale *et al.*, (2021) [1].

Table 1: Efficacy of novel insecticides against leaf webber, (*Maruca vitrata* Geyer)

Treatment	Dose *a.i*(kg)/ha	Population mean									
		1st spray					2nd spray				
		Before application	3rd DAS#	7th DAS	10th DAS	Reduction over control	Before application	3rd DAS	7th DAS	10th DAS	Reduction over control
Spinosad	0.07	9.3 (3.1)*	2.0 (1.5)	1.7 (1.4)	2.0 (1.4)	87.2	2.7 (1.7)	0.7 (1.1)	1.0 (1.2)	1.3 (1.3)	94.9
Indoxacarb	0.05	10.0 (3.2)	3.0 (1.8)	3.0 (1.8)	3.3 (1.8)	78.9	3.7 (2.1)	1.0 (1.2)	1.7 (1.5)	2.3 (1.6)	91.4
Profenophos	0.50	9.7 (3.1)	3.0 (1.8)	4.0 (2.0)	5.3 (2.3)	72.2	6.3 (2.6)	1.7 (1.4)	3.0 (1.8)	4.3 (2.1)	84.6
Quinalphos	0.35	8.0 (2.8)	4.3 (2.1)	4.7 (2.2)	6.3 (2.5)	65.4	7.3 (2.7)	3.0 (1.8)	3.7 (2.0)	4.7 (2.2)	80.6
Chlorantraniliprole	0.03	9.7 (3.2)	5.3 (2.4)	6.7 (2.6)	8.0 (2.8)	54.9	9.0 (3.0)	3.7 (1.9)	5.0 (2.3)	6.3 (2.4)	74.3
Emmamectin Benzoate	0.011	10.0 (3.2)	5.3 (2.4)	8.0 (2.8)	9.3 (3.1)	48.8	9.7 (3.1)	5.0 (2.3)	5.7 (2.4)	8.7 (2.9)	66.8
Cypermethrin	0.05	9.3 (3.1)	6.3 (2.5)	8.0 (2.8)	8.7 (2.9)	48.1	9.3 (3.1)	5.3 (2.3)	7.0 (2.7)	9.0 (3.0)	63.4
Beauveria bassiana	0.10	10.0 (3.2)*	8.0 (2.8)	9.3 (3.0)	9.7 (3.1)	39.1	10.7 (3.3)	8.7 (2.9)	9.7 (3.1)	12.3 (3.6)	47.4
Control	-	10.0 (3.2)	13.3 (3.7)	14.7 (3.9)	16.3 (4.1)	-	17.3 (4.1)	18.0 (4.3)	19.0 (4.4)	21.3 (4.7)	-
CD at 5%		NS	0.40	0.43	0. 47	-	NS	0.44	0.38	0.41	-
CV(%)		40.23	15.45	16.01	16.91	-	16.34	18.09	14.81	14.94	-

#Day after spray, *Figures in parentheses are transformed values (√x+0.5)

Table 2: Efficacy of novel insecticides against pod borer (*Helicoverpa armigera*)

Treatment	Dose *a.i*(g)/ha	Population mean									
		1st spray					2nd spray				
		Before application	3rd DAS#	7th DAS	10th DAS	Reduction over control	Before application	3rd DAS	7th DAS	10th DAS	Reduction over control
Spinosad	70	9.0 (3.0)*	0.7 (1.0)	1.3 (1.3)	2.7 (1.7)	91.1	3.3 (1.9)	0.3 (0.9)	0.7 (1.1)	1.7 (1.4)	96.8
Indoxacarb	50	9.3 (3.1)	2.3 (1.5)	3.0 (1.8)	4.0 (2.1)	82.3	5.0 (2.2)	0.7 (1.1)	1.3 (1.3)	2.0 (1.5)	95.2
Emmamectin Benzoate	11	9.0 (3.0)	3.0 (1.9)	4.0 (2.0)	5.3 (2.3)	76.6	7.3 (2.8)	2.3 (1.6)	2.7 (1.7)	3.7 (1.9)	89.5
Profenophos	500	8.7 (2.9)	3.3 (1.7)	4.0 (2.0)	5.3 (2.3)	76.0	8.0 (2.8)	4.0 (1.9)	4.7 (2.2)	5.7 (2.4)	82.7
Chlorantraniliprole	30	9.0 (3.0)	5.0 (2.1)	6.3 (2.5)	7.7 (2.8)	63.9	9.0 (3.0)	5.3 (2.3)	6.0 (2.4)	6.7 (2.6)	78.2
Quinalphos	350	8.3 (2.9)	5.0 (2.3)	7.0 (2.6)	9.0 (3.0)	60.2	10.3 (3.2)	6.7 (2.6)	7.7 (2.8)	8.3 (2.8)	72.6
Cypermethrin	50	8.7 (3.0)	6.0 (2.1)	8.0 (2.8)	9.0 (3.0)	56.4	9.7 (3.1)	7.3 (2.7)	8.3 (2.9)	9.3 (3.1)	69.8
Beauveria bassiana	100	7.3 (2.7)	6.3 (2.3)	8.0 (2.9)	9.7 (3.1)	54.5	10.3 (3.3)	9.3 (3.1)	10.0 (3.2)	11.3 (3.4)	62.9
Control	-	8.0 (2.8)	13.3 (3.2)	18.3 (4.2)	21.0 (4.6)	-	24.7 (5.0)	26.0 (5.1)	27.3 (5.3)	29.3 (5.5)	-
CD at 5%	-	NS	0.45	0.47	0.44	-	0.38	0.44	0.42	0.42	-
CV(%)	-	14.80	18.36	17.54	15.58	-	12.7	17.20	15.68	15.01	-

#Day after spray, *Figures in parentheses are transformed values (√x+0.5)

Table 3: Efficacy of novel insecticides against pod fly (*Melanagromyza obtuse*)

Treatment	Dose *a.i* (g)/ha	Maggot population mean				
		Before application	After 1st spray	Before application	After 2nd spray	Mean reduction over control (%)
Spinosad	70	6.3 (2.6)*	0.7 (1.1)	6.0 (1.6)	2.0 (1.6)	93.2
Indoxacarb	50	5.7 (2.4)	1.0 (1.2)	10.0 (1.8)	3.3 (1.8)	89.0
Emmamectin Benzoate	11	5.7 (2.4)	2.7 (1.7)	12.0 (2.0)	4.0 (2.0)	83.0
Quinalphos	350	6.0 (2.5)	2.7 (1.7)	14.0 (2.2)	4.7 (2.2)	81.3
Profenophos	500	6.0 (2.5)	3.7 (1.9)	20.0 (2.6)	6.7 (2.6)	73.7
Chlorantraniliprole	30	5.3 (2.3)	4.3 (2.1)	21.0 (2.7)	7.0 (2.7)	71.2
Cypermethrin	50	6.3 (2.6)	4.0 (2.0)	22.0 (2.8)	7.3 (2.8)	71.2
Beauveria bassiana	100	6.0 (2.5)	16.3 (4.0)	37.0 (3.5)	14.3 (3.7)	22.0
Control	-	6.0 (2.5)	17.3 (4.1)	66.0 (4.7)	22.0 (4.7)	
CD at 5%		NS	0.43	0.42	0.42	
CV(%)		13.91	17.56	15.21	15.11	

*Figures in parentheses are transformed values (√x+0.5)

Table 4: Efficacy of insecticides against pod and grain damaging and C:B ratio on pigeonpea

Treatments	Dose *a.i.*(gm)/ha	Pod infestation		Grain infestation					Increased yield over control# (kg/ha)	BCR
		Mean of pod infestation	Reduction over control (%)	By insect			Over all infestation	Reduction over control (%)		
				Pod borer	Pod fly	Pod bug				
Spinosad	70	7.0 (2.7)*	91.8	2.2 (8.1)$	3.4 (9.9)	1.5 (6.9)	2.4 (8.7)	92.1	266.5	1:3.1
Indoxacarb	50	12.3 (3.5)	85.5	3.5 (10.2)	5.1 (12.1)	3.0 (9.4)	3.9 (11.3)	87.1	254.6	1:3.0
Emmamectin Benzoate	500	11.7 (3.4)	86.3	5.9 (13.4)	9.8 (17.4)	8.4 (16.3)	12.3 (20.4)	72.1	230.7	1:2.5
Quinalphos	11	20.3 (4.5)	76.2	13.7 (20.9)	7.0 (14.6)	6.6 (13.9)	14.9 (22.2)	61.9	190	1:2.0
Profenophos	350	27.0 (5.1)	68.3	8.2 (15.9)	15.6 (22.3)	9.4 (17.4)	8.4 (16.7)	58.3	174.1	1:1.5
Chlorantraniliprole	30	27.7 (5.3)	67.6	9.2 (17.0)	11.5 (18.8)	13.7 (20.9)	12.5 (20.5)	58.9	142.1	1:1.7
Cypermethrin	50	37.7 (6.1)	55.8	17.5 (24.0)	20.5 (26.0)	13.6 (20.8)	11.4 (19.5)	50.4	122.4	1:1.3
Beauveria bassiana	100	57.3 (7.6)	32.8	20.2 (26.1)	23.7 (28.3)	14.7 (21.9)	19.5 (26.1)	34.9	71.5	1:0.1
Control	-	85.3 (9.3)	-	34.3 (35.4)	37.8 (37.6)	17.8 (24.7)	30.0 (32.9)	-	-	-
CD at 5%	-	0.44	-	9.05	10.57	8.04	4.69	-	-	-
CV(%)	-	11.43	-	20.1	23.12	19.57	10.41	-	-	-

#Grain yield from control = 513kg/ha; *Figures in parentheses are transformed values (√x+0.5) ; $Figures in parentheses are sine transformed values.

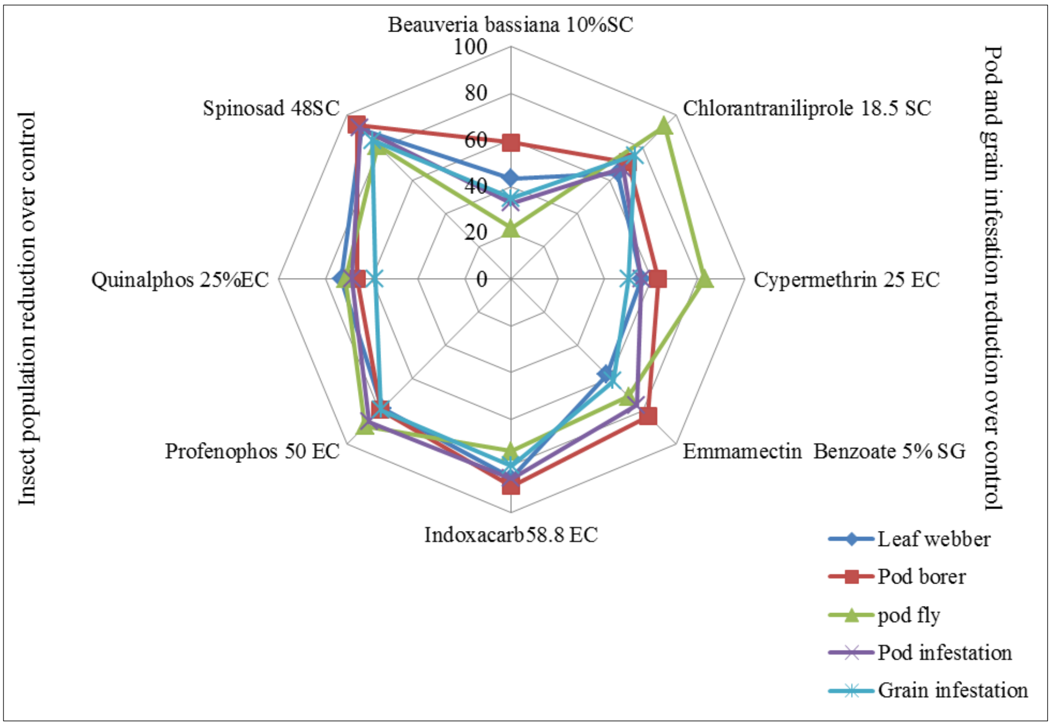

Fig 1: Efficacy of insecticides against leaf webber, pod borer, pod fly, pod and grain infestation reduction in pigeonpea in per cent (%)

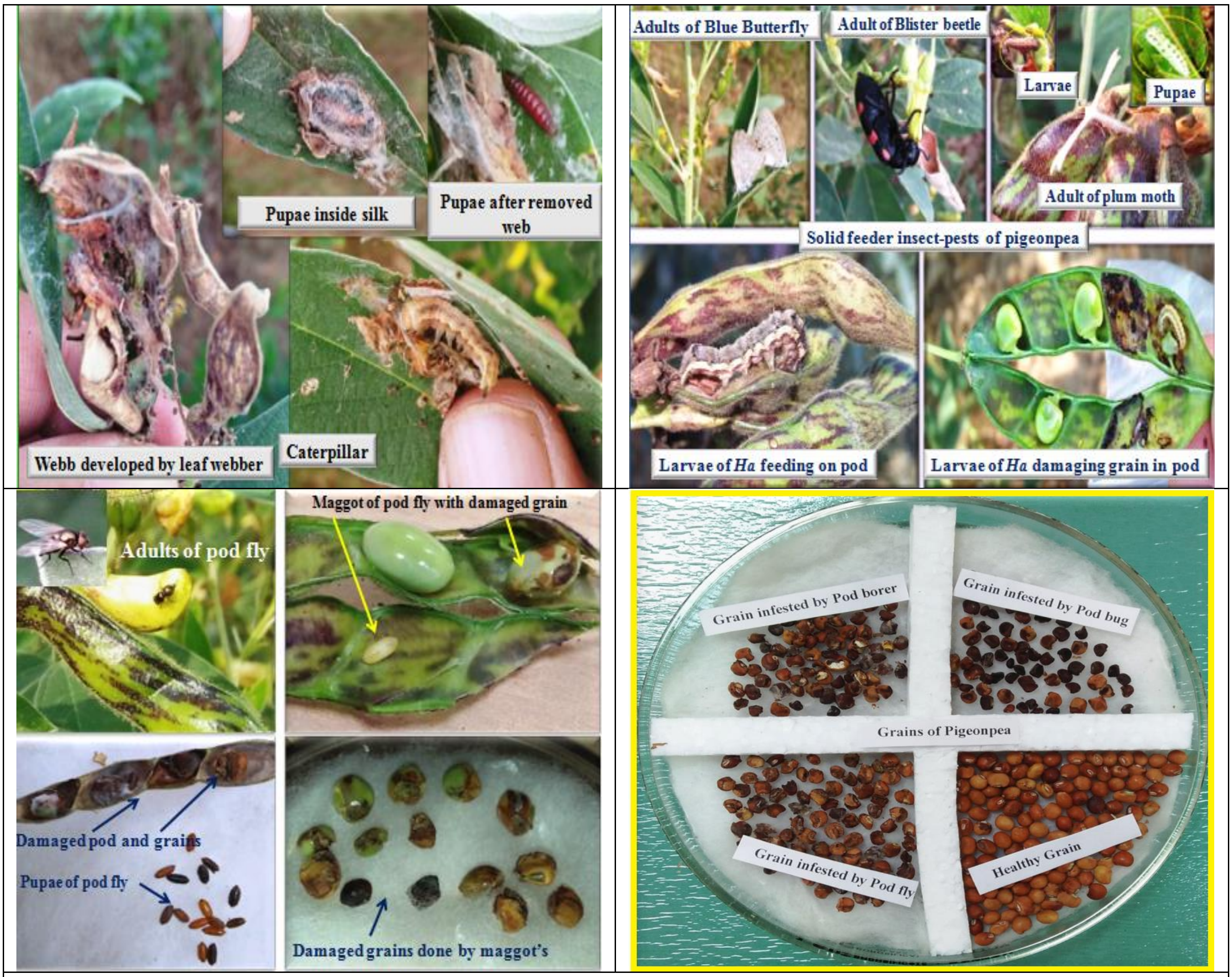

Fig 2: Insect pest infestation in pigeonpea crop and damaged grain by pod borer, pod fly and pod bugs

Plate-I

Conclusion

Looking at effectiveness and overall economic benefits of insect pests (pod borer complex and sap sucking pests) management in pigeonpea two insecticides namely, spinosad and indoxacarb can be recommended in Bundelkhand region of India. These insecticides will not only save pigeonpea crop from insect pests damage but also help in good harvest.

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