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Field efficacy of new insecticides for management of tobacco aphid, *Myzus persicae nicotianae* (Blackman) and impact on natural enemies in flue cured Virginia tobacco

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Abstract
Tobacco aphid, *Myzus persicae nicotianae* Blackman is one of the important pests of tobacco in India. The studies were conducted to find alternative molecules for neo nicotinoids for management of aphids in Virginia tobacco. Flupyradifurone 17.09 SL @ 0.026%, flonicamid 50 WG @ 0.02%, pymetrozine 50 WG @ 0.02% and sulfoxaflor 21.8 SC @ 0.007% were evaluated in comparison with neo nicotinoids. The results showed cent per cent mortality of aphids within 4 days in flupyradifurone, sulfoxaflor and flonicamid whereas 8 days for rest of the treatments except thiamethoxam. Higher yield parameters were recorded in flupyradifurone, sulfoxaflor and flonicamid. Studies on persistent residual toxicity indicated that sulfoxaflor was the most persistent (PTI 2332.98) followed by flupyradifurone (PTI 2149.68), flonicamid (PTI 2082.08) and pymetrozine (PTI 1946.16). Studies on safety of the insecticides to the natural enemies of aphid in tobacco ecosystem revealed, that pymetrozine, flonicamid and sulfoxaflor were found relatively less toxic to the predators of tobacco aphid. Based on the studies flupyradifurone 17.09 SL @ 0.026%, flonicamid 50 WG @ 0.02%, pymetrozine 50 WG @ 0.02% and sulfoxaflor 21.8 SC @ 0.007% can be good alternatives to the neo nicotinoids, imidacloprid and thiamethoxam for management of aphids in Virginia tobacco.

Keywords: Aphid, insecticides, *Myzus persicae nicotianae*, natural enemies, *Nicotiana tabacum*, tobacco

1. Introduction

Tobacco aphid, *Myzus persicae nicotianae* Blackman (Hemiptera: Aphididae) is one of the important pests of tobacco in India. It causes significant loss to tobacco directly by sucking the sap and honeydew deposition on which sooty mold grow adversely affecting the quality of tobacco. They also cause indirect loss as vectors of viral diseases. Tobacco aphid causes an avoidable loss of cured leaf and bright leaf to an extent of 125 kg and 70 kg/ha respectively [1]. Application of insecticides against the insect pests remains indispensable and economical to minimize the losses. As the pest appears late in the season repeated application of certain insecticides to control the pest may lead to the buildup of residues. Tobacco leaves with large surface to weight ratio are vulnerable to retain the pesticide residues, which is not desirable. Neo-nicotinoids, imidacloprid and thiamethoxam were found effective and are widely used for management of the aphid on tobacco since more than two decades [2, 3]. Studies have indicated the possibility of developing resistance in aphid species to these insecticides [4, 5]. Also, use of neo-nicotinoids has been linked to adverse ecological effects, including honey-bee colony collapse disorder (CCD) [6]. The field use of imidacloprid and thiamethoxam has been banned by European Union in 2018 [7]. Hence, there is an urgent need to find alternative molecules for effective management of aphids. Flupyradifurone is a new insecticide representing the novel butenolide class of insecticides, showing an excellent safety profile. The discovery of flupyradifurone was inspired by the butenolide scaffold in naturally occurring stemofoline a derivative from the plant *Stemona japonica* [8]. Flonicamid, a pyridine carboxamide compound with systemic as well as trans laminar activity rapidly inhibits the feeding behaviour of aphids, has a different mode of action to that of neo-nicotinoids and is reported to be relatively safe to the natural enemies [9, 10]. Pymetrozine, a pyridine azomethine compound, blocks stylet penetration of aphids causing immediate cessation of feeding. It is having high degree of selectivity, low mammalian toxicity and safe to nontarget arthropods [11]. Sulfoxaflor represent a new class of insecticides sulfoximines classified for use against sap-feeding insects.

It is an agonist at insect nicotinic acetylcholine receptors (nAChRs) and functions in a manner distinct from other insecticides acting at nAChRs [12]. The objective of this study was to evaluate the efficacy of new insecticides for management of tobacco aphid and their impact on insect predators of aphid on Virginia tobacco.

2. Material and Methods

A replicated field experiment was conducted for two seasons in planted flue cured Virginia tobacco cv. *Siri* at the institute research farm during 2017-19 to evaluate the efficacy of flupyradifurone 17.09 SL @ 0.026%, flonicamid 50 WG @ 0.02%, pymetrozine 50 WG @ 0.02% and sulfoxaflor 21.8 SC @ 0.007% in comparison with imidacloprid 17.8 SL @ 0.005% and thiamethoxam 25 WG @ 0.005% for management of tobacco aphid in Virginia tobacco. The experiment was laid out in randomized block design with 3 replications in plots measuring 5.6 X 4.9 m with a row to row and plant to plant distance of 70 cm. The treatments were imposed using the knapsack sprayer fitted with hollow cone nozzle. To maintain optimum level of aphid infestation, 5 plants/plot were infested with 100 aphids on each plant coinciding with the appearance of aphids naturally in the field and were allowed to multiply for about a week before spraying was undertaken. Observations on the aphid population were made on 5 plants from each plot following the method of Sreedhar [13]. The indices 0- 5 were standardized by counting the number of aphids on 3 (top, middle, bottom) leaves/plant which formed a particular index (0-5). At the time of recording observations, the aphids based on the numbers will fall in one of these indices and these indices were converted to their corresponding numbers. The average number of aphids on a plant was determined by adding up the aphids on three leaves per plant and average numbers recorded on 5 plants were considered as number of aphids/plant. Observations on aphid population were recorded before spraying as well as 2, 4, 8 and 16 days after spray (DAS). Observations on predator population were recorded on 5 randomly selected plants per plot on whole plant basis. The data on population count were used to work out per cent reduction in population over untreated control by using the following formula and the data were subjected to statistical analysis of variance (ANOVA).

$$\text{Per cent reduction of predators} = \frac{\text{population in untreated plot} - \text{population in treatment}}{100} \text{ X } 100$$

Yield data on cured leaf, bright leaf and grade index were collected and subjected to ANOVA [14]. The persistent residual toxicity of flupyradifurone 17.09 SL @ 0.026%, flonicamid 50 WG @ 0.02%, pymetrozine 50 WG @ 0.02% and sulfoxaflor 21.8 SC @ 0.007% imidacloprid 17.8 SL @ 0.005% and thiamethoxam 25 WG @ 0.005% was studied. Fifty day old tobacco plants were treated with respective insecticides and the leaves were used to study the residual persistent toxicity from 0 days till there is no mortality in that particular treatment at 24 hrs interval. One hundred second instar aphids were released on each treated leaf and mortality was recorded at 24 hrs interval till the mortality dropped to zero. The persistent residual toxicity was determined by a method [15] that was slightly modified subsequently [16].

3. Results and Discussion

During both the years all the treatments gave significantly better protection compared to control from aphid damage at 2, 4, 8 and 16 days after spray (DAS). Among the treatments, 2 DAS, the aphid population was lowest in the treatment of sulfoxaflor (2.76) followed by flupyradifurone (3.06), flonicamid (3.28) and pymetrozine (3.58) during 2017-18 (Table 1). The recommended insecticides imidacloprid and thiamethoxam recorded higher aphid population compared to the above three insecticides. However, they remained on a par with others. At 4 DAS the treatments of sulfoxaflor, flupyradifurone and flonicamid recorded cent per cent mortality of the aphids. All the treatments recorded cent per cent mortality at 8 & 16 days after spray except thiamethoxam at 8 DAS (1.49). During 2018-19 season, at 2 DAS flupyradifurone recorded the lowest aphid population (2.76) followed by flonicamid (3.06), sulfoxaflor (3.28) and pymetrozine (3.58). The recommended insecticides imidacloprid and thiamethoxam recorded higher aphid population compared to the three highly effective insecticides, but remained on par with others (Table 2). At 4 DAS the treatments of flupyradifurone, flonicamid and sulfoxaflor recorded cent per cent mortality of the aphids. All the treatments recorded cent per cent mortality at 8 & 16 days after spray except thiamethoxam at 8 DAS (1.49). Effectiveness of flupyradifurone [17, 18, 19, 20, 21], sulfoxaflor [21, 22, 23, 24] flonicamid [25, 26, 27, 28] and pymetrozine [29, 30] was reported against aphids on tobacco and various other crops. Combined analysis of data on yield parameters of two seasons showed that flupyradifurone recorded the highest cured leaf yield (2330 kg/ha), bright leaf yield (1240 kg/ha) and grade index (1478) followed by sulfoxaflor (2325, 1230 &1483) and flonicamid (2310, 1205 & 1458). All the treatments remained statistically on a par with each other in all the yield parameters and were significantly higher than that in control (Table 3).

Studies on persistent toxicity of new insecticides to tobacco aphid on FCV tobacco showed that among the treatments, superior persistence of sulfoxaflor 21.8 SC @ 0.007% is evident as shown by the highest PT value (89.73) followed by flupyradifurone 17.09 SL @ 0.026% (82.68). Pymetrozine 50 WG @ 0.02% (81.09), flonicamid 50 WG @ 0.02% (80.08) and imidacloprid 200SL @ 0.005% (79.44) recorded more or less similar PT values. Sulfoxaflor, flupyradifurone and flonicamid recorded cent per cent mortality of the aphid up to 16 days after treatment whereas in all others except thiamethoxam cent per cent mortality was recorded up to 14 DAT (Table 4). The period of persistency was longest (26 days) in sulfoxaflor, flupyradifurone and flonicamid treatments. Whereas, it was same (24 days) for pymetrozine, imidacloprid and thiamethoxam. The persistent toxicity index (PTI) was the highest (2332.98) for sulfoxaflor followed by flupyradifurone (2149.68) and flonicamid (2082.08). The order of persistency was sulfoxaflor > flupyradifurone > flonicamid > pymetrozine > imidacloprid > thiamethoxam.

The studies on the effect of the insecticides on predators in tobacco ecosystem indicated that, pymetrozine 50 WG @ 0.02%, flupyradifurone 17.09 SL @ 0.026%, flonicamid 50 WG @ 0.02% and sulfoxaflor 21.8 SC @ 0.007% were relatively safe as compared to imidacloprid and thiamethoxam to *Cheilomenes sexmaculata* and *Xanthogramma scutellarae* and *Nesidiocoris tenuis.* Among the promising treatments against the pest, the reduction in population of *C. sexmaculata* was highest (64.1%) in imidacloprid followed thiamethoxam (50.9%) which was significantly high compared to pymetrozine (37.5 %), flupyradifurone (38.5%), flonicamid (39.1%) and sulfoxaflor (39.6%). As regards *X. scutellarae*, highest reduction of 62.9 per cent was recorded in imidacloprid followed by thiamethoxam (48.6%). The least reduction was observed in pymetrozine treatment (33.4%) followed by flupyradifurone (35.7%), flonicamid (35.9%) and sulfoxaflor 38.5%. Imidacloprid was found to be relatively detrimental to *N.tenuis* as shown by 54.9 % reduction followed by thiamethoxam (40.6%). Pymetrozine recorded relatively less reduction (30.5 %) of *N.tenuis* population followed by flonicamid (32.2%), sulfoxaflor (33.1%) and flupyradifurone (34.9 %). These results indicate that among the treatments, flonicamid, pymetrozine, flupyradifurone and sulfoxaflor were found to be relatively less toxic to the predators, *C. sexmaculata*, *X. scutellarae* and *N. tenuis* in tobacco crop ecosystem and could be compatible with integrated management programmes.

Table 1: Evaluation of new insecticides against *tobacco aphid, Myzus nicotianae* Blackman in FCV tobacco 2017-18

Treatments	Pre-spray	Mean aphids /plant			
		Days after spray			
		2	**4**	**8**	**16**
Flupyradifurone 17.09 SL 0.026%	1094.83	3.06 (8.37)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Sulfoxaflor 21.8 SC 0.007%	1113.17	2.76 (6.63)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Flonicamid 50 WG 0.02%	1083.17	3.28 (9.79)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Pymetrozine 50 WG 0.02%	1028.5	3.58 (11.79)	1.49 (1.22)	1.00 (0.00)	1.00 (0.00)
Imidacloprid 17.8 SL 0.005	1021.5	4.00 (15.03)	1.98 (2.92)	1.00 (0.00)	1.00 (0.00)
Thiamethoxam 25 WG 0.005	1018.17	4.20 (16.64)	1.98 (2.92)	1.49 (1.22)	1.00 (0.00)
Control	1044.83	35.8 (1251.98)	38.95 (1449.63)	57.69 (3327.65)	65.15 (4251.50)
CD (p=0.05)	NS	2.33	1.73	2.34	2.26

Figures in parentheses are retransformed means

Table 2: Evaluation of new insecticides against *tobacco aphid, Myzus nicotianae* Blackman in FCV tobacco 2018-19

Treatments	Pre-spray	Mean aphids /plant			
		Days after spray			
		2	4	8	16
Flupyradifurone 17.09 SL 0.026%	1061.5	2.76 (8.37)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Sulfoxaflor 21.8 SC 0.007%	1021.5	3.28 (9.79)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Flonicamid 50 WG 0.02%	1094.83	3.06 6.63	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Pymetrozine 50 WG 0.02%	1044.83	3.58 (11.79)	1.49 (1.22)	1.00 (0.00)	1.00 (0.00)
Imidacloprid 17.8 SL 0.005	1028.5	3.81 (15.03)	1.49 (1.22)	1.00 (0.00)	1.00 (0.00)
Thiamethoxam 25 WG 0.005	111.3.17	4.00 (16.64)	1.98 (2.92)	1.49 (1.22)	1.00 (0.00)
Control	1.18.17	35.73 (1251.98)	38.95 (1516.34)	57.69 (3327.65)	63.20 (3993.91)
CD (p=0.05)	NS	1.89	1.39	2.18	2.26

Figures in parentheses are retransformed means

Table 3: Influence of new insecticides on FCV tobacco yield parameters- Pooled data (2017-19)

Treatments	Cured leaf	Bright leaf	Grade index
Flupyradifurone 17.09 SL 0.026%	2330	1240	1478
Sulfoxaflor 21.8 SC 0.007%	2325	1230	1483
Flonicamid 50 WG 0.02%	2310	1205	1458
Pymetrozine 50 WG 0.02%	2280	1165	1428
Imidacloprid 17.8 SL 0.005%	2228	1140	1395
Thiamethoxam 25 WG 0.005%	2220	1130	1388
Control	1840	845	1135
CD (p=0.05)	182	106	118

Table 4: Persistent residual toxicity of new insecticides against *M.nicotianae*

Treatments	Per cent mortality (Days after treatment)														Period of persistency (P)	Mean persistent toxicity (PT)	Persistent toxicity index (PTI)
	0	2	4	6	8	10	12	14	16	18	20	22	24	26			
Flupyradifurone 17.09 SL 0.026%	100	100	100	100	100	100	100	100	100	92.8	78	52.2	24.6	10	26	82.68	2149.68
Sulfoxaflor 21.8 SC 0.007%	100	100	100	100	100	100	100	100	100	94	80.6	58.4	28.2	12.4	26	89.73	2332.98
Flonicamid 50 WG 0.02%	100	100	100	100	100	100	100	100	100	90.2	70.8	40.8	16.6	2.8	26	80.08	2082.08
Pymetrozine 50 WG 0.02%	100	100	100	100	100	100	100	100	94	76.4	50.2	26.8	6.8	0	24	81.09	1946.16
Imidacloprid 17.8 SL 0.005	100	100	100	100	100	100	100	100	86.8	68.6	46.8	24.6	6	0	24	79.44	1906.56
Thiamethoxam 25 WG 0.005	100	100	100	100	100	100	100	96.4	80.2	56.8	40.2	16.8	4.8	0	24	76.55	1837.2

Table 5: Relative toxicity of new insecticides against insect predators of tobacco aphid

Treatment	Per cent reduction of predators over control		
	C. Sexmaculata	*X. scutellarae*	*N. tenuis*
Flupyradifurone 17.09 SL 0.026%	38.5 (38.7)	35.7 (34.1)	34.9 (32.7)
Sulfaxaflor 21.8 SC 0.007%	39.6 (40.7)	38.3 (38.5)	33.1 (29.9)
Flonicamid 50 WG 0.02%	39.1 (39.9)	35.9 (34.4)	32.2 (28.5)
Pymetrozine 50 WG 0.02%	37.5 (37.1)	33.4 (30.3)	30.5 (25.8)
Imidacloprid 17.8 SL 0.005	64.1 (81.0)	62.9 (79.3)	54.9 (67.0)
Thiamethoxam 25 WG 0.005	50.9 (60.3)	48.6 (56.3)	40.6 (42.5)
CD *(p=0.05)*	5.23	6.37	5.38

Figures in parentheses are retransformed means

The relative safety of pymetrozine, flonicamid, flupyradifurone and sulfoxaflor and their usefulness in IPM programmes was also reported against various natural enemies of sap feeding insect pests. [11, 31, 32, 33, 34, 35, 36]. The selectivity of flonicamid, pymetrozine, flupyradifurone and sulfoxaflor to the predators helps in conservation of native natural enemies in tobacco ecosystem.

Based on the two seasons field experimental results on the aphid population on flue cured Virginia tobacco, yield data, persistent toxicity studies and relative toxicity of the insecticides to the tobacco aphid predators it was found that flupyradifurone 17.09 SL @ 0.026%, flonicamid 50 WG @ 0.02%, pymetrozine 50 WG @ 0.02% and sulfoxaflor 21.8 SC @ 0.007% were found promising for management of aphid on tobacco.

4. Conclusion

Flupyradifurone 17.09 SL @ 0.026%, sulfoxaflor 21.8 SC @ 0.007%, flonicamid 50 WG @ 0.02% and pymetrozine 50 WG @ 0.02% were superior and highly effective in terms of reduction in population of aphid, *M p.nicotianae*, higher yields and better persistence on tobacco. These insecticides were also found to be relatively less toxic to the native predators of tobacco aphid, compared to the neonicoitinoids, imidacloprid and thiamethoxam. Based on the studies, it can be inferred that flupyradifurone 17.09 SL @ 0.026%, sulfoxaflor 21.8 SC @ 0.007%, flonicamid 50 WG @ 0.02% and pymetrozine 50 WG @ 0.02% can be used for management of tobacco aphid, *M.p.nicotianae* in flue cured Virginia tobacco.

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