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Efficacy of insecticides on adults and soil inhabiting maggots of cotton flower bud midge (*Dasineura gossypii* Fletcher)

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Abstract: The cotton flower bud midge, *Dasineura gossypii* Fletcher (Cecidomyiidae: Diptera) has recently been reported as key pest of cotton in Southern parts of India. The laboratory studies have been carried out during 2014-16 on the efficacy of six commercially available insecticides *viz.,* Lambda Cyhalothrin 5 EC, Fipronil 5 SC, Profenophos 50 EC, Quinalphos 25 EC, Spinosad 45 SC and Rynaxypyr 18.5 EC against cotton flower bud midge. In CDC bottle assay method, Lambda Cyhalothrin 5 SC, Profenophos 50 EC and Quinalphos 25 EC were found to be the most effective against adults with highest per cent mortality (100%) while, Fipronil 5 SC, Spinosad 45 SC and Rynaxypyr 18.5 EC were found to be least effective insecticides. Lambda Cyhalothrin was found to be effective with comparatively very low LT_{50} of 4.56 and 2.80 min at 10 and 100 ppm, respectively, followed by quinalphos and profenophos. As the pupation of this insect pest happens in the soil and debris, management of pupae with soil application of insecticides can be done. Accordingly, the soil application assays conducted with three insecticides *viz.,* Phorate 10 G, Carbofuran 3 G and DDVP 76% EC, against maggots of cotton FBM indicated that DDVP 76% EC found to be the most effective with the lowest adult emergence (3.33 %) followed by Phorate (5.56 %) as against 55 % in control.

Keywords: Cotton, Flower bud midge, Insecticides

Introduction

Cotton is one of the most important fiber crops in the world and plays a pivotal role in social and economic development of India. The data from Cotton corporation of India indicates that during 2015-16, cotton was planted in an area of 118.81 lakh ha, which produced 352 lakh bales with the productivity of 504 kg/ha. However, cotton production in India is impacted by several biotic stresses that directly cause production losses. According to Sundaramurthy (1985), there are as many as 156 species of insects and mites infesting cotton. *Bt* cotton technology has achieved the goal of providing an effective tool for bollworm (*Helicoverpa armigera Hübner, Earias* spp. and *Pectinophora gossypiella* Saunders) control and more environmentally benign than broad-spectrum insecticides. During this period some of the secondary pests have emerged into economically important insect pests in countries such as the USA (Greene and Capps, 2002). Similarly, the cotton flower bud midge, *Dasineura gossypii* Fletcher, a little known pest in cotton has emerged into an economically damaging pest in some parts of the cotton growing areas of the India; and has been now recognized as a key emerging pest in cotton (Udikeri *et al.,* 2011).

Dasineura (Diptera: Cecidomyiidae) is the gall midge genus with the highest number of known species (466) reported throughout the world (Maia and Silva, 2013). Genus *Dasineura* contains eight different species on different host plants In India. A checklist of Indian gall midges is provided in the World Catalog (Gagne´, 2004) and additions thereafter including *D. gossypii. Dasineura gossypii* was described by Professor T. B. Fletcher in 1940 in Pusa, Bihar, based on collections from cotton flower buds. It has been reported earlier as a pest on cotton and referred to as floral bud maggot from Coimbatore (Tamil Nadu) (Ayyar, 1932). Thus, it could find a place in "Cotton in India: A monograph" Vol. II (Dastur *et al.,* 1960). After the initial reports of infestations in cotton, this pest neither attacked cotton severely nor attracted attention of researchers, until its first severity was reported from Karnataka, India, with 90% fruiting body damage (Udikeri *et al.,* 2011).

During 2009 severe incidence was observed in farmers' fields in Hesarur village (Taluk: Savanur, District: Haveri) of Karnataka State. The biological observations revealed by Chakraborthy *et al.* (2015) and Udikeri *et al.* (2011), indicate oviposition at the tip of squares and development of maggots in flower buds. They have also reported that the maggots cause damage and 5-20 maggots can be found in single flower bud in favorable conditions. Mature maggots feed on anthers, staminal column and outer wall of style leading to decaying of inner content of the flower buds which fail to grow properly, leading to twisted petals with decaying and drying of the flower bud. Further, Nandihalli *et al.* (2015) observed fully matured maggots moving to soil for pupation and reported 8-10 generations in a year. Similar behavior of maggots and damage manifestations were reported in *Dasineura oxycoccana* of blueberry and other *Dasineura* species (Roubos and Liburd, 2013).

The multivoltine life history and short adult lifespan necessitate careful scouting and timing of insecti-cide application. The maggot stages are mostly protected by surrounding plant tissue and may not be managed with insecticide sprays. At present the options for management of flower bud midge in cotton are limited to Malathion sprays (Udikeri *et al.* (2011). Hence, the present investigation was carried out to evaluate a few of the widely used and easily available insecticides with different modes of action, for their efficacy against adult flies and maggots of the flower bud midge.

Material and methods

Experiments were carried out to assess the efficacy of different insecticides against different life stages of cotton flower bud midge in laboratory conditions during 2014-16, at Mahyco Research Centre, Dawalwadi, (Maharashtra-India).

In order to study the efficacy of insecticides against adults of *D. gossypii,* an experiment was carried out by using CDC bottle assay method. In the absence of standard methods suggested for adult flower bud midge flies, CDC bottle assay method used for evaluation of insecticides on mosquitoes has been used. A detailed description of the CDC bottle bioassay, including the methodology has been published by the United States Centers for Disease Control and Prevention, based in Atlanta, GA, in October 2010, as Guideline for evaluating insecticide resistance in arthropod vectors using the CDC bottle bioassay. The study was conducted in completely randomized design with seven treatments *viz.,* six insecticides and untreated control and replicated three times. Insecticidal formulations used in this experiment were Lambda Cyhalothrin (Karate 5 EC – Syngenta India Ltd., Pune), Fipronil (Regent 5 SC – Bayer Crop science Ltd., Mumbai), Profenophos (Curacron 50 EC – Syngenta India Ltd., Pune), Quinalphos (Ekalux 25 EC, Syngenta India Ltd., Pune), Spinosad (Tracer 45 SC – Dow Agro Sciences India Pvt. Ltd., Mumbai) and Rynaxypyr (Coragen 18.5 EC – E. I. Dupont India Pvt. Ltd., Gurgaon), which have been selected based on mode of action and ease of availability. All the stock solutions (1000 ppm) were prepared by using formulated insecticides and acetone as solvent. Different concentrations of insecticide i.e. 1000, 100 and 10 ppm, were used with an untreated control (acetone only). Glass bottles (Schott Duran bottle, SCHOTT, USA) of 250 mL capacity were used for testing, by baking at 180°C, washed with 90% ethanol and air dried under fume hood for 2-3 h. One ml of the insecticide dilution was transferred into each of the bottles and it was ensured that entire internal surface of the bottle gets coated uniformly. One ml of Acetone AR (Rankem brand, Avantor Performance materials India Ltd., India) was used as untreated control. The bottles were left open overnight without their lids, on a clean surface in a fume hood, to ensure complete drying. Ten flower bud midge adult flies were collected with an aspirator and were released gently into each of the bottles. Adults were released to the untreated control bottle(s) first and then to the bottles with different insecticide concentrations, to avoid any contamination transmitted via the aspirator. The observations on mortality were recorded at five minutes intervals during half an hour assay period.

In order to evaluate the efficacy of soil applied insecticides against pupa of the cotton flower bud midge, an experiment was set up with plastic containers (0.072m^2) and moistened soil (approximately 20 % moisture in soil) tightly covered with a muslin cloth. Three most widely used soil applied insecticides viz., Phorate 10 G, Carbofuran 3 G and DDVP 76 EC were used in this study at four different concentrations (recommended or label dose (X), 2X, 0.5X, 0.25X). The concentrations of insecticides were prepared and applied considering the recommended dose of respective insecticides (g per acre or mL per liter of water). Accordingly, 180 mg (2X), 90 mg (X), 45 mg (0.5X) and 22.5 mg (0.25X) of Phorate, 288 mg (2X), 144 mg (X), 72 mg (0.5X) and 36 mg (0.25X) of Carbofuran and 100 ml (2X), 50 ml (X), 25 ml (0.5X) and 12.5 ml (0.25X) of DDVP were used in the assays.

In case of granular insecticides (Phorate 10 G and Carbofuran 3 G), estimated amount of granules were broadcasted over the moistened soil surface present in plastic containers, while DDVP, dissolved in water, was applied as soil drenching at required concentrations. After the soil treatment, ten third instar maggots were released with the help of fine hair camel brush in each container and covered with muslin cloth. The observations on adult emergence were recorded at 10-15 days after release.

The differences in outcome variables (mortality and adult emergence) between the insecticides were analysed separately for the different insecticide concentrations by using PROC GLM method in SAS 9.3, using the Duncan's New Multiple Range Test. The effects of two insecticides were considered to be significantly different when the *P*-value was less than 0.05.

Results and discussion

The data recorded on per cent adult mortality of *D. gossypii* revealed that effect of insecticide was statistically significant at all time periods of observations (Figure, 1). The results of the assays showed that there were significant differences in the mortality among the different insecticides and their concentrations at a particular time period. The exposure to the insecticides *viz.,* Lambda Cyhalothrin and Quinalphos gave consistently highest mortality at 5 and 10 min after exposure with 30-90% and 60-83.33% mortality, respectively. The significantly highest mortality (100 %) was found at 1000 and 100 ppm concentrations of the three insecticides *viz.,* Lambda Cyhalothrin, Profenophos and Quinalphos, during the observations recorded after 15 and 20 minutes (P = 0.0001) of exposure; as compared to the mortality with other insecticides and in untreated control. Further, there was significantly highest mortality (100 %) was observed in assays done with Lambda Cyhalothrin, Profenophos and Quinalphos as compared to a mortality of 53.33%, 26.67% and 10% in assays with Fipronil, Rynaxypyr and Spinosad, respectively, after 30 minutes of exposure (Fig. 1).

Thus, the assays indicated that Lambda Cyhalothrin, Profenophos and Quinalphos would cause 100% mortality at highest concentrations used. Elmhirst (2006), reported Lambda Cyhalothrin to be highly effective as foliar application to reduce bud damage caused by rose midge, *Dasineura rhodophaga* Coquillett. Similarly higher efficacy of Lambda Cyhalothrin on Brassica pod midge, *Dasineura brassicae* (Winnertz), as a foliar spray after flowering stage was observed by Pavella *et al.* (2007). Lambda Cyhalothrin was also found to be effective in managing apple leaf midge, *Dasineura mali* (Keiffer), when used in combination with sex pheromones (Cross *et al.,* 2009). These present findings are in corroboration with Chavalle *et al.* (2014), Jian *et al.* (2014), Nabil *et al.* (2013), and Oakley (2009), who

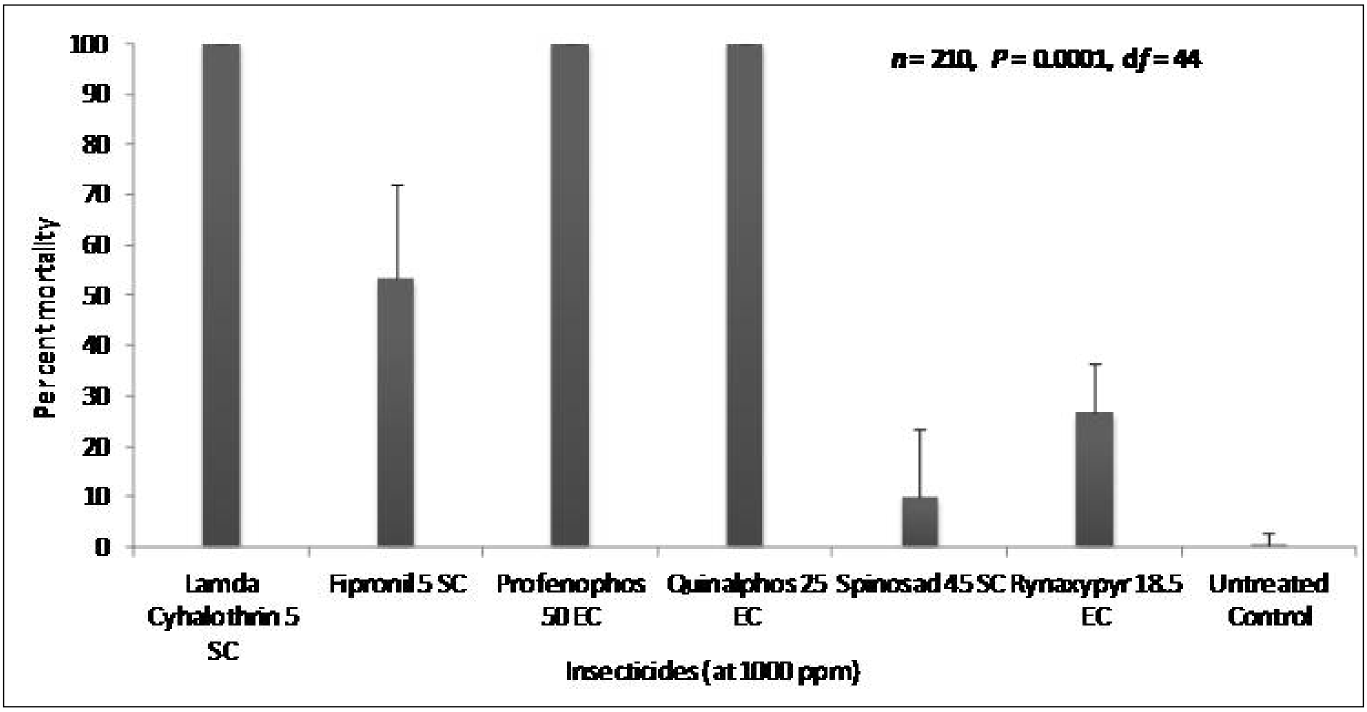

Fig. 1. Mortality of *Dasineura gossypii* in assays with different insecticides

proved the effectiveness of Lambda Cyhalothrin against other midges such as Orange wheat blossom midge, *Sitodiplosis mosellana* (Géhin) and yellow wheat blossom midge, *Contarinia tritici* (Kirby). In India, Lamani (2014) also reported Profenophos 50 EC @ 2 ml/l and Quinalphos 20 EC @ 2 ml/l as effective against *D. gossypii* by recording the lower incidence with a highest cost benefit ratio of 2.39 and 2.35, respectively. Udikeri *et al.* (2016) opined that Profenophos 50 EC @ 2 ml/l + DDVP 100 EC 0.5 ml/l provides better control of this pest. Our laboratory studies also demonstrated efficacy of Profenophos 50 EC and Quinalphos 25 EC against adult flies of cotton flower bud midge.

The mortality data recorded at different time intervals was used to estimate median lethal time (LT_{50}) through probit analysis (Table 1). The results indicated that Lambda Cyhalothrin killed 50 % of the *D. gossypii* adults within 4.56±0.70 and 2.80±0.50 minutes at 10 ppm and 100 ppm concentrations, respectively. In the assays with Quinalphos the estimated LT_{50} was 7.77±0.60 and 4.44±0.60 minutes at 10 and 100 ppm concentrations, respectively. The estimated LT_{50} in the assays with Fipronil, Rynaxypyr and Spinosad indicate that these insecticides were found to be less toxic to *D. gossypii* adults (Table 1). These results demonstrate that Lambda Cyhalothrin, Profenophos and Quinalphos cause higher mortality within a short period of time, as compared to other insecticides.

In soil application study adult emergence was low in all the insecticidal treatments (10-40 %) at recommended and lower than recommended doses, as against 55.00 % emergence in the untreated control (p = 0.0481) (Fig. 2). There were significant differences among treatments in terms of mortality observed at highest applied doses (p = 0.0013). There was no adult emergence (0.00 %) at highest applied doses of Phorate and DDVP. Thus, Phorate and DDVP appeared highly efficacious as soil applications by killing the larvae and/or pupae in the assays.

Most midges including *D. gossypii* pupate in soil and targeting the pupae in soil and emerging adults could be a good control method. Soil applications of Diazinon for control of *D. mali* and *D. oxycoccana* has been reported by Burnip *et al.,* 1998, Rhodes *et al.,* 2014, and Tomkins *et al.,* 2000. There is no literature available with regards to the efficacy of soil applied insecticides against cotton flower bud midge, *D. gossypii.* The results of soil application assays demonstrated that DDVP 76 EC was the most effective soil treatment with least (10 %) adult emergence at recommended doses. Present results are also in agreement with Zhao *et al.* (2010), who reported DDVP 80 % had the best efficacy against pear blossom gall midge, Dasineura sp. The assay results also demonstrated that Phorate can be used alternatively with DDVP and in situations where DDVP may not be available. It is also notable that DDVP and Phorate may have to be used at double the label dose for 100%

Table 1. Lethal time (LT_{50}) of insecticides at different concentrations against adults of *Dasineura gossypii*

Insecticides	LT_{50} (Mean ± SE) min.	
	10 ppm	100 ppm
Lambda Cyhalothrin 5 SC	4.56 ± 0.70	2.80 ± 0.50
Fipronil 5 SC	65.35 ± 6.30	35.77 ± 0.90
Profenophos 50 EC	17.24 ± 0.60	8.22 ± 0.80
Quinalphos 25 EC	7.77 ± 0.60	4.44 ± 0.60
Spinosad 45 SC	130.09 ± 2.90	48.91 ± 0.70
Rynaxypyr 18.5 EC	66.93 ± 0.80	37.45 ± 1.82

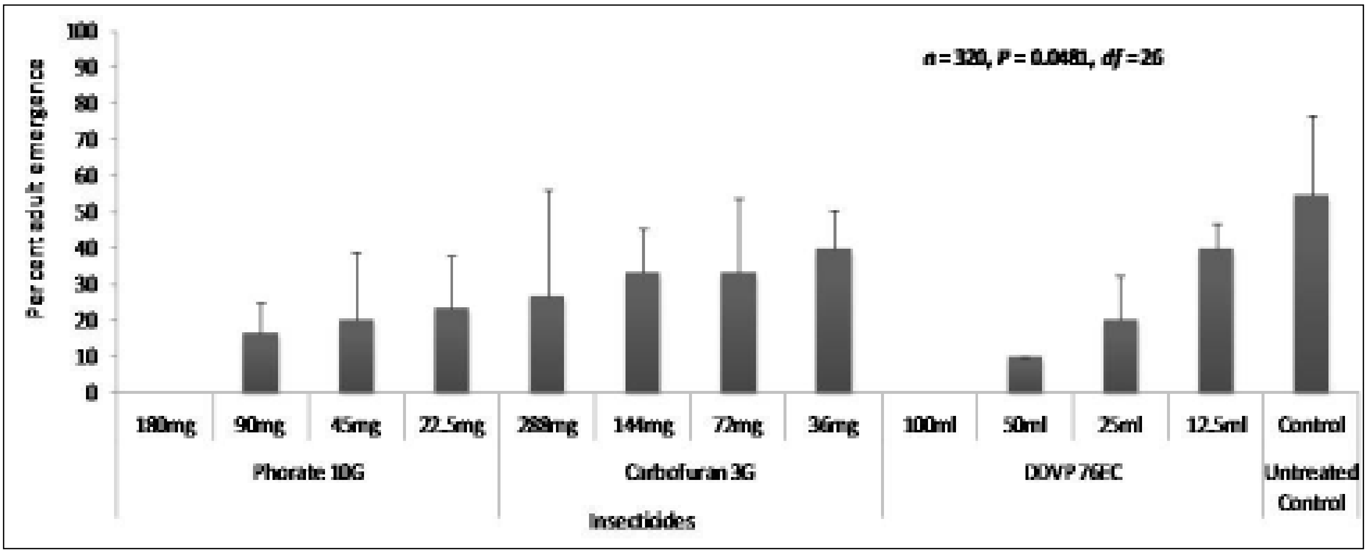

Fig. 2. Per cent adult emergence of *Dasineura gossypii* from soils treated with different insecticides

control of cotton flower bud midge. The results from our studies also indicate that carbofuran which is being recommended for flower bud midge is not effective in adult flies' management.

Hence, it could be concluded that the foliar application of Lambda Cyhalothrin 5SC, Profenophos 50EC and Quinalphos 25EC, and/or soil applications of DDVP 76EC and Phorate 10G could be relied in better management of *D. gossypii* in cotton. However, the laboratory data from these studies need to be validated for field level efficacy for strategic inclusion in pest management programs.

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