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Effectiveness of flonicamid 50 wg and flupyradifurone 200 SL against leafhopper and whitefly in okra

BK Singh, Rakesh Pandey, AK Singh and MK Mishra

Abstract
A field study was carried out to determine the efficacy of different insecticides against leafhopper and whitefly on okra crop during *Kharif* 2015 and 2016. Three different concentrations of each insecticide *viz.*, flonicamid 50 WG and flupyradifurone 200 SL and single concentration of commonly used neonicotinoid *i.e.*, imidacloprid 17.8 SL were used to observe their efficacy against leaf hoppers and whitefly on okra. The lowest population of leafhopper, 1.0/five leaves/plant during 2015 and 1.33/five leaves/plant during 2016 after 10 days of third spray was recorded in flonicamid 50 WG @ 0.4 g/l. However, the lowest population of whitefly, 1.53/five leaves/plant during 2015 and 1.33/five leaves/plant during 2016 after 10 days of third spray was observed in flupyradifurone 200SL @ 2.5 ml/l. The highest marketable fruit yield, 41.55 q/ha and 64.27 q/ha, respectively, during 2015 and 2016 was recorded from the treatment flonicamid 50 WG @ 0.4 g/l. Flonicamid and flupyradifurone both the chemicals gave satisfactory control in comparison to imidacloprid, thus, these new class insecticides may be a suitable option for the management of sucking insect-pests in okra.

Keywords: Flonicamid, flupyradifurone, imidacloprid, leafhopper, okra, whitefly

Introduction
Okra [*Abelmoschus esculentus* (L.) Moench] or Lady's finger is one of the important vegetables grown throughout the tropics and subtropics. In India, it is cultivated in an area of 0.509 m ha with an annual production of 6.095 million tones with an average productivity of 12 t/ha [5]. The Okra has a great scope in world trade. The crop is grown year round under varied soil and climatic conditions of India. There are more than 37 insect-pests which attack throughout growing season [20]. The leafhoppers, *Amrasca biguttula biguttula* (Ischida) (Hemiptera: Cicadellidae) and whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) are the most devastating and cause 32-56% losses [4, 13, 26, 28]. The damage of different insect pests varies from year to year depending upon weather conditions and the intensity of insect-pest attack. In addition, the sucking insect-pests also cause serious damage in transmitting various plant diseases. Among various diseases of okra, yellow vein mosaic (YVM) and leaf curl (LC) diseases are the most important causing colossal losses by affecting quality and yield of fruits [3, 24]. Both the viral diseases are transmitted by the whiteflies, *B. tabaci* (Gennadius) in a persistent manner [27].
Different measures are adopted to control the insect-pests in okra *viz.*, seed treatment before planting or some other cultural practices for the management of sucking insect-pests, but still the chemical control has been the most effective tool to control these insect-pests [10]. Though, chemical control is effective but frequent and injudicious use of insecticides has led the development of resistance in insect-pests. Among chemicals, now-a-days, the neonicotinoids are the most widely used insecticides against sucking insect-pests. They are systemic in action, passing through plant tissues and protecting all parts of the crop, and are widely applied as seed dressings. They possess lower mammalian toxicity, less resurgence problems, environmental protection, pest management selectivity and less toxicity to natural enemies [15]. Neonicotinoids are relatively safe for use around people, animals and the environment [18, 29].
Compared with already commercialized nAChR agonists, the butenolide flupyradifurone contains a different pharmacophore system as a new bioactive scaffold [11]. The novel butenolide insecticide flupyradifurone shows unique properties and may become a new tool for integrated pest management around the globe, as demonstrated by its insecticidal,

eco-toxicological and safety profile [19]. It is under global development for foliar, drench and seed treatment applications, particularly against sucking pest insects in numerous agricultural and horticultural crops. Flonicamid belongs to pyridinecarboxamide group that has the promising potential to manage the sucking insect-pests. Keeping in view the economic importance of okra and significant losses caused by insect-pests, the present research work was carried out to investigate the efficacy of different chemistry pesticides against leafhoppers and whiteflies.

Materials and methods

The present study was carried out to evaluate the efficacy of different molecules having unique mode of action against leafhoppers and whitefly in the instructional farm of Banda University of Agriculture & Technology, Banda during *Kharif* seasons of 2015 and 2016.

The seed of okra variety Pusa A4 was sown on first week of August, 2015 and 2016. The experiment was conducted in a Randomized Block Design (RBD), the size of sub plot maintained as 5x3 m. The experimental plots had eight treatments including untreated (control) and each treatment was replicated three times. The crop was sown on 45 cm apart ridges and keeping plant to plant distance of 30 cm. The agronomic practices were followed throughout the growing season of the crop as per the recommendations except pesticidal applications.

Three different concentrations of each insecticide *viz.*, flonicamid 50 WG and flupyradifurone 200 SL and single concentration of commonly used neonicotinoid *i.e.*, imidacloprid 17.8 SL were used to observe their efficacy against leafhoppers and whitefly on okra. Total three sprays were applied at 10 days' interval. The incidence of insect-pests was recorded from random five plants in each treatment. Pre-treatment observations of insect-pests were taken from five leaves per plant. The post-treatment observations on population of leafhoppers and whiteflies were taken from five leaves per plant on 3rd, 5th, 7th and 10th days after spray (DAS). The insecticidal application was carried out in the evening and observations on the population of the insects were recorded at morning hours (8-10 am) carefully. The population of leafhoppers and whiteflies were observed separately in each replication and their efficacy was analyzed.

The data thus recorded were subjected to analysis of variance to record the level of significance for variation and the mean values were compared by using critical difference (CD) as suggested by Gomez and Gomez [8].

Results and discussion

The results on population of leafhoppers are presented here under (Tables 1&2), whiteflies (Tables 3 & 4) and yield data is depicted in Fig. 1.

Effect on leaf hoppers

It is evident from the Table 1 that the pre-treatment population of leafhoppers was ranged from 15.77 to 22.22. The lowest population (0.22) of leafhopper was recorded in T3 (Flonicamid 50 WG @ 0.4 g/l) followed by 0.66, 0.77, 1.11, 1.66, 2.33, 8.97 and 33.33 in treatments *viz.*, T6 (Flupyradifurone 200 SL @ 2.5 ml/l), T2 (Flonicamid @ 0.3 g/l), T1 (Flonicamid @ 0.2 g/l), T5 (Flupyradifurone 200 SL @ 2 ml/l), T4 (Flupyradifurone 200 SL @ 1.5 ml/l), T7 (Imidacloprid 17.8 SL @ 0.35 ml/l) and T8 (control), respectively, on 3 DAS during first spray. All the treatments differed significantly from control, however, T1, T2, T3, T4, T5 and T6 were statistically at par. Similar observations were recorded after 5 DAS. The population of leafhoppers observed in T3 and T6 were statistically at par on 7 DAS. The population trend on 10 DAS was similar to 3 DAS and 5 DAS.

The lowest population (0.67 and 0.80) was observed in Flupyradifurone 200 SL @ 2.5 ml/l on 3 DAS and 5 DAS, respectively, during second spray. However; the lowest population, 3.2 and 2.0 was observed on 7 DAS and 10 DAS, respectively, in Flonicamid 50 WG @ 0.4 g/l. Here, the observed values were statistically at par in T1, T2, T3, T4, T5 and T6, during all observational period after second spray except T1 at 7 DAS at second spray.

The population of leafhoppers fluctuated very widely during third spray and the lowest population was observed in Flonicamid 50 WG @ 0.4 g/l during all observational period. The treatments T1, T2, T3, T4, T5 and T6 were significantly different from T7 and T8. The treatments T1, T2, T3, T4, T5 and T6 were statistically at par on 3 DAS and 5 DAS except T4 at 5DAS.

The pre-treatment population of leafhopper was ranged from 10.87 to 15.87 during second year experimentation (Table 2). The lowest leafhopper population (0.26) was recorded in T3 (Flonicamid 50 WG @ 0.4 g/l) followed by T2 (0.53), T6 (0.67), T5 (1.07), T1 (1.26), T4 (2.13) and T7 (8.33) in comparison to control (17.00) on 3DAS during first spray. All the treatments were significantly effective than control. However, T1, T2, T3, T5 and T6 were significantly at par and T3 and T4 were differed significantly. The similar trend was followed at 5 DAS, 7 DAS and 10 DAS at first spray.

During second spray, the most effective treatment was T3 where the leafhopper population was the lowest (0.73) followed by T6 (0.87), T5 (1.2), T1 (1.33), T2 (1.6), T4 (1.67) & T7 (24.47) in comparison to control T8 (41.47) on 3 DAS. The population trend of leafhoppers followed the same on 5 DAS, 7 DAS and 10 DAS.

However, T3 received greater attention in reducing the leafhopper population and the lowest population (1.13) was recorded followed by T2 (1.2), T1 (2.4), T6 (4.53), T5 (5.13), T4 (6.53), T7 (32.53) and T8 (77.93) during third spray on 3 DAS. Here, T1, T2, T3, T4, T5 and T6 were significantly at par on 3 DAS. The similar trend of leafhopper population was followed at 5 DAS, 7 DAS and 10 DAS.

Effect on whiteflies

Table 3 shows that the pre-treatment population of whiteflies ranged in between 8.88 to 14.30. The lowest populations (3.89, 6.55, 17.22 and 17.33) were observed in T3, T6, T6 and T8 on 3 DAS, 5 DAS, 7 DAS and 10 DAS, respectively, during first spray. However, the values were non-significant with each other.

During second spray, the lowest population (0.6) was recorded in T6 (Flupyradifurone 200 SL @ 2.5 ml/l) followed by 1.2, 2.0, 2.0, 2.6, 2.8, 2.87 and 3.37 in T5, T4, T1, T2, T3, T7 and T8, respectively, on 3 DAS. However, the observed values in T1, T2, T3 and T4 were statistically at par. The lowest populations (4.07 and 3.0) were observed in T7 on 5 DAS and 7 DAS, respectively. At 10 DAS, the lowest population was observed in T7; however, T7 and T8 were statistically at par here. The lowest populations (5.93, 6.53, 7.33 and 0.80) were observed in T7 on 3 DAS, 5 DAS, 7 DAS and 10 DAS, respectively, during third spray. The values of T7 and T4 were statistically at par.

It is evident from Table 4 that the pre-treatment population of whiteflies fluctuated in between 8.93 to 13.33. The population of whiteflies was reduced after spraying of different treatments but all the treatments were not differed significantly except on 5 DAS during first spray. The lowest population (6.33) was recorded from T6 (Flupyradifurone 200 SL @ 2.5 ml/l) followed by T3 (7.00), T5 (8.00), T7 (8.22), T4 (9.33), T2 (9.33), T1 (10.00) and T8 (15.67). Here, T2, T3, T4, T5, T6 and T7 were significantly at par.
The population of whiteflies was also observed as non significant during second spray on 3 DAS, however, it was significant on 5 DAS, 7 DAS and 10 DAS. At 5 DAS, the lowest population was recorded from control (3.67) followed by T7 (3.73), T3 (3.80), T6 (5.33), T5 (6.27), T2 (9.40), T1 (10.27) and T4 (14.07). T3, T6 and T7 were significantly at par. The lowest population was recorded from T7 (2.67) followed by 10.40, 11.27, 11.27, 15.80, 16.27 and 18.07 in T1, T2, T3, T6, T5 and T4, respectively, on 7 DAS during second spray. However, the lowest population (3.00) was observed in control followed by T7 (4.00), T3 (12.50), T2 (16.67), T1 (17.33), T6 (17.67), T4 (22.00), T5 (24.33) at 10 DAS. T2 and T3; T4 and T5 were statistically not different. The most effective treatment was T6 on 10 DAS during third spray as it received the lowest population (1.33). T3, T4, T5 and T6 were significantly at par in reducing the whitefly population.

Effect on yield

The highest yield (41.55 q/ha) was recorded from T3, followed by T2 (39.11 q/ha), T4 (38.44 q/ha), T1 (38.00 q/ha), T6 (37.78 q/ha), T5 (37.11 q/ha), T7 (22.66 q/ha) and T8 (20.44 q/ha) (Fig. 1). The treatments T1, T2, T3, T4, T5 and T6 were statistically at par but significantly different from T7 and T8 during 2015. The highest yield (64.27 q/ha) was recorded from T3 during 2016 (Fig. 1). However, the next effective treatments were recorded 59.57 q/ha, 58.10 q/ha, 56.33 q/ha, 56.00 q/ha, 55.90 q/ha, 41.77 q/ha and 38.77 q/ha yield in T6, T2, T5, T4, T1, T7 and T8, respectively.
The present experiment was conducted to evaluate the effect of new molecules having unique mode of action on the population of leafhoppers and whiteflies on okra crop. It was observed that both flonicamid and flupyradifurone at different concentrations were significantly effective against the leafhoppers and whiteflies. Both the chemicals are novel and belong to different groups and have unique mode of action. That is why; results were encouraging in comparison to imidacloprid. The available literature shows that the new class e.g., flupyradifurone performed well in comparison to neonicotinoids for the management of sucking insect-pests. Pawar and co-workers reported that two sprays of flupyradifurone 200 SL @ 2.0 ml/lit was found effective for control of leaf hoppers and whiteflies in okra [22]. The present findings are at par with the findings of Misra [17]. Hancock also observed that flonicamid was effective against sucking insect-pests of cotton [9]. Ghelani and co-workers also observed that the higher mortality in leafhoppers after the application of flonicamid @ 0.02% in Bt cotton [7]. Similarly, Kodandaram and co-workers reported that application of flonicamid @ 75 g a.i./ha reduced the population of leafhoppers and whiteflies in okra. Besides, it did not produce any harmful effect on natural enemies and there was no phytotoxic effect on okra crop [12]. The findings of Meghana and others corroborated with the present finding that flonicamid 50 WG @ 0.3 g/l reduced the population of leafhopper and whitefly in Bt cotton [16]. Flupyradifurone 200 SL even at lower dose of 150 g a.i./ha exhibited superior efficacy against cotton leafhopper, *Amrasca devastans* than the neonicotinoids in cotton [23]. The reports of Alston and Lindstrom; Garg and others agree with the present findings [2, 6]. Rao and other co-workers observed that flupyradifurone 20 SC @ 200 g a.i./ha was effective in cotton ecosystem and alternatives to neonicotinoids [25]. Patil and others reported that residual toxicity of flupyradifurone 200 SL was up to 15th days found best for control of mulberry thrips without deleterious effect on silk worm growth [21]. The imidacloprid did not provide the satisfactory control to leaf hoppers in the present finding. It might be due to development of resistance. In addition, the concentration of imidacloprid may be one of the reasons not to control effectively. The higher concentrations were most effective in comparison to lower concentrations against the jassid, *Amrasca devastans* (Distant) in brinjal [1]. Though there are the observations which show that applications of imidacloprid 17.8 SL (0.5 ml/l) gave maximum population reduction per cent of sucking insect-pests of brinjal aphid, jassid and whitefly [14] but it does not support to the present finding. The result of imidacloprid was not up to the mark in reducing the population of whiteflies in the present finding. It might be due not having the sufficient population during spray as the data depicted in the tables clearly shows the population of leafhoppers was quite high in the imidacloprid treated plots and the okra plants might be devitalized in due course of plant growth. Therefore, whitefly population could not build up in those treated plots as it has clearly shown in the results that whitefly population was also not recorded from control plots. It is envisaged that the incidence of leaf hoppers adversely affected the plant growth during early days in the control plot that is why, the lowest population of whiteflies was recorded from control plot. The plants treated with the chemicals other than imidacloprid were allowed to build up of the population of whiteflies because they were better in plant health in response to the chemicals sprayed. The potential yield of okra variety has not attained in the present study because there was severe incidence of yellow vein mosaic disease during the period of experiments.

Table 1: Efficacy of different insecticides against leaf hoppers during 2015

Treatments	Average number of leafhoppers/five leaves/plant												
	Pre-treatment	First spray				Second spray				Third spray			
		3 DAS	5DAS	7DAS	10 DAS	3DAS	5DAS	7 DAS	10DAS	3DAS	5 DAS	7DAS	10DAS
T1- Flonicamid 50 WG @ 0.2 g/l	17.11	1.11	3.0	3.66	4.33	1.13	2.2	6.67	5.73	2.07	1.53	1.4	5.0
T2- Flonicamid 50 WG @ 0.3 g/l	15.77	0.77	2.44	3.11	4.33	1.07	1.4	3.33	3.27	1.27	1.07	0.8	4.0
T3- Flonicamid 50 WG @ 0.4 g/l	20.66	0.22	2.44	3.0	3.33	0.87	1.4	3.2	2.0	1.07	0.6	0.6	1.0
T4- Flupyradifurone 200 SL @ 1.5 ml/l	20.33	2.33	4.0	7.0	7.89	1.4	3.33	5.6	5.87	6.87	7.07	8.0	14.53
T5- Flupyradifurone 200 SL @ 2.0 ml/l	18.33	1.66	3.89	5.55	6.44	0.8	3.33	4.26	4.33	5.47	5.67	5.33	14.0
T6- Flupyradifurone 200 SL @ 2.5 ml/l	21.22	0.66	3.78	3.89	4.55	0.67	0.8	3.93	3.6	4.73	3.8	3.67	8.2
T7- Imidacloprid 17.8 SL @ 0.35 ml/l	22.22	8.97	10.0	10.66	13.22	26.0	27.27	32.13	32.67	35.53	39.27	43.67	98.00
T8-Untreated Control	20.77	33.33	28.11	29.33	48.33	64.47	68.66	71.67	72.67	81.27	91.40	117.73	173.60
CD at 5%		2.37	2.47	3.68	5.16	3.68	5.48	2.74	4.73	10.14	5.84	4.58	7.89

DAS- Days after spray

Table 2: Efficacy of different insecticides against leaf hoppers during 2016

Treatments	Average number of leafhoppers/five leaves/plant												
	Pre-treatment	First spray				Second spray				Third spray			
		3 DAS	5DAS	7DAS	10 DAS	3DAS	5DAS	7 DAS	10DAS	3DAS	5 DAS	7DAS	10DAS
T1- Flonicamid 50 WG @ 0.2 g/l	10.87	1.26	3.0	4.13	5.13	1.33	2.27	7.0	6.07	2.4	2.60	1.87	5.47
T2- Flonicamid 50 WG @ 0.3 g/l	12.13	0.53	2.27	3.47	5.2	1.6	1.4	4.0	4.27	1.2	1.47	1.27	3.6
T3- Flonicamid 50 WG @ 0.4 g/l	11.26	0.26	1.67	3.40	3.67	0.73	1.20	3.53	2.33	1.13	0.8	0.87	1.33
T4- Flupyradifurone 200 SL @ 1.5 ml/l	15.40	2.13	3.73	7.13	8.93	1.67	3.0	6.87	7.53	6.53	7.40	8.0	13.20
T5- Flupyradifurone 200 SL @ 2.0 ml/l	14.64	1.07	2.93	5.67	6.87	1.2	3.0	5.6	5.0	5.13	6.46	5.00	13.33
T6- Flupyradifurone 200 SL @ 2.5 ml/l	14.73	0.67	2.6	4.67	4.8	0.87	1.27	4.27	3.93	4.53	3.3	3.33	9.33
T7- Imidacloprid 17.8 SL @ 0.35 ml/l	15.87	8.33	11.40	11.33	13.53	19.33	24.47	30.2	29.87	32.53	37.60	42.66	66.67
T8-Untreated Control	11.90	17.00	23.27	25.47	30.87	41.47	57.27	64.0	68.67	77.93	85.07	101.67	111.0
CD at 5%		1.80	2.95	2.45	1.77	2.40	2.67	4.29	2.21	7.08	3.13	4.58	4.36

DAS- Days after spray

Table 3: Efficacy of different insecticides against whitefly during 2015

Treatments	Average number of adult whiteflies /five leaves/ plant												
	Pre-treatment	First spray				Second spray				Third spray			
		3 DAS	5DAS	7DAS	10DAS	3DAS	5DAS	7DAS	10DAS	3DAS	5DAS	7DAS	10DAS
T1- Flonicamid 50 WG @ 0.2 g/l	10.88	7.89	9.44	21.00	23.33	2.0	11.13	10.13	15.67	17.93	11.67	8.33	3.0
T2- Flonicamid 50 WG @ 0.3 g/l	10.55	4.22	8.78	21.21	22.67	2.6	10.13	12.67	17.0	21.00	11.33	8.27	4.13
T3- Flonicamid 50 WG @ 0.4 g/l	9.89	3.89	9.11	21.55	23.00	2.8	4.40	12.47	12.83	13.73	10.33	7.73	2.60
T4- Flupyradifurone 200 SL @ 1.5 ml/l	8.88	5.0	9.44	17.88	21.33	2.0	16.73	18.07	22.33	15.73	9.33	7.40	1.67
T5- Flupyradifurone 200 SL @ 2.0 ml/l	10.11	4.44	12.22	20.33	24.00	1.2	6.93	21.53	23.67	14.73	8.67	7.93	1.47
T6- Flupyradifurone 200 SL @ 2.5 ml/l	9.55	4.79	6.55	17.22	19.33	0.6	6.17	17.60	18.33	10.13	8.67	9.47	1.53
T7- Imidacloprid 17.8 SL @ 0.35 ml/l	14.30	6.11	8.55	20.88	23.00	2.87	4.07	3.00	3.67	5.93	6.53	7.33	0.80
T8-Untreated Control	9.78	8.77	7.22	19.55	17.33	3.37	3.87	3.80	3.67	5.00	4.00	4.27	0.26
CD at 5%		NS	NS	NS	NS	0.70	1.69	3.45	4.41	6.35	4.20	NS	1.23

DAS- Days after spray

Table 4: Efficacy of different insecticides against whitefly during 2016

Treatments	Average number of adult whiteflies /five leaves/ plant												
	Pre-treatment	First spray				Second spray				Third spray			
		3 DAS	5DAS	7DAS	10DAS	3DAS	5DAS	7DAS	10DAS	3DAS	5DAS	7DAS	10DAS
T1- Flonicamid 50 WG @ 0.2 g/l	13.13	6.67	10.00	16.67	23.67	2.33	10.27	10.40	17.33	19.33	12.00	9.0	3.67
T2- Flonicamid 50 WG @ 0.3 g/l	11.47	4.33	9.33	15.67	22.00	2.93	9.40	11.27	16.67	19.60	11.67	7.93	3.60
T3- Flonicamid 50 WG @ 0.4 g/l	10.40	3.33	7.00	12.33	22.00	2.00	3.80	11.27	12.50	11.60	10.67	7.40	2.70
T4- Flupyradifurone 200 SL @ 1.5 ml/l	8.93	6.33	9.33	17.33	20.33	2.20	14.07	18.07	22.00	16.20	9.67	7.87	1.93
T5- Flupyradifurone 200 SL @ 2.0 ml/l	10.60	4.67	8.00	17.67	23.00	1.87	6.27	16.27	24.33	14.88	9.33	7.93	1.73
T6- Flupyradifurone 200 SL @ 2.5 ml/l	10.93	4.33	6.33	14.33	18.67	2.33	5.33	15.80	17.67	10.40	8.00	7.60	1.33
T7- Imidacloprid 17.8 SL @ 0.35 ml/l	11.74	7.00	8.22	17.33	21.00	2.93	3.73	2.67	4.00	5.00	6.20	6.67	1.80
T8-Untreated Control	11.78	14.00	15.67	19.00	18.00	4.10	3.67	4.00	3.00	4.60	3.67	3.93	0.20
CD at 5%		NS	3.27	NS	NS	NS	2.05	3.29	4.42	4.64	3.30	2.32	1.47

DAS- Days after spray

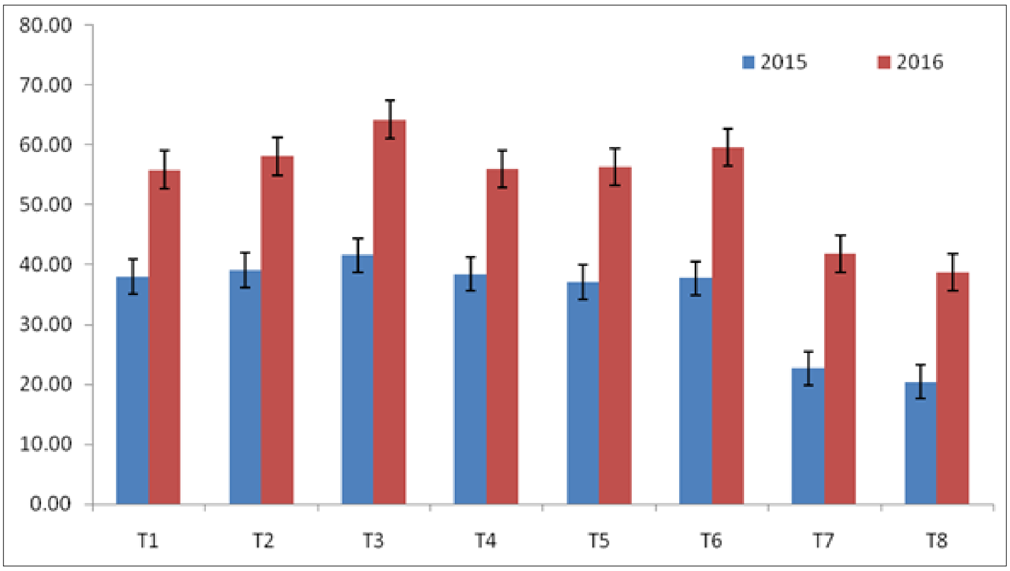

Fig 1: Effect of insecticides on okra yield (q/ha)

Conclusion

New chemical classes of insecticides are considered to be one of the solutions in challenging pest management scenario in order to assure the sustainable yields. It is more pertinent particularly in the management of sucking insect-pests, which are known to include some of the most destructive global crop pest species. By seeing the promising potential of flonicamid @ 0.4 g/l and flupyradifurone @ 2.5 ml/l, both the chemicals may be taken as an option in the management programme of okra insect-pests.

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