International Journal of Bio-resource and Stress Management https://pphouse.org/ijbsm.php

IJBSM March 2022, 13(3):261-267 Print ISSN 0976-3988 Online ISSN 0976-4038 Article AR2620b

Research Article Stress Management

DOI: HTTPS://DOI.ORG/10.23910/1.2022.2620b

Evaluation of Bio-rational Insecticides and Bio-pesticides Against Pod Borer Complex in Pigeon Pea

Bilash Chandra Das[1], Sandip Patra[2], A. Samanta[1] and P. P. Dhar[1]

[1]Dept. of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal (741 252), India
[2]ICAR Research Complex for NEH Region, Umiam, Meghalaya (793 103), India

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Corresponding bilash.ch.das@gmail.com

0000-0002-6684-4180

ABSTRACT

The field experiments were conducted at Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal, India during kharif seasons (July–October) of 2013 and 2014 to evaluate the efficacy of different bio-rational pesticides against the major production constrains of the pigeon pea which is the pod borer complex. The experiments were laid out following randomized block design comprising eleven treatments including control with three replications. Treatments were applied twice with pneumatic knapsack at fifteen days interval starting with initiation of target pest at pod formation stage. Pre-treatment counts of larvae of different lepidopteran borers had been taken from arbitrarily selected five tagged plants from every replication discarding the border effect and subsequently post treatment counts have been taken at 3, 7 and 14 days after each spray. Number of maggots per pod had been recorded for pod fly infestation at before spray and after spray at 7 and 14 days after each spray. Pooled of two years results revealed that flubendiamide recorded lowest mean larval population of *Helicoverpa armigera* (0.98 larvae plant^{-1}) and *Maruca vitrata* (0.65 larvae plant^{-1}) with highest seed yield.Among the bio-pesticides, *Bacillus thuringiensis* and azadirachtinfound to beeffective against pod borer complex in pigeon pea. Pooled of two seasons data showed that fenvalerate, spinosad and flubendiamide were effective treatments against pod fly with 1.13, 1.63 and 1.75 maggots pod^{-1} respectively.

KEYWORDS: Bio-pesticides, *Helicoverpa*, *Maruca*, *Melanagromyza*, *Maruca vitrata*, Spinosad

***Citation* (VANCOUVER):** Das et al., Evaluation of Bio-rational Insecticides and Bio-pesticides Against Pod Borer Complex in Pigeon Pea. *International Journal of Bio-resource and Stress Management,* 2022; 13(3), 261-267. HTTPS://DOI.ORG/10.23910/1.2022.2620b.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 14th September 2021 RECEIVED in revised form on 15th February 2022 ACCEPTED in final form on 19th March 2022 PUBLISHED on 31st March 2022

1. INTRODUCTION

Pulses remain as vital ingredient in the dietary habits of majority of the Indians, as they provide a mere perfect blend of vegetarian protein constituent of high biological value when supplemented with cereals. The protein malnutrition among the under privileged population mass has been resulted from significant reduction in the average protein intake from 66 g in 1965 to 33 g person^{-1} day^{-1} in 2005 (Saxena et al., 2018; Tomar and Talukdar, 2016). Pigeon pea is the second most important pulse crop after chickpea in India. Tur (Arhar) remained at 2nd position in total pulse production with 3.83 mt of production in an area of 4.54 mha at a yield of 842 kg ha^{-1}, during 2019-20 (Anonymous, 2020). According to Anonymous, 2017 statistics, the estimated globally sown pigeon pea area now stands at over 7.03 mha, with a production of 4.89 mt and average yield of 695 kg ha^{-1}. This crop suffers damage by over 200 insect species at different growth stages (Lateef and Reed, 1990). Pod borers are the key barriers for the low productivity of pigeon pea in India. The average productivity was as low as 604 kg ha^{-1} as compared to 728 kg ha^{-1} of total pulses production during 2014-15 (Anonymous, 2016). Insect pests damage is one of the major biotic factors of low productivity. The key pests include pod borer complex which cause significant losses in grain yield ranging from 30 to 100% (Satpute and Barkhade, 2012).Borer complex comprising of American bollworm, *Helicoverpa armigera* (Hubner); spotted pod borer, *Maruca vitrata* (F.); blue butterfly, *Lampides boeticus* (L.) and plume moth, *Exelastis atomosa* (Walsingham) inflicts serious damage to this crop. Besides other pests *viz*., pod fly, *Melanagromyza obtusa* (Malloch); different species of pod bugs, *Clavigralla gibbosa* Spinola and other species; Blister beetle, *Mylabris pustulata* Thunberg; Eriyophid mite, *Aceria cajani* (Acarina :Eriophyidae) have also been found to be important. (Nebapure et al., 2018). The estimates of avoidable losses due to pod borer complex, mainly pod fly and *Helicoverpa armigera* were 43.5 and 30.2%, respectively (Anonymous, 2012). In a survey conducted during 2007–2008 in the pigeon pea growing areas of the Nigeria Dailoke et al., 2010 reported upto 40.21% damage by pod borers (Dailoke et al., 2017). The tur pod fly, gram pod borer and spotted pod borer are major pod boring insects causing massive damage to this crop almost every year throughout India. Pod fly has been recognized as the most vital pest based on pod (55 to 85%) and grain (29 to 63%) damage (Landge, 2009) and 31.35% pod damage recorded from northeastern hill region (Patra et al., 2016). *Helicoverpa* is one of the major biotic components causing direct impact on the economic produce of the crop irrespective of agroclimatic zones of India. It's feeing on the reproductive parts of the arhar causes a challengeable menace to the quality and quantity of the final harvest. The estimated yield loss can be upto the tune of 60% or more due to the intensity of infestation of *H. armigera*at tropics(Anonymous, 2007). In recent years with the introduction of short duration pigeon pea cultivars the damage caused by *M.vitrata* has been intensified (Sharma et al., 1999). The yield losses by this species in pigeon pea have been estimated to be around $US 30 million annually (Anonymous, 1992) whereas Singh (1999) reported 70-80% yield loss in this crop. To combat the pod borer complex of red gram huge quantity of insecticides are being used by the farmers which imparts detrimental effect on both environment and the natural enemy complex present in the ecosystem. Extensive use of conventional chemical insecticides may lead to the development of resistance to insecticides, outbreaks of secondary pests and the problem of residues in the food and fodder as chemical control is the most effective and produce instantaneous effects in reducing these menaces. Therefore, keeping these views in mind the present experiments were conducted to formulate an effective bio rational strategy comprising insecticides against pod borer complex in pigeon pea.

2. MATERIALS AND METHODS

The field experiments were conducted at Bidhan Chandra Krishi Viswavidyalaya (BCKV), Kalyani, Nadia (22°58'60 N latitude, 88°28'60 E longitude and at an altitude of 9.75 m from MSL), West Bengal, India to evaluate the bio-rational insecticides and bio-pesticides against pod borer complex in pigeon pea. The field trials were conducted on medium high land with sandy loam soil having pH almost neutral. Pigeon pea (Variety: UPAS 120) seeds was sown in the plots of 20 m^2 area with 60×20 cm^2 (R-R×P-P) spacing during *kharif* season (July–October) of 2013 and 2014. Standard agronomical management practices except pest management were followed for raising the crop. The experiments were carried out in randomized block design (RBD) with eleven treatments including control with three replications. Treatments *viz.* flubendiamide 480 SC @ 60 g a.i. ha^{-1} (0.25 ml l^{-1}), indoxacarb14.5 SC @ 75 g a.i. ha^{-1} (1 ml l^{-1}), spinosad 45 SC @ 75 g a.i. ha^{-1} (0.30 ml l^{-1}), *Metarhizium anisopliae* (1×10^8 CFU g^{-1}, WP) (5 g l^{-1}), *Beauveria bassiana* (1×10^8 CFU g^{-1}, WP) (5 g l^{-1}), *Bacillus thuringiensis* (18000 IU mg^{-1}, WP) (5 g l^{-1}), anonin1 EC @ 100 g a.i. ha^{-1} (2 ml l^{-1}), azadirachtin 1% EC @ 100 g a.i. ha^{-1} (2 ml l^{-1}), karanjin 2 EC @ 50 g a.i. ha^{-1} (2 ml l^{-1}), fenvalerate 20 EC @ 100 g a.i. ha^{-1} (1 ml l^{-1}) and control (water spray). First spray was given at pod initiation stage with the initiation of target pests and subsequently second spray was applied after 15 days interval of first spray.Spraying was conducted with pneumatic knapsack sprayer using spray volume @ 500 l ha^{-1}. Pre-treatment counts of larvae of different lepidopteran borers had been recorded from randomly selected five tagged plants from each replication discarding the border effect and subsequently post treatment counts have been taken at 3, 7 and 14 days after each spray. For assessing damage caused by pod fly 50 pods from each treatment had been harvested and observed for damage at before spray and after spray at 7 and 14 days after each spray. Number of maggots pod^{-1} had been recorded for pod fly infestation. After maturity of the crop the pods were harvested, dried and threshed separately for each replication for calculation of seed yield of pigeon pea. The pooled data on infestation of different pod borers on UPAS 120 before and after spray of different insecticides had been transformed into square root transformed values and then data were subjected to analysis of variance (ANOVA) as per randomized block design to calculate the critical difference (CD) at 5% level of significance.

3. RESULTS AND DISCUSSION

3.1. *Efficacy of different treatments against Helicoverpa armigera in pigeon pea.*

Pooled efficacy of different treatments against larvae of *H. armigera* is depicted in Table 1. Pre-treatment observation showed that there was no significant difference among the treatments. Successive observations during first and second spray revealed that there was clearly significant variation among the treatments. The most effective treatment was Flubendiamide which recorded minimum mean population of 0.98 larvae plant^{-1} and 80.71% reduction over control followed by spinosad and indoxacarb with 1.22 and 1.41 larvae plant^{-1} and 76.15 and 72.46% reduction over control. The botanical and microbial treatments were comparatively less effective in controlling *Helicoverpa* but all these treatments were superior over untreated control

Table 1: Mean effect of insecticides against *Helicoverpa armigera* during 2013 and 2014 (Pooled of two seasons)

Treatments	Dose (ml l^{-1})	*H. armigera* larvae plant^{-1} before spray	Number of *Helicoverpa armigera* larvae plant^{-1}						Overall mean larvae plant^{-1}	Reduction over control (%)
			First spray			Second spray				
			3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
Flubendiamide 480 SC	0.25	2.53 (1.74)	1.19 (1.30)	0.92 (1.18)	1.15 (1.27)	0.82 (1.14)	0.68 (1.07)	1.14 (1.27)	0.98 (1.21)	80.71
Indoxacarb 14.5 SC	1.00	2.01 (1.54)	1.88 (1.53)	1.22 (1.30)	1.68 (1.47)	1.24 (1.31)	1.01 (1.22)	1.41 (1.37)	1.41 (1.37)	72.46
Spinosad 45 SC	0.30	3.41 (1.94)	1.56 (1.42)	1.07 (1.24)	1.33 (1.35)	1.00 (1.22)	0.87 (1.17)	1.31 (1.34)	1.22 (1.29)	76.15
M. anisopliae	5.00	4.03 (2.11)	3.66 (2.03)	3.28 (1.94)	3.78 (2.06)	3.39 (1.97)	3.03 (1.87)	3.45 (1.98)	3.43 (1.98)	33.10
B. bassiana	5.00	4.39 (2.14)	3.74 (2.05)	3.03 (1.87)	3.55 (2.00)	3.00 (1.86)	2.75 (1.79)	3.36 (1.95)	3.24 (1.93)	36.80
Bt.	5.00	3.46 (1.98)	2.29 (1.66)	2.09 (1.60)	2.73 (1.79)	2.32 (1.67)	2.03 (1.58)	2.57 (1.74)	2.34 (1.68)	54.42
Anonin 1% EC	2.00	3.56 (1.98)	3.33 (1.95)	3.20 (1.92)	3.77 (2.06)	2.81 (1.81)	2.50 (1.72)	3.13 (1.90)	3.12 (1.90)	39.15
Azadirachtin 1% EC	2.00	3.89 (2.06)	3.10 (1.89)	2.89 (1.83)	3.46 (1.98)	3.05 (1.88)	2.78 (1.80)	3.31 (1.94)	3.10 (1.89)	39.53
Karanjin 2% EC	2.00	4.34 (2.18)	3.84 (2.08)	3.09 (1.89)	3.85 (2.08)	3.38 (1.96)	2.61 (1.76)	3.36 (1.96)	3.35 (1.96)	34.66
Fenvalerate 20 EC	1.00	3.03 (1.83)	2.12 (1.61)	1.38 (1.36)	2.27 (1.66)	1.68 (1.46)	1.47 (1.39)	2.10 (1.60)	1.84 (1.52)	64.12
Control	-	3.53 (1.98)	4.55 (2.24)	4.74 (2.28)	4.98 (2.33)	5.15 (2.37)	5.56 (2.45)	5.88 (2.52)	5.14 (2.37)	-
SEm±	-	0.18	0.02	0.02	0.02	0.02	0.02	0.02	0.02	-
CD (p=0.05)	-	NS	0.05	0.06	0.05	0.06	0.06	0.06	0.05	-

Data in parenthesis are the square root transformed values √ (x+0.5) plots (5.14 larvae plant^{-1}). Among the bio-pesticides, *Bt* (2.34 larvae plant^{-1}), azadirachtin (3.10 larvae plant^{-1}) and annonin (3.12 larvae plant^{-1}) showed better performances in controlling the larvae.

3.2. Efficacy of different treatments against Maruca vitrata in pigeon pea.

Pooled results of two years experiments for efficacy of different treatments against *M. vitrata* is presented in Table 2. Pre-treatment data revealed no significant difference among the treatments before spraying. At different days of interval after both sprays, there has been a significant difference among the treatments in managing the population of *Maruca* in pigeon pea.The pooled data (Table 2) of two years experiments showed that the minimum population and highest percent reduction were recorded in flubendiamide (0.65 larvae plant^{-1} and 91.83% reduction)treated plots among the treatments followed by spinosad (0.80 larvae plant^{-1}), indoxacarb (1.23 larvae plant^{-1}), fenvalerate (1.54 larvae plant^{-1}), *Bt.* (3.56 larvae plant^{-1}), azadirachtin (3.84 larvae plant^{-1}), *B. bassiana* (4.42 larvae plant^{-1}), annonin (4.53 larvae plant^{-1}), karanjin (4.64 larvae plant^{-1}) and *M. anisopliae* (4.86 larvae plant^{-1}) with 89.91, 84.55, 80.53, 55.07, 51.50, 44.19, 42.80, 41.45 and 38.61% reduction over control (7.90 larvae plant^{-1}).

Table 2: Mean effect of insecticides against *Maruca vitrata* during 2013 and 2014 (Pooled of two seasons)

Treatments	Dose (ml l^{-1})	*Maruca vitrata* larvae plant^{-1} before spray	Number of *Maruca vitrata* larvae plant^{-1}						Overall mean larvae plant^{-1}	Reduction over control (%)
			First spray			Second spray				
			3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS		
Flubendiamide 480 SC	0.25	4.85 (2.31)	0.68 (1.08)	0.53 (1.01)	0.92 (1.18)	0.45 (0.97)	0.27 (0.87)	1.06 (1.24)	0.65 (1.07)	91.83
Indoxacarb 14.5 SC	1.00	4.84 (2.31)	1.36 (1.36)	1.00 (1.22)	1.58 (1.43)	1.29 (1.32)	0.87 (1.15)	1.27 (1.33)	1.23 (1.31)	84.55
Spinosad 45 SC	0.30	5.40 (2.43)	0.96 (1.20)	0.66 (1.07)	1.03 (1.23)	0.59 (1.04)	0.59 (1.04)	0.99 (1.22)	0.80 (1.14)	89.91
M. anisopliae	5.00	5.11 (2.36)	5.41 (2.41)	4.71 (2.26)	5.15 (2.35)	4.71 (2.25)	4.50 (2.22)	4.70 (2.26)	4.86 (2.30)	38.61
B. bassiana	5.00	4.96 (2.33)	4.94 (2.32)	4.45 (2.21)	4.57 (2.24)	4.40 (2.18)	3.72 (2.04)	4.43 (2.20)	4.42 (2.20)	44.19
Bt.	5.00	5.42 (2.43)	3.67 (2.02)	3.28 (1.93)	3.95 (2.09)	3.52 (1.97)	3.05 (1.85)	3.92 (2.09)	3.56 (2.00)	55.07
Anonin 1% EC	2.00	5.32 (2.41)	4.96 (2.32)	4.33 (2.18)	4.92 (2.31)	4.27 (2.16)	3.99 (2.10)	4.70 (2.27)	4.53 (2.23)	42.80
Azadirachtin 1% EC	2.00	4.86 (2.31)	3.94 (2.09)	3.54 (1.98)	4.36 (2.18)	3.52 (1.98)	3.39 (1.94)	4.28 (2.13)	3.84 (2.05)	51.50
Karanjin 2% EC	2.00	5.27 (2.40)	5.23 (2.37)	4.66 (2.25)	4.99 (2.32)	4.72 (2.27)	3.92 (2.08)	4.31 (2.17)	4.64 (2.25)	41.45
Fenvalerate 20 EC	1.00	5.28 (2.40)	2.41 (1.70)	1.19 (1.29)	2.05 (1.58)	1.06 (1.24)	0.75 (1.10)	1.81 (1.51)	1.54 (1.42)	80.53
Control	-	4.88 (2.32)	5.47 (2.43)	6.74 (2.67)	7.85 (2.87)	8.37 (2.96)	9.09 (3.08)	9.89 (3.20)	7.90 (2.88)	-
SEm±	-	0.05	0.07	0.07	0.08	0.09	0.09	0.08	0.07	-
CD (p=0.05)	-	NS	0.19	0.19	0.24	0.26	0.27	0.24	0.18	-

Data in parenthesis are the square root transformed values $\sqrt{(x+0.5)}$

3.3. Efficacy of different treatments against Melanagromyza obtusa in pigeon pea.

Pooled effect of different treatments against *M. obtusa* is illustrated in the Table 3. The pre-treatment count of maggots pod^{-1} was nonsignificant for all the treatment. After the two sprays the overall mean maggots pod^{-1} was significantly different among the treatments. The maximum reduction over control was achieved in fenvalerate with

Table 3: Mean effect of insecticides against *Melanagromyza obtusa* during 2013 and 2014 (Pooled of two seasons.)

Treatments	Dose (ml l^{-1})	*M. obtusa* maggot plant^{-1} before spray	No. of *Melanagromyza obtusa* maggot pod^{-1}				Overall mean maggot pod^{-1}	Reduction over control (%)
			First spray		Second spray			
			7 DAS	14 DAS	7 DAS	14 DAS		
Flubendiamide 480 SC	0.25	1.51 (1.68)	1.53 (1.36)	2.13 (1.54)	1.33 (1.29)	1.99 (1.50)	1.75 (1.43)	61.55
Indoxacarb 14.5 SC	1.00	2.53 (1.71)	1.59 (1.36)	2.40 (1.60)	1.17 (1.24)	2.49 (1.62)	1.91 (1.47)	57.96
Spinosad 45 SC	0.30	1.96 (1.51)	1.09 (1.21)	2.12 (1.53)	1.23 (1.26)	2.10 (1.53)	1.63 (1.39)	64.17
M. anisopliae	5.00	1.10 (1.51)	1.82 (1.44)	3.43 (1.85)	2.39 (1.60)	3.09 (1.78)	2.68 (1.68)	41.25
B. bassiana	5.00	1.71 (1.77)	2.12 (1.53)	3.39 (1.84)	2.01 (1.50)	3.69 (1.91)	2.80 (1.71)	38.64
Bt.	5.00	1.59 (1.51)	2.18 (1.54)	3.53 (1.87)	2.58 (1.65)	3.40 (1.84)	2.92 (1.73)	36.04
Anonin 1% EC	2.00	1.64 (1.39)	1.43 (1.33)	3.76 (1.92)	2.80 (1.70)	3.90 (1.95)	2.97 (1.75)	34.95
Azadirachtin 1% EC	2.00	1.69 (1.42)	1.48 (1.30)	3.05 (1.77)	2.00 (1.50)	3.22 (1.81)	2.44 (1.61)	46.91
Karanjin 2% EC	2.00	2.49 (1.63)	1.88 (1.46)	2.63 (1.66)	1.70 (1.41)	2.77 (1.70)	2.24 (1.56)	51.35
Fenvalerate 20 EC	1.00	1.26 (1.57)	0.77 (1.08)	1.75 (1.43)	0.81 (1.11)	1.18 (1.24	1.13 (1.23)	75.32
Control	-	1.77 (1.41)	3.32 (1.83)	4.02 (1.98)	4.91 (2.15)	6.08 (2.36)	4.58 (2.09)	-
SEm±	-	0.21	0.07	0.06	0.09	0.09	0.07	-
CD (p=0.05)	-	NS	0.20	0.16	0.24	0.24	0.20	-

Data in parenthesis are the square root transformed values $\sqrt{(x+0.5)}$

75.32% reduction followed by spinosad, flubendiamide, indoxacarb, karanjin and azadirachtin with 64.17, 61.55, 57.96, 51.35 and 46.91% reduction. Other treatments were also found to be effective in reducing the population of *M. obtusa* over untreated control plots (4.58 maggots pod^{-1}).

3.4. Effect of bio-rational insecticides and bio-pesticides on seed yield of pigeon pea

During 2013, the highest yield was recorded for flubendiamide (1638.58 kg ha^{-1}) followed by spinosad (1470.35 kg ha^{-1}), indoxacarb (1325.97 kg ha^{-1}), fenvalerate (1274.75 kg ha^{-1}) (Table 4). Among the bio-pesticides, azadirachtin found to be the best in recording comparatively higher yield with 1190.01 kg ha^{-1} and was statistically at par with karanjin (1027.92 kg ha^{-1}). In the year 2014, the same trend of yield had been followed. The best treatment was flubendiamide with 1889.04 kg ha^{-1} and the lowest was annonin with 731.84 kg ha^{-1} of seed yield. The Pooled results revealed that flubendiamide treated plots recorded highest mean yield of 1763.81 kg ha^{-1} followed by spinosad (1607.75 kg ha^{-1}), fenvalerate (1424.27 kg ha^{-1}) and indoxacarb (1419.49 kg ha^{-1}). Among the bio-pesticides, azadirachtin recorded good seed yield (1301.21 kg ha^{-1}) as compared to others. From pooled data, it was clearly showed that all the treatments were significantly effective in increasing the yield over untreated control plots (347.81 kg ha^{-1}).

The present study showed that flubendiamide, spinosad, indoxacarb and fenvalerate were very much effective against lepidopteran borers, *Maruca vitrata* and *Helicoverpa armigera*. The present results may be corroborated with the findings of Ameta and Bunker (2007), who revealed that

Table 4: Mean effect of bio-rational insecticides and bio-pesticides on yield of pigeon pea during 2013 and 2014 (Pooled of two seasons)

Treatments	Dose (ml or g l^{-1})	Seed yield (kg ha^{-1})		
		2013	2014	Mean (Pooled of two years)
Flubendiamide 480 SC	0.25	1638.58	1889.04	1763.81
Indoxacarb 14.5 SC	1.00	1325.97	1513.00	1419.49
Spinosad 45 SC	0.30	1470.35	1745.15	1607.75
Metarhizium anisopliae	5.00	685.24	813.28	749.26
Beauveria bassiana	5.00	735.68	873.17	804.43
Bacillus thuringiensis	5.00	939.12	1114.64	1026.88
Anonin 1 EC	2.00	616.60	731.84	674.22
Azadirachtin 1 EC	2.00	1190.01	1412.40	1301.21
Karanjin 2 EC	2.00	1027.92	1220.03	1123.97
Fenvalerate 20 EC	1.00	1274.75	1573.80	1424.27
Control	-	310.78	384.84	347.81
SEm±	-	62.69	23.28	33.43
CD (p=0.05)	-	184.89	68.66	95.56

Data in parenthesis are the square root transformed values √ (x+0.5)

flubendiamide, indoxacarb and spinosad were significantly superior to untreated control in reducing *H. armigera* infestation in tomato. The findings are in line of Neupane and Sah (1988) who reported the higher effectiveness of deltamethrin, fenvalerate and cypermethrin against the noctuid *Heliothis armigera* [*Helicoverpa armigera*] infesting the pigeon pea. The present findings can also be supported by the by the findings of Das et al. (2015) who suggested that mixed formulation of novaluron+indoxacarb and novaluron+fipronil were the most effective against *H. armigera* and *Melanagromyza obtusa* in pigeon pea. In the present study, the efficacies of the botanical and microbial insecticides can be explained with the findings of Singh and Yadav (2006) who studied the efficacy of indoxacarb, spinosad, carbosulfan, endosulfan, 2 *Bacillus thuringiensis*-based insecticides (Halt and Biolep), and 3 neem-based formulations (Nimbicidine, Neemarine and Achook) against *H. armigera* on pigeon pea cv. Pusa-992. Indoxacarb was the most effective in the reduction of crop damage, followed by spinosad and carbosulfan. Among bio insecticides, Halt was superior to Biolep and neem-based formulations. Nahar et al. (2004) revealed that *M. anisopliae* isolate M34412 conidia in an oil formulation of diesel and sunflower oil at 7:3 ratio was the most effective in controlling *H. armigera*. The bio-efficacy study against *M. obtusa* suggests that fenvalerate, spinosad and flubendiamide were most effective respectively. These results can be corroborated with the findings of Ram (1999) who evaluated foliar spray and dust insecticidal treatments for the control of major insect pest borers (*Maruca testulalis* [*M. vitrata*], *Helicoverpa armigera* and *Melanagromyza obtusa*) on early pigeon pea (*Cajanus cajan*) during the kharif seasons of 1989-93 and reported that quinalphos, fenvalerate, deltamethrin and fenvalerate were effective at reducing pod borer damage and losses in grain yield.

4. CONCLUSION

Flubendiamide was the best treatment against *Helicoverpa armigera* and *Maruca vitrata* followed by spinosad and indoxacarb whereas fenvalerate was effective treatment against pod fly followed by spinosad and flubendiamide. Therefore, flubendiamide and spinosad against lepidopteran borers and fenvalerate against pod fly may be recommended for effective management of pod borer complex in pigeon pea. Among the bio-pesticides, *Bacillus thuringiensis* and azadirachtin may be incorporated in integrated pest management of pod borer complex in pigeon pea.

5. ACKNOWLEDGEMENT

First author is highly grateful to the Department of Science and Technology, Ministry of Science and Technology, Government of India for providing financial support through Inspire Fellowship (Sanction order no:DST/Inspire Fellowship/2013/IF130286 dated 28th May, 2013) during Doctoral Degree Programmeand authors are also duly acknowledged to the Director, Indian Institute of Pulse Research, Kanpur, India for supplying seeds of pigeon pea for conducting the experiments.

6. REFERENCES

Ameta, O.P., Bunker, G.K., 2007. Efficacy of flubendiamide against fruit borer, *Helicoverpa armigera* in tomato with safety to natural enemies. Indian Journal of Plant Protection 35, 235–237.

Anonymous, 1992. ICRISAT (International Crops Research Institute for the Semi-arid Tropics), 1992. The medium term plan. Patancheru 502324, Andhra Pradesh, India,103.

Anonymous, 2007. The medium term plan. ICRISAT, Patancheru 502324, Andhra Pradesh, India 3, 1–10.

Anonymous, 2012. Annual report national centre for integrated pest management, LBS Building, Pusa

Campus, New Delhi-110012; ipmnet@bol.net.in: www.ncipm.org.in.,1–113.

Anonymous, 2016. AICRP on MULLaRP. Annual Report. All India Coordinated Research Project on MULLaRP, Indian Institute of Pulses Research, Kanpur 208 024, India available at: https://iipr.icar.gov.in/aicrp.html accessed on July 18,2017

Anonymous, 2017. FAOSTAT. URL: Available at http://www.faostat3.fao.org. Accessed on July 17, 2017.

Anonymous, 2020. Agricultural statistics at a Glance - Min. of Agri. & FW (DAC&FW), GOI, pp 64.Available at https://eands.dacnet.nic.in/PDF accessed on March 13, 2022

Das, B.C., Patra, S., Dhote, V.W., Alam Sk, F., Chatterjee, M.L., Samanta, A., 2015. Mix formulations: An alternative option for management of gram pod borer, *Helicoverpa armigera* H. and pod fly, *Melanagromyza obtusa* M. in pigeon pea. Legume Research38, 396–401.

Dialoke, A., Emosairue, S., Akparobi, S.O., Nwosu, L., Ogbedeh, K., Onyirioha, C., Echerobia, E.O., 2017. Management of pod borer *Helicoverpa armigera* Hubner) on Pigeonpea (*Cajanus cajan* (L.) Millsp.: using plant density and planting dates for increased yield in owerri. Nigeria. Nigeria Journal of Entomology 33, 83–92. 10.36108/NJE/7102/33(0101).

Dialoke, S.A., Agu, C.M., Ojiako, F.O., Onweremadu, E., Onyishi, G.O., Ozor, N., Echezona, B.C., Ofor, M.O., Ibeawuchi, J.I., Chigbundu, 1.N., Ngwuta, A.A., Ugwoke, F.O., 2010. Survey of insect pests on pigeonpea in Nigeria. journal of SAT Agricultural Research, ICRISAT, INDIA8, 1–8

Gomez, K.A., Gomez, A.A., 1984. Statistical procedures for agricultural research. John Wiley & Sons.

Landge, K.S., 2009. Studies on pest complex of pigeon pea *Cajanus cajan* (L.) and their management under late sown condition. M.Sc. (Ag). thesis submitted to JNKVV Jabalpur., 1–164.

Lateef, S.S., Pimbart, M.P., 1990. The search for host plant resistance of *H.armigera* in chickpea and pigeon pea at ICRISAT. (In) Host Selection and Behavior of *H. armigera* Sunmary. (In) Proceedings of first Consumptative Group Meeting, 5-7 March, Patencheru, A.P., 14–16.

Nahar, P., Yadav, P., Kulye, M., Hadapad, A., Hassani, M., Tuor, U., Keller, S., Chandele, A.G., Thomas, B., Deshpande, M.V., 2004. Evaluation of indigenous fungal isolates, *Metarhizium anisopliae* M34412, *Beauveria bassiana* B3301 and *Nomuraearileyi* N812 for the control of *Helicoverpa armigera* (Hubner) in pigeon pea field. Journal of Biological Control, 18, 1–7.

Nebapure, S., Dodda, C., Sagar, Chander, S., 2018. Population dynamics of insect pests on short duration pigeon pea in relation to weather parameters. Journal of Agrometeorology 20, 234–237.

Neupane, F.P., Sah, L.N., 1988. Efficacy of some insecticides against the chickpea pod borer, *Heliothis armigera* Hübner. Journal of the Institute of Agriculture and Animal Science 9, 103–105.

Patra. S., Firake, D.M., Azad Thakur, N.S., Roy, A., 2016. Insect pest complex and crop losses in pigeon pea in medium altitude hill of Meghalaya. The Bioscan 11, 297–300.

Ram, U., 1999. Field efficacy of insecticides against pod borer complex in early pigeon pea, *Cajanus cajan* (L.) Millsp.at Pantnagar, Northern India. Annals of Plant Protection Sciences 7, 19–25.

Satpute, N.S., Barkhade, U.P., 2012. Evaluation of rynaxypyr 20 SC against pigeonpea pod borer complex. Journal Food Legumes 25, 162–163.

Saxena, K., Choudhary, A., Saxena, R., Varshney, R., 2018. Breeding pigeonpea cultivars for intercropping: Synthesis and strategies. Breeding Science 68. Doi: 10.1270/jsbbs.17105.

Sharma, H.C., Saxena, K.B., Bhagwat, V.R., 1999. The Legume pod borer, *Maruca vitrata*: Bionomics and management. International crops research institute for the semi-arid tropics, Patancheru, Andhra Pradesh. Information Bulletin, 55.

Singh, S.P., 1999. The eco-friendly approach. The Hindu: Survey of Indian Agriculture, 175–184.

Singh, S.S, Yadav, S.K., 2006. Efficacy and economics of some modern insecticides, bioinsecticides and neem-based formulations against pod borer, *Helicoverpa armigera*, in pigeon pea. Indian Journal Entomology 68, 139–143.

Tomar, S.M.S., Talukdar, A., 2016. About the special issue, Editorial message. Indian Journal of Human Genetics 76 (Editorial Message).