Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2020; 8(2): 1625-1630

Received: 08-01-2020
Accepted: 10-02-2020

Rachappa V
Zonal Agricultural Research Station (UAS, Raichur), Aland Road, Kalaburgi, Karnataka, India

Rajani Rajput
College of Agriculture, Kalaburagi, Karnataka, India

Raju Teggelli
Krishi Vignan Kendra Kendra, Aland Road, Kalaburgi, Karnataka, India

SS Karbantnal
Regional Agricultural Research Station, Vijayapur

Pandit Rathod
Zonal Agricultural Research Station (UAS, Raichur), Aland Road, Kalaburgi, Karnataka, India

Corresponding Author:
Rachappa V
Zonal Agricultural Research Station (UAS, Raichur), Aland Road, Kalaburgi, Karnataka, India

Management of pigeon pea pod borers using a novel meta diamide molecule: broflanilide 30% SC

Rachappa V, Rajani Rajput, Raju Teggelli, SS Karbantnal and Pandit Rathod

Abstract
Field trials were conducted during *kharif* 2015, 2016 and 2017 at Agricultural Research Station, Kalaburagi, University of Agricultural Sciences, Raichur, Karnataka, India to study the bio- efficacy of a new green insecticide meta-diamide molecule, broflanilide 30% SC against major pod borer pests of pigeon pea. Among the treatments, broflanilide 30% SC at both the dosage @18.6 and @12.6 g.a.i./ha were highly effective in controlling pigeon pea pod borers by registering lowest mean larval numbers of *Helicoverpa armigera* (0.19 and 0.42 larvae /5plants, respectively) and *Maruca vitrata* (0.97 and 1.09 webs/5 plants respectively) at five days after spray. Further because of lower pest load which led to lesser pod damage (6.6 to 8.1%) in above treatments, culminated in higher mean grain yield on 1058.21 and 1031.60 kg/ha respectively). The observations made on activity of natural enemies in the Broflanilide 30% SC treated plots had no effect on the numbers of predatory such as spiders and coccinellids. Further it does not produce any phytotoxicity symptoms in recommended and double the recommended dose.

Keywords: Broflanilide 30% SC, bio-efficacy, pigeon pea pests and natural enemies

Introduction
The production and productivity of pigeon pea is oscillating greatly due to biotic and abiotic factors. Among biotic factors, the legume pod borer or cotton bollworm *Helicoverpa armigera* (Hubner) is an important constraint and causes significant and economic damage to the crop. It is perennial, polyphagous and a persistent pest attacking more than 182 plant species including pigeon pea and is widely distributed in Asia, Africa, Australia and the Mediterranean Europe (Fitt, 1989) [5]. In recent period legume pod borer *Maruca vitrata* (Geyer) is also gaining more attention of growers to manage this cryptic behaving insect in pigeon pea. Farmers are unable to control these pests to desired level in spite of spending millions of dollars on pesticides. Apart from the pod borers, pod fly, pod bug, leaf webber, stem fly etc., cause loss to pigeon pea throughout the cropping season.

Chemical pesticides play a pivotal role in the management of pigeon pea pests; the commonly used ones being organophosphates, carbamates, synthetic pyrethroids, neonicotinoids etc. However, the major concerns with the use of pesticides are their residues in the food and their effect on non-target organisms.

Therefore, there is a need to develop and evaluate newer and safe chemistry molecules. Currently, the green chemistry molecules tested in pigeon pea for the control of lepidopteran insect pests include broflanilide is a meta-diamide [3-benzamido-**N**-(4-(perfluoropropan-2-yl) phenyl) benzamide] (Nakao and Banba, 2016) [11]. It has been reported that broflanilide is metabolized to desmethyl-broflanilide and that it acts as a noncompetitive resistant-to-dieldrin (RDL) γ-aminobutyric acid (GABA) receptor antagonist (Nakao *et al*., 2013) [13].

Meta diamide insecticides are a new class of insecticides with a novel mode of action (GABA-gated chloride channel allosteric modulators). These insecticides allosterically inhibit the GABA-activated chloride channel, causing hyper excitation and convulsions. GABA is the major inhibitory neurotransmitter in insects (IRAC mode of action classification, group 30) [IRAC, 2018] [9]. Nakao *et al.* (2015) [12] reported that the meta diamide (broflanilide) is differ in their mode of action compared to macrocyclic lactones.

However, broflanilide field efficacy against insect pests of pigeon pea is not reported yet. Therefore, it was planned and executed to study the field efficacy of broflanilide against pod borers, phytotoxicity and safety to natural enemies in pigeon pea ecosystem.

Materials and methods

The field trials on bio-efficacy of broflanilide 30% SC against insect pests of pigeon pea were carried out during the kharif seasons of 2015, 2016 and 2017 at Zonal Agricultural Research Station, Gulbarga, Karnataka, India. The experiment was laid out in a randomized block design with seven treatments and four replications in medium black soil. Pigeon pea (variety : TS3-R) was sown on first fortnight of July and the crop was raised as per the University recommended Package of practices (Anon., 2013) [2]. The non-target insect pests were managed as per the standard recommendations. The treatments details mentioned in the table were imposed based on pest occurrence with high volume sprayer and hollow cone nozzle. The effects of broflanilide 30 SC on crop health was also tested at doses of 12.60 and 25.20 g.a.i/hectare.

Data on incidence of spotted pod borer (*Maruca vitrata*) and pod borer (*H. armigera*) was recorded from five tagged plants/plot. The numbers of flower webs with live larvae in each plot was recorded 1 day before spray (DBS) and 3, 6 and 10 days after spray (DAS). Similarly the numbers of larvae (*H. armigera*) on whole plant basis was recorded 1 day before spray and 3, 6 & 10 days after spray. Pod damage was recorded by counting the number of healthy and damaged pods per plant and converted to per cent pod damage. Grain yield was calculated per hectare basis.

The numbers of coccinellids and chrysoperla were recorded from randomly selected 5 plants after last application. Observations on crop response symptoms like yellowing, leaf injury, vein clearing, wilting, necrosis, epinasty and hyponasty were recorded before and 3,7 and 14 days after spray. The crop response symptoms were visually rated on a 1-10 scale basis.

The statistical analysis of the data on numbers of pest and natural enemies was done after transferring the values to √X+1 and per cent pod damage to arc sine transformation. The significance of differences between the treatments was estimated using multiple ranges test (DMRT) as suggested by Gomez and Gomez (1984) [6].

Results and discussion

Bio-efficacy of broflanilide against Pod borer, *H. armigera:* Bio-efficacy of test product was assessed for three years on pigeon pea crop against *H. armigera* through making observations on larval load before and after spray of pesticide and pod damage (%) at maturity stage. One day before spray, the mean number of larval load of average of three years varied from 5.31 to 6.18 per five plants and no significant differences were observed among the treatments indicating uniform distribution of the pest in the experimental area in all the three seasons (Table 1).

Table 1: Comparative efficacy of Broflanilide 30% SC against *Helicoverpa armigera* infesting pigeon pea (larval load/5 plants)

Treatment details	PTC				5 DAT*				10 DAT*			
	2015	2016	2017	Mean	2015	2016	2017	Mean	2015	2016	2017	Mean
T1: Broflanilide 30% SC @6.6 g.a.i/ha	5.55 (2.56)	6.17 (2.68)	5.66 (2.58)	5.79 (2.60)	1.20 (1.48)^{b}	1.62 (1.62)^{c}	1.15 (1.47)^{c}	1.32 (1.52)^{b}	1.37 (1.54)^{b}	1.88 (1.70)^{c}	1.38 (1.55)^{b}	1.54 (1.59)^{b}
T2: Broflanilide 30% SC @12.6 g.a.i/ha	5.78 (2.60)	5.50 (2.55)	5.00 (2.45)	5.42 (2.53)	0.56 (1.25)^{a}	0.33 (1.15)^{ab}	0.38 (1.17)^{ab}	0.42 (1.13)^{a}	0.22 (1.10)^{a}	0.50 (1.22)^{b}	0.70 (1.30)^{a}	0.47 (1.20)^{a}
T3: Broflanilide 30% SC @18.6 g.a.i/ha	5.33 (2.52)	5.67 (2.58)	4.93 (2.43)	5.31 (2.51)	0.22 (1.10)^{a}	0.10 (1.04)^{a}	0.26 (1.12)^{a}	0.19 (1.08)^{a}	0.11 (1.05)^{a}	0.00 (1.00)^{a}	0.58 (1.25)^{a}	0.23 (1.11)^{a}
T4: Emamectin benzoate 5%SG@11 g.a.i/ha	5.89 (2.62)	5.17 (2.48)	5.06 (2.46)	5.37 (2.52)	0.56 (1.25)^{a}	0.67 (1.29)^{b}	0.54 (1.24)^{ab}	0.59 (1.26)^{a}	0.56 (1.25)^{a}	0.83 (1.35)^{b}	0.83 (1.34)^{a}	0.74 (1.31)^{a}
T5: Flubendiamide 35% SC @ 48 g.a.i/ha	6.17 (2.68)	5.67 (2.58)	5.00 (2.45)	5.61 (2.57)	0.22 (1.10)^{a}	0.84 (1.35)^{b}	0.70 (1.30)^{b}	0.50 (1.25)^{a}	0.33 (1.15)^{a}	0.67 (1.29)^{b}	0.68 (1.29)^{a}	0.56 (1.24)^{a}
T6: Chlorantraniliprole 18.5% SC @30 g.a.i/ha	6.33 (2.71)	5.17 (2.48)	5.03 (2.45)	5.51 (2.54)	0.55 (1.25)^{a}	0.84 (1.35)^{b}	0.46 (1.21)^{ab}	0.62 (1.27)^{a}	0.37 (1.16)^{a}	0.17 (1.08)^{ab}	0.63 (1.27)^{a}	0.39 (1.17)^{a}
T7: Untreated check	6.11 (2.67)	6.00 (2.65)	6.45 (2.73)	6.18 (2.68)	5.44 (2.54)^{c}	3.83 (2.20)^{d}	4.83 (2.41)^{d}	4.71 (2.38)^{c}	5.78 (2.60)^{c}	3.00 (2.00)^{d}	2.33 (1.82)^{c}	3.70 (2.14)^{c}
SEm(±)	0.11	0.12	0.11	0.11	0.06	0.07	0.06	0.06	0.07	0.09	0.07	0.07
CD at 5%	NS	NS	NS	NS	0.18	0.20	0.17	0.19	0.21	0.27	0.20	0.16

PTC: pre-treatment count, DAT: Days after treatment, * The larval count data is of average three sprays, values in parenthesis are √(x+1) transformed, Similar letters in the columns don't differ significantly by the DMRT (0.05),

Larval load was varied from 0.19 to 4.71 per five plants at five days after the spray indicating a significant difference among the treatments. Lowest mean larval load of 0.19 per five plants were recorded in the plot sprayed with Broflanilide 30% SC @18.6 gai/ha, followed by same pesticide @12.6 g.a.i/ha (0.42 larvae/5 plants). Among the recommended best pesticides, Flubendiamide 35% SC @ 48 g.a.i/ha, Emamectin benzoate 5%SG and Chlorantraniliprole 18.5% SC @30 g.a.i/ha @11 g.a.i/ha recorded 0.50, 0.59 and 0.62 larvae/5 plants larvae and were at par. Broflanilide 30% SC @6.6 g.a.i/ha recorded the 1.32 larvae/5 plants and found to be inferior over other tested dosages and recommended pesticide checks. Untreated control recorded significantly highest number of larvae of 4.71 per five plants. Same trend was noticed in next post treatment observation (10 days after spray).

Reduction of larval population over untreated check was highest (94.2%) in Broflanilide 30% SC @18.6g.a.i/ha treated plot (Fig. 1). The next best treatment in reducing larval population were Broflanilide 30% SC @12.6 g.a.i/ha (90.1%), Chlorantraniliprole 18.5% SC @30 g.a.i/ha (89.4%), Flubendiamide 35% SC @ 48 g.a.i/ha (88.7%) and Emamectin benzoate 5%SG@11 g.a.i/ha (85.4%). There were no published information on efficacy of Broflanelide against pod borers of pigeon pea indicating the present investigations reports for the first time.

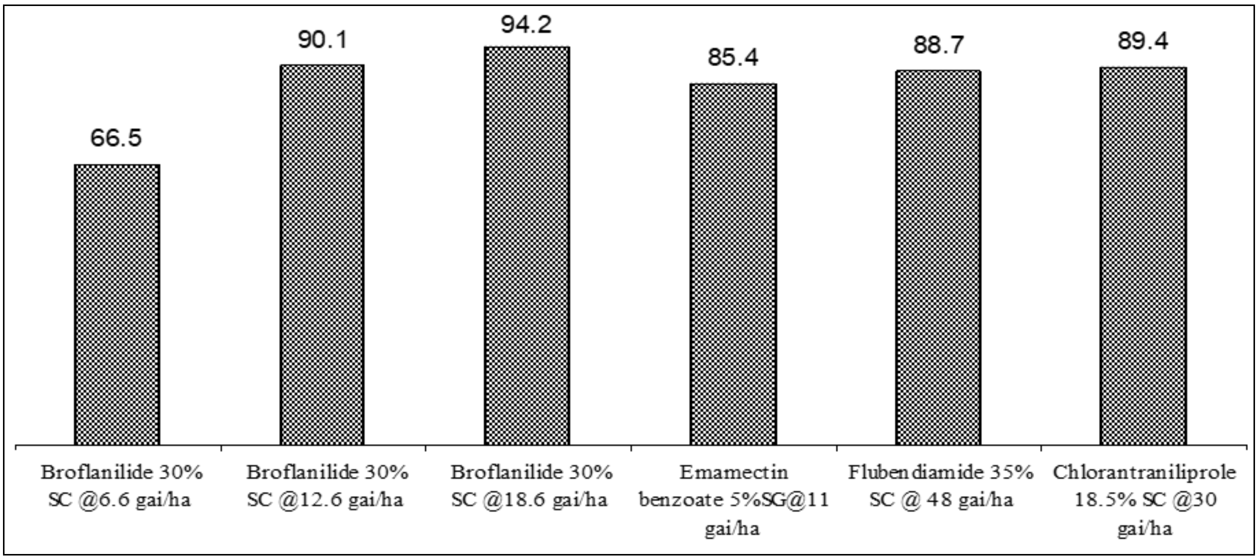

Fig 1: Post treatment reduction (%) of *H. armigera* larval population over untreated control in different treatments

Bio-efficacy of broflanilide against spotted pod borer, *Maruca vitrata:* One day before spray mean larval population or live webs of three years average ranged from 4.61 to 5.10 per five plants in all treatments and difference was non-significant among the treatments indicating uniformity of insect population before treatment.

Five days after the spray, mean number of webs per five plants varied from 0.97 to 3.75 indicating a significant difference among the treatments (Table 2). Broflanilide 30% SC @ 18.60 g.a.i/ha was recorded minimum number of webs (0.97 / 5 plants) and it was on par with Broflanilide 30% SC @ 12.60 g.a.i/ha (1.09) and recommended pesticide Chlorantraniliprole 18.5% SC @30 g.a.i/ha. Other two recommended chemicals Emamectin benzoate 5%SG@11 g.a.i/ha and Flubendiamide 35% SC @ 48 g.a.i/ha were recorded 1.70 and 1.76 webs/5 plants and were at par with each other next best to T2, T3 and T6. Broflanilide 30% SC @6.6 g.a.i/ha recorded the 2.54 webs/5 plants and found to be inferior over other tested dosages and treated checks. Obviously untreated control recorded significantly highest number of webs of 3.75 per five plants. The efficacy of Broflanilide 30% SC at 18.60 g.a.i/ha and at 12.60g.a.i/ha remained superior and maintained same trend even at 10 days after spray.

Table 2: Comparative efficacy of Broflanilide 30% SC against *Maruca vitrata* infestin pigeon pea (webs /5 plants)

Treatment details	PTC				5 DAT				10 DAT			
	2015	2016	2017	Mean	2015	2016	2017	Mean	2015	2016	2017	Mean
T1: Broflanilide 30% SC @6.6 g.a.i/ha	4.06 (2.13)	7.70 (2.95)	2.88 (1.84)	4.88 (2.30)	1.93 (1.56)^{b}	3.33 (2.08)^{c}	2.37 (1.69)^{c}	2.54 (1.77)^{c}	1.55 (1.43)^{c}	1.80 (1.67)^{b}	1.48 (1.41)^{b}	1.61 (1.50)^{c}
T2: Broflanilide 30% SC @12.6 g.a.i/ha	3.68 (2.04)	8.32 (3.05)	2.79 (1.81)	4.93 (2.30)	1.03 (1.23)^{a}	1.30 (1.52)^{ab}	1.06 (1.25)^{a}	1.09 (1.24)^{a}	0.10 (0.77)^{a}	0.67 (1.29)^{a}	0.97 (1.21)^{a}	0.58 (1.09)^{a}
T3: Broflanilide 30% SC @18.6 g.a.i/ha	3.97 (2.11)	7.76 (2.96)	2.98 (1.87)	4.90 (2.31)	0.87 (1.17)^{a}	1.00 (1.41)^{a}	0.94 (1.20)^{a}	0.97 (1.27)^{a}	0.07 (0.75)^{a}	0.33 (1.15)^{a}	1.01 (1.23)^{a}	0.47 (1.04)^{a}
T4: Emamectin benzoate 5%SG@11 g.a.i/ha	3.78 (2.07)	7.33 (2.89)	2.73 (1.80)	4.61 (2.25)	1.63 (1.46)^{b}	1.90 (1.70)^{b}	1.57 (1.44)^{b}	1.70 (1.53)^{b}	0.67 (1.07)^{b}	0.87 (1.37)^{a}	1.05 (1.24)^{a}	0.86 (1.22)^{ab}
T5: Flubendiamide 35% SC @ 48 g.a.i/ha	3.83 (2.07)	8.66 (3.11)	2.82 (1.82)	5.10 (2.25)	2.07 (1.60)^{b}	1.66 (1.63)^{ab}	1.56 (1.44)^{b}	1.76 (1.55)^{b}	1.03 (1.23)^{b}	0.67 (1.29)^{a}	1.09 (1.26)^{a}	0.91 (1.26)^{b}
T6:Chlorantraniliprole 18.5% SC @30 g.a.i/ha	3.80 (2.06)	8.00 (3.00)	3.12 (1.90)	4.97 (2.32)	1.05 (1.25)^{a}	1.35 (1.53)^{ab}	0.85 (1.16)^{a}	1.05 (1.30)^{a}	0.10 (0.77)^{a}	0.33 (1.15)^{a}	1.02 (1.24)^{a}	0.48 (1.06)^{a}
T7: Untreated check	3.93 (2.11)	7.90 (2.98)	3.03 (1.88)	4.95 (2.32)	3.71 (2.09)^{c}	4.90 (2.43)^{d}	2.64 (1.77)^{d}	3.75 (2.09)^{d}	2.93 (1.85)^{d}	2.90 (1.97)^{c}	1.99 (1.58)^{c}	2.88 (1.79)^{d}
SEm(+)	0.23	0.14	0.10	0.09	0.05	0.08	0.04	0.05	0.04	0.10	0.04	0.04
CD at 5%	NS	NS	NS	NS	0.15	0.25	0.12	0.16	0.13	0.30	0.12	0.14

PTC: pre-treatment count, DAT: Days after treatment, * The larval count data is of average three sprays, values in parenthesis are $\sqrt{(x+1)}$ transformed, Similar letters in the columns don't differ significantly by the DMRT (0.05),

The reduction of live webs over control after treatments was highest in Broflanilide 30% SC @ 18.60 g.a.i/ha (73.6%) and next dosage (T2) was very close to this treatment. The performance of other three treated checks was also better in per cent reduction of larval population (Fig.2). Similar kind of efficacy of diamide pesticides like flubendiamide, chlorantranili-prole + lambda-cyhalothrin on reducing the percentage of attacked soy bean plants by M. vitrata was reported by Grigolli *et al.* (2015) [7].

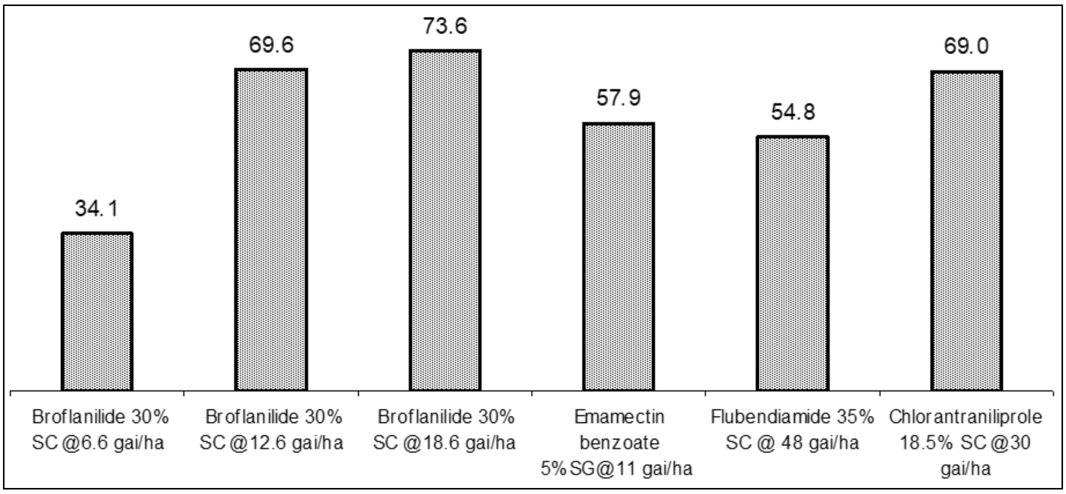

Fig 2: Post treatment reduction (%) of *M. vitrata* larval population over untreated control in different treatments

Pod damage by pod borers: The mean pod damage by above mentioned pod borers of three years ranged from 6.66 (Broflanilide 30% SC sprayed at 18.60 g.a.i./ha) to 39.73% (in untreated control) indicating variation in pod damage percentage among treatments (Table 3). Significantly lowest pod damage of 6.66 per cent was observed in Broflanilide 30% SC sprayed at 18.60 g.a.i./ha treated plot which was on par with Flubendiamide 35% SC @ 48 g.a.i/ha (6.92%), Chlorantraniliprole 18.5% SC @30 g.a.i/ha (7.44%), Broflanilide 30% SC @12.6 g.a.i/ha (8.16%) and Emamectin benzoate 5%SG@11 g.a.i/ha (9.06%). The next best treatment in registering pod damage was Broflanilide 30% SC 6.6g.a.i/ha (13.79%) which was significantly superior over untreated check. Similarly the test insecticide performance at higher two dosages and treated checks in reducing the per cent pod damage over control was maximum (83-77%) and next best was Broflanilide 30% SC @ 6.6 g.a.i/ha (Fig.3).

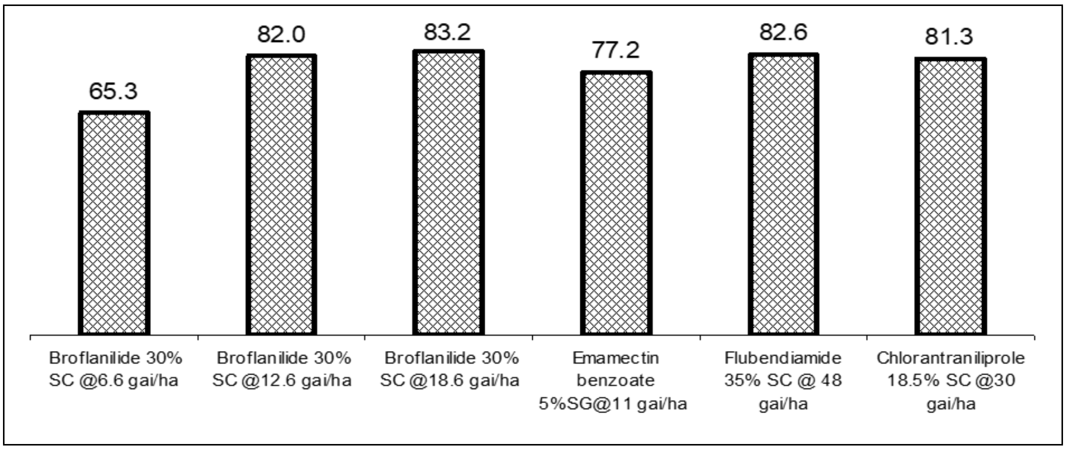

Fig 3: Reduction of per cent pod borer damage over untreated control in different treatments

Table 3: Influence of different insecticide sprays on per cent pod damage pod borer and yield of pigeon pea

Treatment details	Pod Damage (%)				Grain Yield (Kg/ha)				% Increase in yield over control
	2015	2016	2017	Average	2015	2016	2017	Average	
T1: Broflanilide 30% SC @6.6 g.a.i/ha	12.19 (20.36)[b]	13.87 (21.82)[b]	15.30 (23.03)[b]	13.79 (21.80)[b]	571.85[b]	1055[b]	1105[b]	910.6[b]	15.5
T2: Broflanilide 30% SC @12.6 g.a.i/ha	6.08 (14.26)[ab]	8.58 (17.03)[a]	9.81 (18.25)[a]	8.16 (16.59)[a]	742.81[a]	1096[a]	1256[ab]	1031.6[a]	30.9
T3: Broflanilide 30% SC @18.6 g.a.i/ha	5.83 (13.97)[a]	7.29 (15.35)[a]	6.85 (15.17)[a]	6.66 (14.95)[a]	769.63[a]	1110[a]	1295[a]	1058.2[a]	34.2
T4: Emamectin benzoate 5%SG@11 g.a.i/ha	10.35 (18.72)[b]	8.92 (17.38)[a]	7.90 (16.32)[a]	9.06 (17.51)[a]	702.07[a]	1082[a]	1287[ab]	1023.7[a]	29.9
T5: Flubendiamide 35% SC @ 48 g.a.i/ha	3.10 (9.72)[a]	8.99 (17.45)[a]	8.66 (17.11)[a]	6.92 (15.25)[a]	766.52[a]	1084[a]	1271[ab]	1040.5[a]	32.0
T6:Chlorantraniliprole 18.5% SC @30 g.a.i/ha	5.97 (14.04)[ab]	9.35 (17.81)[a]	7.01 (15.35)[a]	7.44 (15.83)[a]	746.96[a]	1094[a]	1298[a]	1036.3[a]	31.5
T7: Untreated check	46.33 (42.68)[c]	39.71 (39.02)[c]	33.15 (35.15)[c]	39.73 (39.07)[c]	480.74[b]	879[c]	1005[c]	788.3[c]	0.0
SEm(+)	1.54	1.45	1.45	1.34	32.28	27.00	26.91	27.15	
CD at 5%	4.71	4.46	5.85	4.07	96.84	83.21	79.50	83.90	

Pigeon pea grain yield: In general the yield of pigeon pea was better in the year 2016 and 2017 compare to 2015 harvested less grains in all the treatments was due to drought (Table 3). Significantly highest seed yield of 1058 kg per ha was recorded in Broflanilide 30% SC @ 18.6 g.a.i/ha and was at par with Broflanilide 30% SC @ 12.6 g.a.i/ha (1031kg/ha), flubendiamide 35 SC @48 g.a.i/ha (1040kg), chlorantraniliprole 18.5%SC (1036kg) and emamectin benzoate 5% SG @11g.a.i/ha(1023kg/ha). The next best treatment was broflanilide 30% SC @ 6.6g.a.i/ha which recorded 910 kg/ha and significantly lowest yield was harvested from untreated check. The per cent increase in yield over control in T2 to T6 was range between 30 to 34 while it was comparatively less in T1.

There was no published information on efficacy of Broflanelide against pod borers of pigeon pea indicating the present investigations reports for the first time. However there were lot of published information on bio-efficacy of green chemistry molecules belongs to Anthranilic diamide group (Chlorantraniliprole18.5% SC, Cyantraniliprole 10.26%w/w OD) which was sister group of meta diamide (Broflanilide) were reported by Rachappa *et al.* (2014) [14] against pod borers of pigeon pea. According to Bhosale *et al.* (2009) [3], chlorantraniliprole @ 30 g a.i/ha was the most effective in controlling the, *Helicoverpa armigera* (Hubner) and Plume moth, *Exelastis atomosa* (Wals.). Hannig *et al.* (2009) [8] reported that chlorantraniliprole had a very high biological activity on lepidopterans.

Cordova *et al.* (2005) [4] against lepidopteron and Mishra (2013) [10] against serpentine leaf miner. All above mentioned authors found that diamide group insecticides were better against tested insects population and their damage reduction. Other diamides like flube diamide field efficacy was reported by Ameta *et al.* (2011) [1] where in flubendiamide 480 SC at 100 ml/ha caused significantly high reduction in pod borers larvae, recorded minimum flower and pod damage and significantly high seed yield compared to indoxacarb 14. 5SC at 500 ml/ha and spinosad 45 SC at 187. 5. Similarly Sreekanth *et al.* (2014) [15] reported that significantly lower pod borer larvae, pod damage and Higher grain yield was recorded in chlorantraniliprole 20 SC and flubendiamide 480 SC sprayed plots.

Effect of broflanilide on natural enemies

Natural enemies such as insect predatory spiders and coccinellids were observed in all the experimental plots during the trial period. The treatments of Broflanilide 30% SC in all the three dosages did not have any significant effect to reduce the predatory coccinellid and spider population as all the treatments were on par with untreated control in both the seasons (Table 4) indicating safety of tested chemicals to the predators. However there was less population in all the treatments during 2016 in all observation periods might be due to less pest and other insects in the experimental arena. The general reduction in coccinellid or predatory population may be attributed to reduction of host density in the insecticide treated plots and resultant congregation of more number of predators in the untreated plots further reducing the host number in untreated check. The reports of Rachappa *et al.* (2015) [14], Misra (2013) [10] and indicates safety of diamide group of insecticides to coccinellid predators which corroborates with the present findings. Ameta *et al.* (2011) [1] reported that flubendiamide did not reduced natural enemies population in field. Sreekanth *et al.* (2014) [15] reported that both chlorantraniliprole 20 SC and flubendiamide 480 SC were safe to natural enemies.

Table 4: Effect of different chemical treatments on natural enemies in pigeon pea ecosystem

Treatment details	Predatory Spiders/10 plants							Coccinellids/10 plants						
	PTC			10 DAT				PTC			10 DAT			
	2015	2016	Mean	2015	2016	Mean	ROC	2015	2016	Mean	2015	2016	Mean	ROC
T1: Broflanilide 30% SC @6.6 g.a.i/ha	0.80	0.65	0.73	0.89	0.45	0.67b	13.0	0.85	0.36	0.61	0.80	0.25	0.53a	18.5
T2: Broflanilide 30% SC @12.6 g.a.i/ha	0.80	0.58	0.69	0.81	0.55	0.68b	11.7	0.88	0.35	0.62	0.74	0.26	0.50a	23.1
T3: Broflanilide 30% SC @18.6 g.a.i/ha	0.82	0.60	0.71	0.79	0.50	0.62b	19.5	0.85	0.35	0.60	0.77	0.28	0.53a	18.5
T4: Emamectin benzoate 5%SG@11 g.a.i/ha	0.79	0.57	0.68	0.83	0.53	0.68b	11.7	0.83	0.39	0.61	0.79	0.30	0.55a	15.4
T5: Flubendiamide 35% SC @ 48 g.a.i/ha	0.81	0.66	0.74	0.80	0.49	0.65b	15.6	0.84	0.45	0.65	0.78	0.30	0.54a	16.9
T6:Chlorantraniliprole 18.5% SC @30 g.a.i/ha	0.91	0.55	0.73	0.82	0.51	0.67b	13.0	0.81	0.42	0.62	0.79	0.25	0.52a	20.0
T7: Untreated check	0.93	0.60	0.77	0.94	0.60	0.77a	0.0	0.83	0.45	0.64	0.91	0.39	0.65b	0.0
SEm(±)	0.04	0.05	0.04	0.04	0.03	0.03		0.03	0.04	0.03	0.03	0.03	0.03	
CD at 5%	NS	NS	NS	0.11	0.10	0.08		NS	NS	NS	0.09	0.10	0.09	

PTC: pre-treatment count, DAT: Days after treatment, ROC: Reduction over untreated check. Similar letters in the columns don't differ significantly by the DMRT (0.05).

Phytotoxicity

The data regarding phytotoxic effects such as injury on leaf tips, leaf surface, necrosis, Epinasty, hyponasty, wilting and vein clearing at 1, 3, 5, 7 and 10 days after spraying revealed that Broflanilide 30% SC even at its higher dose did not show any phytotoxicity on pigeon pea (Table 5).

Table 5: Phytotoxicity parameter score in Broflanilide 30% SC sprayed plots of pigeon pea

Treatments	Phyto-toxicity (%)																				
	Chlorosis			Necrosis			Wilting			Vein clearing			Scorching			Hyponasty			Epinasty		
	0	5	10	0	5	10	0	5	10	0	5	10	0	5	10	0	5	10	0	5	10
T1. Broflanilide 30% SC @12.5 g.a.i/ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2: Broflanilide 30% SC @25 g.a.i/ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T3: Untreated Check	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note: 0: On the day of spray, 5: 5th day of spray, 10: 10th of spray

Conclusion

We can conclude from the present investigations that pigeon pea crop foliar spray with Broflanilide 30% SC @ 12.6 g.a.i/ha at flowering stage and pod initiation stage was found considerably effective to control pod borers. It was also observed from the yield data that yield has been increased in Broflanilide 30% SC treatments which was attributed to effective control of the pod borers. Broflanilide 30% SC also found to be soft against natural enemies exist in pigeon pea ecosystem. Higher dose of Broflanilide 30% SC did not produce any phytotoxic symptoms on pigeon pea crop sprayed at different stages. Therefore, a novel and green chemistry molecule belongs to Meta diamide group with very site specific mode action it can be recommended @12.60 g.a.i/ha as a best insecticide to manage pod borers on pigeon pea.

Acknowledgement

The authors are thankful to M/S BASF India Private Limited, NMHO-II, Thane Belapur Road, Turbhe, Navi Mumbai for the financial assistance given for execution of this research work

References

1. Ameta OP, Sharma US, Jeengar KL. Efficacy of flubendiamide 480 SC against pod borers, *Helicoverpa armigera* (Hubner) and *Maruca testulalis* (L.) in pigeon pea. Indian Journal of Entomology. 2011; 73(3):191-195.
2. Anonymous. Package of Practices (for all regions of North Karnataka) University of Agricultural Sciences, Dharwad and University of Agricultural Sciences Raichur, 2013, 105-111.
3. Bhosale BB, Nishantha KM, Patinge NR, Kadam DR. Comparative efficacy of microbial insecticide molecule E2Y45 against pod borer complex of pigeonpea. Pestology, 2009; 33:38-42.
4. Cordova D, Benner EA, Sacher MD, Rauh JJ, Sopa JS, Lahm GP *et al.* Anthranilic diamides: A new class of insecticides with a novel mode of action, ryanodine receptor activation. Pest. Biochem. Physio. 2005; 84:196-214.
5. Fitt GP. The ecology of *Heliothis* species in relation to Agro-ecosystems. Annu. Rev. Entomol. 1989; 34:17-52.
6. Gomez KA and Gomez AA. Statistical Procedures for Agricultural Research. 2nd edition A Wiley Inter science Publication, John Wiley and Sons, Singapore, 1984, 302-307.
7. Grigolli JFJ, Lourenção ALF, Ávila CJ. Field Efficacy of Chemical Pesticides against *Maruca vitrata* Fabricius (Lepidoptera: Crambidae) Infesting Soybean in Brazil. American Journal of Plant Sciences, 2015; 6:537-544.
8. Hannig GT, Ziegler M, Macron PG. Feeding cessation effects of chlorantraniliprole, a new anthranilic diamide insecticide, in comparison with several insecticides in distinct chemical classes and mode of action groups. Pest Mgmt. Sci. 2009; 65:12-16.
9. IRAC. IRAC Mode of Action Classification Scheme Insecticide Resistance Action Committee April. 2018; 72:1-23. http://W/Ww.irac-online.org/content/uploads/MoA classification.pdf.
10. Mishra HP. Management of serpentine leaf miner (*Liriomyza trifolii*) (Diptera: Agromyzidae) on tomato (*Lycopersicon esculentum*) with a new insecticide cyantraniliprole. Indian J. of Agri. Sci. 2013; 83(2):210-15.
11. Nakao T, Banba S. Broflanilide: A meta-diamide insecticide with a novel mode of action. Bioorganic & Medicinal Chemistry. 2016; 24(1):372-377.
12. Nakao T, Banba S, Hirase K. Comparison between the modes of action of novel meta-diamide and macrocyclic lactone insecticides on the RDL GABA receptor. Pestic Biochem Physio. 2015; 120:101-108.
13. Nakao T, Banba S, Nomura M, Hirase K. Meta-diamide insecticides acting on distinct sites of RDL GABA receptor from those for conventional noncompetitive antagonists, Insect Biochem. Mol. Biol. 2013; 43(4):366-375.
14. Rachappa V, Suhas Yelshetty, Chandra Shekhara, Pampapathi G. Mmanagement of insect pests of pigeon pea using a novel anthranilic diamide molecule, J. Exp. Zool. India. 2014; 17(2):621-626.
15. Sreekanth M, Lakshmi MSM, Rao YK. Bio-efficacy and economics of certain new insecticides against gram pod borer, *Helicoverpa armigera* (Hubner) infesting pigeonpea (*Cajanus cajan* L.). International Journal of Plant, Animal and Environmental Sciences. 2014; 4(1):11-15.