Evaluation of *Bt* liquid formulations against gram pod borer, *Helicoverpa armigera* (Hubner) and spotted pod borer, *Maruca vitrata* (Geyer) in Pigeonpea

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ABSTRACT

A field experiment was conducted during 2012-15 at Regional Agricultural Research Station, Lam, Guntur district, Andhra Pradesh to evaluate the efficacy of *Bt* liquid formulations and other biopesticides against gram pod borer, *Helicoverpa armigera* and spotted pod borer, *Maruca vitrata* in pigeonpea. There were nine treatments [2 strains of *Bt* liquid formulations each at two doses, two doses of *Beauveria bassiana*, neem formulation (azadirachtin 1500 ppm), and chemical check] including untreated control. Pooled analysis of three years data revealed that two sprays of NBAII BtG4 @ 2% at fortnight interval significantly superior over other treatments in suppressing the larval population of *H. armigera* (3.2 larvae / plant) and *M. vitrata* (5.9 larvae / plant) on pigeonpea and recorded minimum pod damage (3.7 and 11.4%, respectively) with maximum yield (1565 kg/ha). Further, it was also revealed that all *Bt* liquid formulations and *B. bassiana* were safe to natural enemy population *viz.*, spiders and coccinellids existing in pigeonpea ecosystem. It is suggested to utilize biopesticides as ecofriendly insecticides for pigeonpea production.

Keywords: *Beauveria bassiana*, *Bt*, *Helicoverpa armigera*, *Maruca vitrata*, Pigeonpea.

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INTRODUCTION

Pigeonpea, *Cajanus cajan* (L.) Millsp is an important grain legume crop of the semi-arid tropics. India is the largest producer of pigeonpea contributing more than 90 per cent of the world's production (3.17 million tonnes) and 817 kg/ha of productivity (AICRP Report, 2016). In Andhra Pradesh, it is grown in an area of about 0.509 million hectares with a production of 0.251 million tonnes and with a productivity of 524 kg/ha. More than 300 species of insect species have been reported infesting the crop (Lal and Singh, 1998) of which those attack pods like spotted pod borer (*Maruca vitrata* (Geyer)) and gram pod borer, (*Helicoverpa armigera* (Hubner)) cause considerable yield losses to the pigeonpea growing farmers. Sometimes their infestation level is so high that farmers do not get adequate return on occasions. The pod damage due to *H. armigera* and *M. vitrata* in pigeonpea could vary from 55 to 100% (Thakur *et al*., 1989; Bant and Harpreet, 2006; Malathi *et al*., 2008). In order to reduce the menace by these pests a large number of insecticides are being used by ignorant farmers excessively and indiscriminately which leads to development of resistance against insecticides by these pests, adversely affecting the crop ecosystem and increasing the total cost of production. In recent past more emphasis has been given on safer and eco-friendly management of pests. The relative specificity, potential activity, environmental safety and immunity to insecticides have made microbial pesticides a favoured component of Integrated Pest Management (IPM) strategies. Several microbial insecticides like *Bacillus* *thuringiensis* (*Bt*), *Beauveria* and Nuclear Polyhydrosis Virus (NPV) were already developed as commercial formulations and utilized on *H. armigera* (Rabindra and Jayaraj, 1988; Sarode *et al*., 1994; Srinivasa *et al*., 2008; Shivanand, 2009). Pathogens have been reported to be most important as population regulating factors of *M. vitrata* in the field. The usefulness and effectiveness of *Bt* has been reported on *M. vitrata* (Karel and Schoonhoven, 1986) in regulating its populations under field conditions. However, work is continuing to develop new *Bt* isolates by different institutes and they may be explored for integrated management of the pod borers.

Attempts have been made in the present investigation to study the efficacy of *Bt* liquid formulations and other biopesticides in comparison with traditional insecticides against *H. armigera* ad *M. vitrata* in pigeonpea.

MATERIALS AND METHODS

The field experiment was conducted for three consecutive years (2012-2013, 2013-2014 and 2014-15) at Regional Agricultural Research Station, Lam, Guntur district, Andhra Pradesh. The trial was laid out in randomized block design with nine treatments and three replications. The pigeonpea variety ICPL 85063 (Lakshmi) was grown with all suitable package of agronomical practices at 180 x 20 cm spacing in 7.2 x 5 m plots. The treatments comprised spraying of liquid formulations of *Bt* strains PDBC BT1 @ 1 and 2%, NBAII *Bt*G4 1 and 2%, *Be. bassiana* @ 1.5 and 2.0 kg/ha, azadirachtin 1500 ppm @ 0.2%, chlorpyriphos 20 EC @ 0.25% as standard chemical check and untreated control. Two sprays of treatments were given -first spray of treatments was given at pod initiation stage and subsequent spray at fortnightly interval. Observations on the larval population of *H. armigera* and *M. vitrata* were recorded from five randomly selected plants from each treatment a day before treatment application as pre-count and post counts at 5 and 10-days after spray (DAS). Pod damage per cent was estimated by counting the total number of pods and affected ones on five randomly selected plants in each treatment. Simultaneously, the natural enemy population *viz.*, spiders and coccinellids were also recorded 5 and 10-DAS. At harvest, the pods from individual plots were threshed separately and the yield was recorded from the net plot area. Yield data was converted into kg per ha. The data recorded on each parameter was subjected to statistical scrutiny by the analysis of variance (ANOVA) technique as described by Panse and Sukhatme (Panse and Sukhatme, 1967). The treatment means were compared using the critical difference values calculated at 5 per cent level of significance.

Table 1. Effect of *Bt* liquid formulations against *H. armigera* in pigeonpea (Pooled data for 2012-13, 2013-14 & 2014-15)

Treatments	No. of *H. armigera* larvae / plant				
	Pre count	5 DAS	10 DAS	Cumulative average	Reduction over control (%)
PDBC *Bt*1@ 1%	7.0	5.3(2.51)^{bcd}	4.0 (2.24)^{cd}	4.7(2.39)^{cde}	42.7
PDBC *Bt*1 @ 2%	7.7	4.3(2.30)^{cd}	3.0 (2.00)^{de}	3.7(2.17)^{de}	54.9
NBAII *Bt*G4 @ 1%	6.7	4.7(2.39)^{bcd}	3.3 (2.07)^{cde}	4.0(2.24)^{cde}	51.2
NBAII *Bt*G4 @ 2%	6.3	4.0(2.24)^{d}	2.3 (1.82)^{e}	3.2(2.05)^{e}	61.0
B. bassiana-(Toxin WP 1.15%) @ 1.5 kg/ha	6.7	6.3(2.70)^{ab}	4.0 (2.24)^{cd}	5.2(2.49)^{cd}	36.6
B. bassiana-(Toxin WP 1.15%) @ 2.0 kg/ha	8.3	5.7(2.59)^{abcd}	3.0 (2.00)^{de}	4.4(2.32)^{cde}	46.3
Neem formulation 1500 ppm @ 0.2%	7.3	6.0(2.65)^{abc}	4.7 (2.39)^{bc}	5.4(2.53)^{bc}	34.2
Chlorpyriphos 20EC @ 0.25%	8.0	4.3(2.30)^{cd}	4.7 (2.39)^{bc}	4.5(2.35)^{cde}	45.1
Control	8.3	7.7(2.95)^{a}	8.7 (3.12)^{a}	8.2(3.03)^{a}	--
C.D (P=0.05)	NS	0.37	0.33	0.35	--
CV (%)	9.2	8.5	8.4	8.4	--

* Figures in ( ) are SQRT transformed values; DAS- Days after spraying; Within a column, mean followed by the same letter are not significantly different at *P*=0.05

RESULTS AND DISCUSSION

Pooled analysis of three years data (Table 1) revealed that all the treatments significantly reduced larval population of *H. armigera* over untreated check after 5 and 10 days after spraying. Two sprays of NBAII *Bt* G4 at fortnightly interval was significantly superior to other treatments in suppressing the larval population of *H. armigera* with 61.0% reduction over control and was most promising, followed by PDBC *Bt*1@2%, NBAII *Bt* G4, *B. bassiana*, chlorpyriphos and PDBC *Bt*1@1% which have respectively recorded 3.7, 4.0, 4.4, 4.5 and 4.7 larvae per plant with 54.9, 51.2, 46.3, 45.1 and 42.7 % reduction of larval population over control respectively. *B. bassiana* and azadirachtin were found to be least effective which have respectively recorded 5.2 and 5.4 larvae per plant with 36.6 and 34.2 per cent reduction of larval population over control respectively.

Similarly, all the treatments significantly reduced larval population of *M. vitrata* over untreated check after 5 and 10 days after spraying (Table 2).

Table 2. Effect of *Bt* liquid formulations against *M. vitrata* in pigeonpea (Pooled data for 2012-13, 2013-14 & 2014-15)

Treatments	No. of *M. vitrata* larvae / plant				
	Pre count	5 DAS	10 DAS	Cumulative average	Reduction over control (%)
PDBC *Bt*1@ 1%	10.3	8.3 (3.05)^{bc}	7.7 (2.95)^{bc}	8.0(3.00)^{bc}	48.1
PDBC *Bt*1 @ 2%	12.7	8.0 (3.00)^{c}	5.3 (2.51)^{cd}	6.7(2.78)^{c}	56.5
NBAII *Bt*G4 @ 1%	12.0	8.0 (3.00)^{c}	6.3 (2.70)^{cd}	7.2(2.86)^{c}	53.3
NBAII *Bt*G4 @ 2%	8.7	7.0 (2.83)^{c}	4.7 (2.39)^{d}	5.9(2.63)^{c}	61.7
***B. bassiana* (Toxin WP 1.15%) @ 1.5 kg/ha**	11.3	8.7 (3.12)^{bc}	7.3 (2.88)^{bcd}	8.0(3.00)^{bc}	48.1
***B. bassiana* (Toxin WP 1.15%) @ 2.0 kg/ha**	12.7	7.7 (2.95)^{c}	6.7 (2.78)^{cd}	7.2(2.86)^{c}	53.3
Neem formulation 1500 ppm @ 0.2%	13.3	12.7 (3.70)^{ab}	10.0 (3.32)^{ab}	11.4(3.52)^{ab}	26.0
Chlorpyriphos 20EC @ 0.25%	12.0	8.7 (3.12)^{bc}	7.0 (2.83)^{bcd}	7.9(2.98)^{bc}	48.7
Control	12.3	17.7(4.32)^{a}	13.0 (3.74)^{a}	15.4(4.05)^{a}	--
C.D (P=0.05)	NS	0.65	0.52	0.59	--
CV (%)	11.0	11.6	10.4	11.0	--

* Figures in parenthesis indicate SQRT transformed values; Within a column, mean followed by the same letter are not significantly different at *P*=0.05

Two sprays of NBAII *Bt* G4 at fortnightly interval was significantly superior to other treatments in suppressing the larval population of *M. vitrata* (5.9 larvae/plant) with 61.7% reduction of larval population over control which was most promising, followed by PDBC *Bt*1@ 2%, NBAII *Bt*G4, *B. bassiana* @ 2kg/ha, chlorpyriphos, PDBC *Bt* 1@ 1% and *B. bassiana* @ 1.5 kg/ha, respectively with 6.7, 7.2, 7.2, 7.9, 8.0, 8.0 larvae/plant recording 56.5, 53.3, 53.3, 48.7, 48.1 and 48.1% reduction of larval population over control respectively. Azadirachtin was found to be least effective with 26.0% reduction of larval population over control. It is evident from pooled data presented in Table 3 that the biopesticides evaluated remained statistically on par with each other in harbouring natural enemy population. All the bio-pesticide treatments were eco-friendly to predatory population of spiders and coccinellids and significantly superior ($P < 0.05$) to insecticidal check plots in harbouring their population both after first and second round of imposition of treatments. The untreated check has recorded 11.9 and 9.7 spiders and coccinellids per 5 plants respectively. Thus all the biopesticides caused 7.6 to 39.5% and 13.4 to 41.2 % reduction of spider and coccinellid population respectively over control, whereas the chemical check has recorded 70.6 and 65.0% reduction of spider and coccinellid population respectively over control.

The pooled data analysis of three years indicated that pod damage caused by *H. armigera* was significantly reduced by all the treatments over untreated check (Table 4). However, the treatment, NBAII *Bt*G4 @ 2% with 3.7% pod damage has shown 67.8% reduction of pod damage over control which was most promising, followed by PDBC *Bt* 1@2%, *B. bassiana*, chlorpyriphos, azadirachtin, NBAII *Bt*G4 @ 1% and PDBC *Bt* 1@1% with 4.3, 5.1, 5.3, 5.7 6.1 and 6.7% pod damage respectively. They have recorded 62.6, 55.7, 53.9, 50.4, 47.0 and 41.7%

reduction of pod damage over control. The least effective treatment was *B. bassiana* with 35.7% reduction of pod damage over control.

Similarly, the data indicated that pod damage caused by *M. vitrata* was significantly reduced by all the treatments over untreated check (Table 4). The treatments, NBAII *Bt*G4 @2%, PDBC *Bt*1 @2% and *B. bassiana* respectively with 11.4, 11.6 and 11.7% pod damage have shown 51.3, 50.4 and 50.0% reduction of pod damage over control. The treatments, chlorpyriphos, *B. bassiana* 1.5 kg/ha and NBAII *Bt*G4 @ 1% respectively with 13.2, 13.3, 13.9% pod damage have shown 43.6, 43.2 and 40.6% reduction of pod damage over control respectively. PDBC *Bt*1 @ 1% and azadirachtin were least effective with 33.8 and 18.0% reduction of pod damage over control respectively.

Effectiveness of bio-pesticides like *Bt* and neem formulations in reducing the infestation of *H. armigera* in chickpea had been reported (Neeraj Agrawal and Ram, 2013; Bhushan *et al*., 2011). The results were in agreement with the findings of Manjula and Padmavathamma (1996) who reported that *B. thuringiensis* and *B. bassiana* were effective against *Maruca testulalis*. Mahopatra and Srivastava (2002) reported that *Bt* provided good protection and registered significantly lesser incidence of *M. vitrata* larvae and higher yield over control. Thilagam and Kennedy (2007) reported that *B. thuringiensis* var. *kurstaki* based product (Spic-Bio Reg.) was the best treatment, recording lesser *H. armigera* larval population. Bajya *et al*. (2015) reported that *B. bassiana* 1.15% WP @ 3000 g/ha and 2500 g/ha were highly effective in controlling pod borer population. Sreekanth and Seshamahalakshmi (2012) reported that pod damage due to Mauca was the lowest in Spinosad, followed by Bt-1 and *B. bassiana* SC formulation @ 300 mg/L as against control. Nahar *et al*. (2004) reported that *B. bassiana* preparation was less effective against *H. armigera* in pigeonpea. Subhasree and Mathew (2014) reported that Azadirachtin, *M. anisopliae* and *B. thuringiensis* recorded larval population below economic threshold level (ETL) starting from 14th day after first spraying till the end of cropping period. Similarly, Muddu krishna *et al.* (2011) reported that Neemazal – F (0.1%) and neem seed kernel extract were found most effective against *H. armigera* and *M. vitrata*. Khanapara and Kapadia (2011) reported that the treatment endosulfan 0.07 per cent recorded significantly highest larval mortality (96.58%) and it was on par with Bt @ 1.0 kg/ha + endosulfan 0.035 per cent which recorded 95.60 per cent mortality. Sunitha *et al.* (2008) reported that *B. thuringiensis* and *M. anisopliae* were moderately effective while botanical pesticide, neem fruit extract was ineffective. Bhushan *et al.* (2011) reported that Neem seed kernel extract (NSKE 5%) was found most effective in reducing *Helicoverpa* larval population and pod damage. Sushil Kumar Chauhan and Roshan Lal (2009) observed lower pod damage due to *H. armigera* in endosulfan than *B. thuringiensis* var. k*urstaki* in pigeonpea. The results were not in agreement with the findings of Suneel Kumar *et al.* (2016) who reported that two sprays of chlorpyriphos 0.25% at fortnightly interval was significantly superior to other treatments *viz*., *Bt* formulations in suppressing the larval population of *H. armigera* (av. 0.81 larvae/plant) and *M. vitrata* (av. 0.80 larvae / inflorescence) on pigeonpea. The *Bt* strain NBAII *Bt*G4 @ 2% ranked next best to the insecticidal spray in recording surviving larval population of *H. armigera* (av. 1.01 larvae/plant) and *M. vitrata* (av. 1.10 larvae/inflorescence). Consequent upon protection of pigeonpea crop with different biopesticides significant increase in yield over untreated control was noticed (Table 4). The treatments, NBAII *Bt*G4 @ 2% and PDBC *Bt*1 @ 2% respectively with 1565 and 1523 kg/ha were most promising with 101.9 and 96.5% increase in yield over control, followed by NBAII *Bt*G4 @ 1%, *B. bassiana* @ 2.0 kg/ha , PDBC *Bt*1 @ 1% and chlorpyriphos over the control. The least per cent increase in yield over control was recorded with *B. bassiana* @ 1.5 kg/ha and azadirachtin 1500 ppm.

Table 3. Safety of *Bt* liquid formulations on natural enemy population in pigeonpea (pooled data for 2012-13, 2013-14 & 2014-15)

Treatments	No. of Spiders/ 5 plants					No. of Coccinellids/5 plants					Total population of natural enemies	Reduction over control (%)
	Pre count	5 DAS	10 DAS	Cumulative average	Reduction over control (%)	Pre count	5DAS	10DAS	Cumulative average	Reduction over control (%)		
PDBC *Bt*1@ 1%	8.3	9.7(3.27)	10.7(3.42)	10.2(3.35)	14.3	5.0	6.3(2.70)	7.0(2.83)	6.7(2.78)	30.9	16.9(4.23)	21.8
PDBC *Bt*1 @ 2%	10.0	9.0(3.16)	10.3(3.36)	9.7(3.27)	18.5	6.3	6.5(2.74)	9.7(3.27)	8.1(3.02)	16.5	17.8(4.34)	17.6
NBAII *Bt* G4 @ 1%	10.3	10.3(3.36)	11.7(3.56)	11.0(3.46)	7.6	6.0	6.7(2.78)	10.0(3.32)	8.4(3.07)	13.4	19.4(4.52)	10.2
NBAII *Bt* G4 @ 2%	10.0	9.7(3.27)	10.3(3.36)	10.0(3.32)	16.0	5.7	6.3(2.70)	9.0(3.16)	7.7(2.95)	20.6	17.7(4.32)	18.1
***Beauveria bassiana* (Toxin WP 1.15%) @ 1.5 kg/ha**	10.0	9.3(3.21)	10.0(3.32)	9.7(3.27)	18.5	5.7	6.7(2.78)	8.3(3.05)	7.5(2.83)	22.7	17.2(4.27)	20.4
***Beauveria bassiana* (Toxin WP 1.15%) @ 2.0 kg/ha**	9.7	9.0(3.16)	10.0(3.32)	9.5(3.24)	20.2	6.3	6.3(2.70)	8.0(3.00)	7.2(2.86)	25.8	16.7(4.21)	22.7
Azadirachtin (neem formulation) 1500 ppm @0.2%	10.3	6.3(2.70)	8.0(3.00)	7.2(2.86)	39.5	6.0	5.3(2.51)	6.0(2.65)	5.7(2.68)	41.2	12.9(3.73)	40.3
Chlorpyriphos 20EC @ 0.25%	9.3	2.7(1.92)	4.3(2.30)	3.5(2.12)	70.6	6.0	2.7(1.92)	4.0(2.24)	3.4(2.10)	65.0	6.9(2.81)	68.1
Control	10.0	10.7(3.42)	13.0(3.74)	11.9(3.59)	--	7.0	9.3(3.21)	10.0(3.32)	9.7(3.27)	--	21.6(4.75)	--
C.D (P=0.05)	NS	0.52	0.62	0.57	--	NS	0.52	0.62	0.51	--	0.60	--
CV (%)	5.8	9.8	10.9	10.4	--	9.1	12.0	12.0	12.0	--	11.2	--

* Figures in parenthesis indicate SQRT transformed values; Within a column, mean followed by the same letter are not significantly different at *P*=0.05

Table 4. Effect of different *Bt* liquid formulations on pod damage and yield of pigeonpea(Pooled data for 2012-13, 2013-14 and 2014-15)

Treatments	*H. armigera*		*M. vitrata*		Pod damage (%)	Reduction over control(%)	Grain yield (kg/ha)	Increase in yield over control (kg/ha)	Increase in yield over control(%)
	Pod damage (%)	Reduction over control (%)	Pod damage (%)	Reduction over control(%)					
PDBC *Bt*1@ 1%	6.7(15.00)[bc]	41.7	15.5(23.19)[bc]	33.8	22.2(28.11)[bc]	36.4	1378	603	77.8
PDBC *Bt*1 @ 2%	4.3(11.97)[bc]	62.6	11.6(19.91)[c]	50.4	15.9(23.50)[d]	54.4	1523	748	96.5
NBAII *Bt*G4 @ 1%	6.1(14.30)[bc]	47.0	13.9(21.89)[bc]	40.6	20.0(26.56)[bcd]	42.7	1415	640	82.6
NBAII *Bt*G4 @ 2%	3.7(11.09)[c]	67.8	11.4(19.73)[c]	51.3	15.1(22.87)[d]	56.7	1565	790	101.9
Beauveria bassiana **(Toxin WP 1.15%) @ 1.5 kg/ha**	7.4(15.79)[b]	35.7	13.3(21.39)[c]	43.2	20.7(27.06)[bcd]	40.7	1291	516	66.6
Beauveria bassiana **(Toxin WP 1.15%) @ 2.0 kg/ha**	5.1(13.05)[bc]	55.7	11.7(20.00)[c]	50.0	16.8(24.20)[cd]	51.9	1412	637	82.2
Azadirachtin (neem formulation) 1500 ppm @ 0.2%	5.7(13.81)[bc]	50.4	19.2(25.99)[ab]	18.0	24.9(29.93)[b]	28.7	1222	447	57.7
Chlorpyriphos 20EC @ 0.25%	5.3(13.31)[bc]	53.9	13.2(21.30)[c]	43.6	18.5(25.48)[cd]	47.0	1358	583	75.2
Control	11.5(19.82)[a]	--	23.4(28.93)[a]	--	34.9(36.21)[a]	--	775	--	--
C.D (P=0.05)	3.93	--	4.45	--	4.19	--	186	--	--
CV (%)	16.6	--	11.4	--	14.0	--	9.6	--	--

* Figures in parenthesis indicate Arc Sin transformed values; Within a column, mean followed by the same letter are not significantly different at *P*=0.05

Though insecticidal treatment recorded good yield, it had serious repercussions since it reduced the general predators of the pod borers after application. Utilization of fungal pathogens does not ensure satisfactory protection of pigeonpea from pod borers. This was evidenced by higher pod damage and lower grain yield in *B. bassiana* treatment. In support of these observations, Kulkarni (1999) reported the superiority of *Bt*., over fungal as well as viral pathogens in pigeonpea ecosystem. Superiority of *Bt* formulations against pod borers was also reported in recording the highest larval reduction and the lowest pod damage and increasing profitability in pigeonpea (Gundannavar *et al.*, 2004). The results were in agreement with the findings of Suneel Kumar *et al.* (2016) who reported that chlorpyriphos at fortnightly interval was significantly superior in recording minimum pod and seed damage with maximum 16.9 q/ha yield. It was however, at par with the *Bt* strain NBAII *Bt*G4 @ 2% in respect of pod damage, seed damage and yield.

Three years of experimentation on efficacy of *Bt* liquid formulations showed that NBAII BtG4 @ 2% was effective in reducing pod borer population with higher grain yield in pigeonpea ecosystem. For judicious use of synthetic insecticides it is advocated to alter with bio-pesticides like *Bt*, *Beauveria* for prolonged action, economical, ecofriendly and sustainability of management system.

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