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Review article

CRITICAL REVIEW ON BIOEFFICACY OF INSECTICIDES AGAINST POD BORER COMPLEX IN PIGEONPEA

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INTRODUCTION

Pigeonpea (*Cajanus cajan* L. Millsp.) is an important pulse crop in the semi-arid tropics and subtropical farming systems, providing high quality vegetable protein, animal feed and firewood (Mittal and Ujagir, 2005). The crop yields are generally hampered by many pests, which are problematic over years (Kumar and Nath, 2002). Major constraint in the production of pigeonpea is the damage caused by insect pests with avoidable losses extending up to 78 per cent in India (Lateef and Reed, 1983). Nearly 300 species of insects are known to infest pigeonpea crop at its various growth stages in India (Lal and Singh, 1998). Pod borers caused 60 to 90 per cent loss in the grain yield under favourable conditions and damage of seed by pod fly ranged from 14.3 to 46.6 per cent (Lal *et al*., 1992). *Helicoverpa armigera* and *Melanagromyza obtusa* cause adequate economic damage leading to very low yield levels of 500 to 800 kg ha^{-1} as against the potential yield of 1800 to 2000 kg ha^{-1} (Lal *et al*., 1997). An yield loss of 60 to 80 per cent was recorded due to the podfly, *Melanagromyza obtusa* (Durairaj, 2006).

Therefore, keeping in view of the above discussions the available literature related to the efficacy of insecticides against pod borers complex in pigeonpea has been reviewed.

Efficacy of Insecticides against Pod Borer Complex of Pigeonpea

Pigeonpea (*Cajanus cajan* L. Millsp.) is attacked by number of pests which are quite varying according to different agro-climatic conditions. Several insects have been reported to infest pigeonpea crop at different stages during its growth period in different parts of the country (Lefroy, 1906, 1909; Fletcher, 1914, 1920; Pruthi, 1936; Ayyar, 1940; Srivastava, 1964; Pandit and Rawat, 1965; Odok *et al*., 1967; Bohlen, 1973; Davies and Lateef, 1975; Nair, 1975; Singh and Singh, 1978; Rangaiah and Sehgal, 1983; Khokhar and Singh, 1983; Sekhar, 1991 and Reddy *et al*., 2001).

Trehan and Pingale (1946) published an annotated list of crop pests in the erstwhile Bombay Province and enlisted aphid (*Aphis medicagenis* Koch), podborer (*Heliothis obsoleta* Fabricius), plume moth (*Exelastis atomosa* Walsingham.), podfly (*Melanagromyza obtusa* Malloch), pod butterfly (*Catachrysops cnejus* Fabricius), pod bugs (*Riptotus linearis* Fabricius and *Clavigralla gibbosa* Spinola) as the important pests of pigeonpea.

Srivastava (1964) listed about 150 insect pests of pulses and stated 25 pests causing serious damage of which podborer (*Heliothis obsoleta*), plume moth (*Exelastis atomosa*) and podfly (*Melanagromyza obtusa*) were the most important on pigeonpea. Reed *et al.* (1980) considered the pod feeding species such as *Heliothis armigera* Hubner, *Exelastis atomosa* Walsingham and *Melanagromyza obtusa* Malloch as major pest problems of pigeonpea. Yadav and Chaudhary (1993) determined that *H. armigera* damaged 13.6 and 13.7 per cent pods and 5.3 and 5.3 per cent grain; *M. obtusa* damaged 10.1 and 9.4 per cent pods and 3.5 and 3.1 per cent grain during 1984 and 1985, respectively in pigeonpea.

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Sahoo and Senapati (2001) determined that the pod borers together damaged 57.07, 54.09 and 40.08 per cent pods and 34.79, 30.90 and 20.20 per cent seeds incurring the yield losses of 28.07, 21.01 and 15.02 per cent in early, medium and late maturing cultivars, respectively in pigeonpea. Sharma *et al.* (2011) reported that pod fly *Melanagromyza obtusa* Malloch has become important biotic constraint in increasing the production and productivity under subsistence farming conditions and the survey revealed that the damage by pod fly ranged from 25.5 to 36 per cent in pigeonpea.

Synthetic Pyrethroids

Dandale *et al.* (1981) from Maharashtra compared the efficacy of synthetic pyrethroids with commonly used compounds and found that fenvalerate (0.01%) was the most effective followed by cypermethrin (0.01%), permethrin (0.01%), endosulfan (0.05%) and methamidophos (0.05%) in reducing pod infestation by borer complex of pigeonpea. Fenvalerate (0.01%) was effective against *H. armigera*, *E. atomosa and M. obtusa* on pigeonpea in Maharashtra (Patil *et al*., 1988; Khaire *et al*., 1989). Patel and Patel (1989) evaluated that fenvalerate (0.01 and 0.02%), fenvalerate dust (0.4%) at 25 kg ha^{-1} were effective in reducing numbers of *H. armigera* in pods; fenvalerate at 0.02 per cent gave maximum protection of pods and grains against infestation by *M. obtusa* and the maximum grain yield was obtained from plots treated with 0.02 per cent fenvalerate in pigeonpea. Singh and Singh (1990) found that out of seven insecticides tested in reducing infestation of pods and seeds of pigeonpea by *M. obtusa*, fenvalerate (0.02%) was found most effective and also reported that fenvalerate gave the greatest profit per hectare, followed by fluvalinate (0.02%).

Sontakke and Mishra (1991) determined that cypermethrin applied 3 times at 75 g a.i. ha^{-1} was the most effective treatment against the pests (*Maruca testulalis*, *Helicoverpa armigera*, *Exelastis atomosa and Melanagromyza obtusa*), followed by decamethrin at 12.5 g a.i. ha^{-1} and fenvalerate at 150 g a.i. ha^{-1} in pigeonpea. Patil *et al.* (1993) reported that fenvalerate (0.01%) treated plants showed the least damage and greatest grain yield than quinalphos (0.12%) and endosulfan (0.07%) in Maharashtra. Baruah and Ramesh Chauhan (1997) reported that on average, synthetic pyrethroids were more effective than endosulfan against *H. armigera* infesting pigeonpea. Pod damage was lowest following treatment with cypermethrin. Ram Ujagir (1999) reported that cypermethrin (0.006 and 0.004%) gave an effective level of control of *Maruca testulalis* [*M. vitrata*], *Helicoverpa armigera* and *Melanagromyza obtusa* and a higher grain yield compared to untreated plots. Fenvalerate (0.0075 and 0.004%) and deltamethrin (0.002 and 0.006%) were also effective at reducing pod borer damage and losses in grain yield on early pigeonpea (*Cajanus cajan*). Dikshit and Singh (2000) reported that beta-cyfluthrin when sprayed in chick pea at 18.75 and 37.50 g a. i. ha^{-1} against the gram pod borer *Helicoverpa armigera*, population was decreased by 66.2 and 75.4 per cent after one day, respectively. Yadav *et al.*(2000) reported that the synthetic pyrethroids were better than the other treatments in controlling yield loss due to insect pests but were at par with endosulfan and quinalphos in field pea. Singh *et al.* (2001) reported that lowest pod damage caused by the pod borers *viz.*, *Helicoverpa armigera* and *Exelastis atomosa* (2.40%) was obtained upon treatments with fenvalerate (0.02%) and the highest (22.80%) was recorded from the untreated plot. The pod fly (*Melanagromyza obtusa*) was also best controlled by fenvalerate (0.02%). It recorded the lowest pod damage of 2.4 per cent in pigeonpea.

Baruah and Ramesh Chauhan (2002) found that the cypermethrin treated plots registered the lowest damage, weight loss and highest average yield of 28.06 q ha^{-1} compared to deltamethrin (26.69 q ha^{-1}), fenvalerate (25.94 q ha^{-1}) and endosulfan (25.10 q ha^{-1}) treated plots in pigeon pea. Baruah *et al.* (2002) reported that on an average synthetic pyrethroids were better than endosulfan against *Helicoverpa armigera* on the basis of pod damage in pigeon pea. Mohapatra and Srivastava (2002) reported that spraying of lambda-cyhalothrin 5 EC @ 25 g a.i. ha^{-1}, beta-cyfluthrin 25 SC @ 18.8 g a.i ha^{-1} and thiodicarb 75 WP @ 750 g a.i ha^{-1} attributed to higher yield and less larval incidence when compared to alanycarb, profenofos, monocrotophos and endosulfan against legume pod borer, *M. vitrata*, in short duration pigeonpea cv. ICPL 87. Kumar and Nath (2003) evaluated the efficacy of some synthetic insecticides against pod bug and pod fly infesting pigeon pea cv. UPAS-120. The order of efficacy was cypermethrin (0.006%) > fenvalerate (0.02%) > deltamethrin (0.004%) > control. Dushyant Kaushik and Biswajit Das Pal (2006) evaluated that the lambda-cyhalothrin 5 EC was found highly effective in suppressing the pigeon pea pod borer complex, followed by profenofos (40 EC) + cypermethrin (4 EC), lambda-cyhalothrin (5 EC) + azadirachtin (1.0 lt ha^{-1}) and profenofos (40 EC) + cypermethrin (40 EC) + azadirachtin (1.0 lt ha^{-1}). Rao and Rao (2006) reported that thrice spraying of insecticide fenvalerate 20 EC (0.02%) on pigeonpea variety ICPL-85063 was found to be effective in reducing pod borer infestation, pod damage level and seed damage due to pod fly respectively and also contributed to yield enhancement.

Mohapatra and Srivastava (2008) investigated that when beta-cyfluthrin (18.75 g a.i. ha^{-1}) sprayed against the spotted pod borer, *Maruca vitrata* in short duration pigeon pea cv. ICPL 87 recorded the lowest pod damage, seed damage, seed loss (5.00, 3.08 and 2.72 % respectively) and highest grain yield (1139 kg ha^{-1}) than the other insecticides, (706-1019 kg ha^{-1}) and the control (359 kg ha^{-1}). Dhaka *et al.* (2011) reported that indoxacarb, lambda-cyhalothrin, endosulfan, neemarin and Bt, which gave 93.56 and 79.42 q ha^{-1} yield, respectively when sprayed against *Etiella zinckenella* (Treitschke) in vegetable pea.

Organophosphate compounds

Shetgar and Puri (1979) recommended quinalphos @ 350g a.i. ha^{-1} spray at pod formation stage against podborer damage on pigeonpea. Bhaduria *et al.* (1988) observed that monocrotophos, carbaryl, fenvalerate and thiodicarb recorded 9.4 to 12.69 per cent podfly damage and were found significantly superior over phosphomidon (25.54%) but in turn were at par with each other in pigeonpea. Lal and Yadava (1988) reported that the best results against the agromyzid *Melanagromyza obtusa* were obtained with 2 spray applications of dimethoate or monocrotophos 0.05 per cent, and against the noctuid *Heliothis armigera* [*Helicoverpa armigera*] with 2 applications of endosulfan 0.07 per cent or monocrotophos 0.05 per cent. Grain damage in treated plots ranged from 17 to 30.2 per cent for *M. obtusa* and from 5.8 to 18.6 per cent for *H. armigera* in pigeon pea (*Cajanus cajan*). Patel and Patel (1989) determined that quinalphos 1.5 per cent is effective against *H. armigera* and monocrotophos 0.04 per cent showed the maximum grain yield from the plots treated with it in pigeon pea [*Cajanus cajan*]. Sontakke and Mishra (1991) tested and determined that quinalphos at 300 g a.i. ha^{-1} was effective against *M. obtusa* in both spray schedules in pigeon pea. Prasad and Singh (1992) investigated that the monocrotophos, dimethoate and methamidophos were found effective in the control of *Empoasca kerri, Helicoverpa armigera, Megalurothrips usitatus, Euchrysops cnejus and Melanagromyza obtusa* on pigeon pea. Biradar *et al*. (1999) evaluated that the quinalphos and endosulfan sprayed 15 days apart resulted in 20.50 per cent pod damage and a seed yield of 0.83 t ha^{-1} against *Helicoverpa armigera* on Bengal gram. Pandao *et al.* (1993) determined that the quinalphos 0.05 per cent being the most effective against *H. armigera* and monocrotophos (0.04%) was the most effective treatment against *M. obtusa* when applied thrice against the *Helicoverpa armigera* and *Melanagromyza obtusa* on pigeonpea. Ram Ujagir (1999) evaluated that monocrotophos (0.04%) and Quinalphos (0.005%) gave an effective level of control of pod borers (*Maruca testulalis* [*M. vitrata*], *Helicoverpa armigera* and *Melanagromyza obtusa*) on early pigeonpea (*Cajanus cajan*) and a higher grain yield compared to untreated plots. Balikai *et al*. (2001) evaluated that quinalphos 25 EC (0.05%) when sprayed at 15-day intervals commencing at 50 per cent flowering found significantly superior over the untreated control with pod damage and yield of 19.6 per cent and 7.4 q ha^{-1} against the chickpea pod borer, *H. armigera* in chickpea cv. A-1. Biradar *et al.* (2001) determined that quinalphos at 0.05 per cent and monocrotophos at 0.04 per cent found superior compared to the control in reducing the population of *H. armigera* on pigeon pea cv. ICPL 8863. Singh and Yeshbir Singh (2001) determined that quinalphos 25 EC (0.05%) and monocrotophos 36 SL (0.04%) when sprayed against on pigeon pea cv. P 855 showed significant reduction in pod damage. Singh *et al.* (2001) reported that dimethoate (0.03%) was the second best control measure after fenvalerate (0.02%) in pigeonpea against pod borers *Helicoverpa armigera* and *Exelastis atomosa* . The pod fly (*Melangromyza obtusa*) was best controlled by monocrotophos (0.04%) and dimethoate at 750 lt ha^{-1}. Monocrotophos (0.04%) recorded the lowest pod damage of 2.5 per cent. Pinki Bhandari and Ram Ujagir (2002) determined that quinalphos (500g a.i. ha^{-1}), monocrotophos (600 g a.i. ha^{-1})+deltamethrin (12 g a.i. ha^{-1}), profenofos (750 g a.i. ha^{-1}), chlorpyrifos (500g a.i. ha^{-1}) and chlorpyrifos-methyl (1000 g a.i. ha^{-1}) + NPV (500 LE ha^{-1}) + NSKE (5%) were effective treatments when sprayed against the pod borer complex of early maturing pigeon pea cv. UPAS 120. Kirpal Singh Sharma (2003) investigated that dimethoate, chlorpyrifos, cypermethrin, methyl parathion, quinalphos, endosulfan and an untreated control showed pod damage of 6.83, 7.74, 8.33, 8.54, 9.99, 11.24 and 17.12 per cent; grain yield of 14.26, 16.62, 18.40, 18.90, 19.50 and 18.70 q ha^{-1}, respectively when sprayed against *Helicoverpa armigera* in chickpea cv. Gaurav. Yadav and Verma (2007) investigated that spray of quinalphos gave highest (100 %) mortality of larvae after last spraying followed by maximum grain yield 17.85 q ha^{-1} of gram with 6.09 per cent increase in yield over control against *Helicoverpa armigera* in pigeonpea.

Thiacloprid

Thiacloprid is an acute contact and stomach poison with systemic properties. Thiacloprid has a favourable environmental profile with a short half-life in soil, and good margins of safety for birds, fish species and many beneficial arthropods (Elbert *et al.*, 2000).

Thiacloprid, was a novel and highly active chloronicotinyl insecticide with broad spectrum efficacy against sucking and biting insects at 48-180 g a.i. ha^{-1} depending on crop and pest. Five years of field studies in Germany have revealed the excellent control of important pests in fruit, cotton, vegetables and potatoes. Besides aphids and whiteflies it is also active against various species of beetles and lepidoptera, such as leaf miners, codling moth and oriental fruit moth and showed good plant compatibility in all relevant crops. (Elbert *et al.*, 2002). Krishnaiah *et al.* (2003) reported that among the sprays, thiacloprid (120 g a.i. ha^{-1}) was comparable to chlorpyriphos (500 g a.i. ha^{-1}) in controlling insect pests of rice cv. Krishna hamsa. Gengotti *et al.* (2008) found that the synthetic active ingredients pymetrozine, imidacloprid, thiacloprid, thiamethoxam and flonicamid were the most effective in reducing the aphid (*Aphis gossypii*) populations on zucchini crops (cucurbitaceae). Saour (2008) reported that thiacloprid was effective in reducing potato tuber moth larval survival on potato seedlings or adults emergence from potatoes, exhibiting activity for at least 14 days after application. When already infected potato seedlings or tubers were treated with thiacloprid at a rate of 0.4 ml l^{-1}, adult emergence was decreased and suggested that potato plants or tubers treated with thiacloprid at a commonly used rate (0.4 ml l^{-1}) should be well protected from the possibility of infestations by the potato tuber moth.

Flubendiamide

Flubendiamide is a new benzenedicarboxamide insecticide developed for lepidoptera pest control. It is known to act on insect ryanodine receptors. Insecticide resistance has developed in many lepidopteran pests and shows no cross resistance to other chemical classes of insecticides such as pyrethroids, carbamates, organophosphates, chlorinated hydrocarbons, benzoylphenyl ureas or compounds such as indoxacarb. Flubendiamide is the first insecticide in group 28 (ryanodine receptor modulator) of the IRAC (Insecticide Resistance Action Committee) mode of action classification scheme and is therefore an ideal partner of all other classes of insecticides so far described. Flubendiamide is a new chemical option for control of multi-resistant noctuid pests and an excellent choice in resistant management strategies for lepidopteran pests in general (Nauen *et al.*, 2007). Tohnishi *et al.* (2005) reported that flubendiamide showed extremely strong insecticidal activity especially against lepidopteran pests including resistant strains. Flubendiamide would have a novel mode of action, because the insecticidal symptoms accompanied by a discriminative contraction of the larval body are distinguished from those of commercial insecticides. It is also very safe for non-target organisms. Flubendiamide is expected to be a suitable agent for controlling lepidopteran insects as part of the insect resistance management and the integrated pest management programs. Tomar *et al.* (2005) evaluated that flubendiamide 20 WDG at 50 g a.i. ha^{-1} was found to be highly effective in minimizing the bollworm damage and increasing the yield of seed cotton and it was suggested that flubendiamide 20 WDG at 50 g a. i. ha^{-1} could be considered as the optimum dose for controlling cotton bollworms. Ameta and Bunker (2007) investigated that flubendiamide (24, 36 and 48 g a.i. ha^{-1}), indoxacarb (75 g a.i. ha^{-1}) and spinosad (75 g a.i. ha^{-1}) were significantly superior to untreated control in reducing *Helicoverpa armigera* infestation in tomato. However, flubendiamide at 48 g a.i. ha^{-1} caused significantly higher reduction in the population of fruit borer larvae and recorded the lowest fruit damage than the remaining treatments. Ebbinghaus *et al.* (2007) reported that flubendiamide applied at 24-48 g a.i. ha^{-1}, controls the lepidopteran pest complex in cabbage. The product shows an excellent performance in tomato, over a range of 24-60 g a.i. ha^{-1}, against *Helicoverpa armigera* and *Spodoptera exigua*. Tang (2008) reported that flubendiamide was a diamide insecticide have a unique chemical structure and a novel mode of action and show excellent efficacy, a broad insecticidal spectrum against lepidopteran insect pests, excellent safety against various beneficial arthropods and natural enemies and no cross-resistance to existing insecticides and very suitable for insecticide resistance management and IPM programmes. Dodia *et al.* (2009) reported that flubendiamide 20 WDG at 50 g a.i. ha^{-1} when sprayed against *H. armigera* infesting pigeonpea showed most effective results with 5.98 per cent damage. Kumar and shivaraju (2009) reported that flubendiamide 480 SC @ 48 and 36 g a.i. ha^{-1} recorded pod damage of 6.04 and 7.62 per cent by *Helicoverpa armigera*, 2.91 and 3.55 per cent by *E. zinckenella*, respectively in black gram. Tatagar *et al.* (2009) reported that among various dosages flubendiamide 20 WG @ 60 g a.i. ha^{-1} recorded highest yield of 7.48 q ha^{-1} with lowest fruit damage by *H. armigera* and *S. litura* of 3.45 per cent followed by flubendiamide 20 WG@ 40 g a.i. ha^{-1} (6.72 q ha^{-1}), emamectin benzoate 5 SG @ 11 g a.i. ha^{-1} (7.22 q ha^{-1}) and spinosad 45 SC @ 75 g a.i. ha^{-1} (7.32 q ha^{-1}) in chilli. Deshmukh *et al.* (2010) determined that flubendiamide 0.007 per cent in pigeonpea was found the most effective in reducing the *H. armigera* population and pod damage and showed the highest yield of 1850 Kg ha^{-1} and cost benefit ratio of 1:6.10. Tohinshi *et al.* (2010) concluded that flubendiamide was the first example of 1,2-benzenedicarboxamide insecticides but also the first practical synthetic insecticide with a mode of action as an activator of ryanodine receptors. It shows high selective activity against lepidopteran insect pests, which leads to excellent efficacy in the field, and excellent safety against non-target organisms, including various beneficial arthropods and natural enemies.

These properties suggested the suitability of flubendiamide for integrated pest management (IPM) programs. Thilagam *et al*. (2010) evaluated that flubendiamide 60 g a.i. ha^{-1} showed marked reduction in the *Helicoverpa* larval population and recorded up to 96.00 per cent reduction in damage in cotton. Dhaka *et al.* (2011) reported that flubendiamide 39.35 EC @ 75 ml ha^{-1} was best with lowest pod and seed infestation of 11.37 and 12.98 per cent, respectively and 95.84 q ha^{-1} yield against *Etiella zinckenella* (Treitschke) in vegetable pea.

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