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Evaluation of different insecticides against grape flea beetle

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Abstract
Intensive and extensive cultivation of grapes leads to serious pest problem in major grape-growing areas of the world. One hundred insect and mite pests from different Indian grape-growing states have been identified as damaging distinct grapevine regions. Among different insect pests, adult flea beetles are observed from mid-July and reach peak numbers in October–November and cause damage to the plants immediately after pruning in October. Several newer molecules and botanical insecticides were evaluated against grape flea beetle at HREC, Tidagundi, Karnataka during 2021-22. Among the insecticides, Lambda cyhalothrin 5 EC @ 0.50ml / l was recorded lowest number of flea beetle and bud damage followed by Lambda cyhalothrin 4.9 CS, Fipronil 80 WG, Spinosad 45 SC, Cyantraniliprole 10.26 OD, Thiamethoxam 25 WG, Flonicamid 50 WG, and Alphamethrin 10 EC. Finally, the marketable yield (t/ha) was also significantly highest in the treatment Lambda cyhalothrin 4.9 CS @ 0.50ml / l (44.35 t / ha) followed by Cyantraniliprole 10.26 OD @ 0.7ml / l, Lambda cyhalothrin 5 EC @ 0.50ml / l, Fipronil 80 WG @ 0.06g / l, Alphamethrin 10 EC @ 0.5ml / l, Thiamethoxam 25 WG @ 0.25g / l, Spinosad 45 SC @ 0.25ml / l, Flonicamid 50 WG @ 0.3g / l and Azadirachtin 1 EC @ 2.0ml / l (44.32, 40.68, 38.95, 38.72, 38.12, 36.49, 35.42 and 32.02 t / ha, respectively).

Keywords: Flea beetle, insecticides, Grape, Vijayapura

Introduction
Grape (*Vitis vinifera* L.) belongs to the family Vitaceae and is one of the most widely grown fruit crop in the world. It is temperate crop by origin, originated in Western Asia and Europe. Although, it is basically a temperate crop but now a days it is well acclimatized to the tropical and subtropical climatic conditions.

The major grape growing states in India are Maharashtra (56.9%), Karnataka (21.8%), Andhra Pradesh (1.52%), Mizoram (3.05%) and Tamil Nadu (2.99%) accounting nearly 90 per cent of the total production (Anon., 2021) [1]. The present area and production of grapes in India is 1,40,000 hectares with a production of 31,25,000 metric tonnes per year and a productivity of 27.9 tonnes per hectare, mostly in the states of Maharashtra, Karnataka, Andra Pradesh and Tamil Nadu (Anon., 2021) [1]. More over 80 per cent of the crop is produced in Maharashtra, with Karnataka coming in second with an area of 33,770 acre and an production of 8,54,660 tonnes (Devaraj, 2021). Vijayapura is one of the major districts of Karnataka with area 8670 hectare and production 102790 tons in grape cultivation. But compared to other fruit crops, the area planted in grapes is growing as a result of higher net revenue. 71 percent of the entire grape production is used for table purposes; approximately 27 per cent is dried to make raisins; the remaining 1.5 per cent is used to make wine and the last 0.5 per cent is used to prepare juice (Sharma, 2018) [10].

Intensive and extensive cultivation of grapes leads to serious pest problem in major grape-growing areas of the world. The climate in India is ideally suited for high production of table and wine grapes as well as a high prevalence of several pests. In the world, 132 different insects have been found to attack grape vines. One hundred insect and mite pests from different Indian grape-growing states have been identified as damaging distinct grapevine regions (Butani 1979) [3]. Among these, a total of 22 insect and mite pests are found to attack grapevine in northern Karnataka (Balikai and Kotikal, 2003). [2] Among these, grape flea beetle, *Scelodonta strigicollis* Mots. (Coleoptera: Chrysomelidae) is a regular and serious pest in major grape-growing areas. Lefroy (1907) [9] was the first to record this insect as a grapevine pest.

Since 1990, it has been reported as a serious grapevine pest in south India. Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu and Punjab have also reportedly suffered significant damage as a result. (Hussain and Raghava 1968) [5].

Flea beetle adult is a shining beetle with a metallic bronze color and black patches on elytra that is almost 5 mm long. Adults overwinter in debris in and near the vineyard. The beetles begin to feed upon newly swollen grape buds, chewing holes in the ends and sides. Such damage destroys the capacity of a bud to develop a primary or secondary shoot. After berry development they scrape berry and cause the scabbing.

The loss increases to 50 per cent when the sprouting buds are damaged, particularly after October pruning. Adult populations are observed from mid-July and reach peak numbers in October–November and cause damage to the plants immediately after pruning in October. Considering the above points, effort has been made to study the bio-efficacy of different insecticides against grape flea beetle in grape orchards of Vijayapura, Karnataka during 2020-21.

Materials and Methods

Field experiment was conducted to evaluate the insecticides (Table 1) for the management of grape flea beetle during 2020 in HREC, Vijayapura (Tidagundi) on Thompson Seedless variety of grape. No pesticides were applied in the experimental area except fungicides as and when required and other good agricultural practices were followed.

The experiment was laid out in randomized block design using ten treatments with three replications. Both synthetic and botanical insecticides were evaluated for their bio efficacy against flea beetle.

First spray (14th October 2020) was taken 10 days after fruit pruning and second spray was repeated 10 days after 1st spray (24th October 2020). The flea beetle population was counted on three vines in each treatment and five shoots per vine were selected and the flea beetle population was counted separately to know the incidence of flea beetle. Further, the mean population of flea beetles per shoot was calculated. The observations were recorded at day before, one, three and five days after first and second spray from randomly selected grape vines. Similarly, per cent bud damage was recorded from five shoots per vine in each replication by counting the infested buds and total buds present in the shoot and yield per hectare were recorded and B: C ratio was calculated.

$$\text{Per cent bud damage} = \frac{\text{Infested buds}}{\text{Total buds}} \times 100$$

Table 1: Treatment details

Tr. No.	Treatments	Dosage/l
T_1	Fipronil 80% WG	0.06g
T_2	Flonicamid 50% WG	0.30g
T_3	Spinosad 45% SC	0.25ml
T_4	Thiamethoxam 25% WG	0.25g
T_5	Lambda cyhalothrin 5% EC	0.50 ml
T_6	Lambda cyhalothrin 4.9% CS	0.50 ml
T_7	Alphamethrin 10% EC	0.50 ml
T_8	Cyantraniliprole 10.26% OD	0.70 ml
T_9	Azadirachtin 1% EC	2.00ml
T_{10}	Control	-

Results and Discussion

Flea beetle incidence and bud damage during 2021-22

First Spray: Flea beetle incidence and bud damage after first spray

Flea beetle incidence and bud damage a one day before spray (1 DBS)

There was no significant difference among the treatments with respect to number of flea beetle and bud damage per shoot at one day before imposing the treatments. However, the number of flea beetle and bud damage ranged from 2.33 to 2.69 (Table 2) and 15.93 to 19.43, respectively (Table 3).

Table 2: Bio efficacy of insecticides against flea beetle in grape cv. Thompson Seedless during 2021-22

Treatments	Dose/l	Number of flea beetles / shoot (1st Spray)				Number of flea beetles / shoot (2nd Spray)				Average	Per cent reduction over untreated control
		DBS	1 Das	3 Das	5 Das	DBSS	1 Das	3 Das	5 Das		
T_1- Fipronil 80 WG	0.06g	2.42 (1.71)	1.09^{cd} (1.26)	0.22^{ab} (0.85)	0.00^{a} (0.71)	1.53^{ab} (1.41)	0.36^{a} (0.92)	0.18^{ab} (0.82)	0.00^{a} (0.71)	0.31^{a} (0.90)	87.50
T_2- Flonicamid 50 WG	0.30g	2.44 (1.71)	1.13^{d} (1.28)	0.36^{d} (0.92)	0.09^{a} (0.77)	1.20^{a} (1.30)	0.38^{a} (0.94)	0.22^{b} (0.85)	0.00^{a} (0.71)	0.36^{a} (0.93)	85.25
T_3- Spinosad 45 SC	0.25ml	2.47 (1.72)	1.02^{bcd} (1.23)	0.31^{bc} (0.90)	0.09^{a} (0.77)	1.33^{ab} (1.35)	0.36^{a} (0.92)	0.22^{b} (0.85)	0.00^{a} (0.71)	0.33^{a} (0.91)	86.45
T_4- Thiamethoxam 25 WG	0.25g	2.49 (1.73)	0.87^{abc} (1.17)	0.24^{abc} (0.86)	0.07^{a} (0.75)	1.58^{ab} (1.43)	0.42^{a} (0.96)	0.04^{a} (0.74)	0.00^{a} (0.71)	0.27^{a} (0.88)	88.86
T_5- Lambda cyhalothrin 5 EC	0.50 ml	2.51 (1.74)	0.76^{a} (1.12)	0.13^{a} (0.79)	0.04^{a} (0.74)	1.40^{ab} (1.37)	0.40^{a} (0.95)	0.09^{ab} (0.77)	0.00^{a} (0.71)	0.24^{a} (0.86)	90.36
T_6- Lambda cyhalothrin 4.9 CS	0.50 ml	2.64 (1.77)	0.80^{ab} (1.14)	0.27^{bc} (0.88)	0.13^{a} (0.80)	1.38^{ab} (1.36)	0.38^{a} (0.93)	0.11^{ab} (0.78)	0.00^{a} (0.71)	0.28^{a} (0.88)	88.56
T_7- Alphamethrin 10 EC	0.50 ml	2.69 (1.79)	0.93^{abcd} (1.20)	0.20^{ab} (0.84)	0.11^{a} (0.78)	1.24^{ab} (1.32)	0.67^{b} (1.08)	0.09^{ab} (0.77)	0.00^{a} (0.71)	0.33^{a} (0.91)	86.45
T_8- Cyantraniliprole 10.26 OD	0.70 ml	2.47 (1.72)	0.96^{abcd} (1.21)	0.22^{ab} (0.85)	0.00^{a} (0.71)	1.58^{ab} (1.43)	0.51^{ab} (1.01)	0.11^{ab} (0.78)	0.09^{a} (0.77)	0.31^{a} (0.90)	87.20
T_9- Azadirachtin 1 EC	2.00ml	2.56 (1.75)	1.82^{e} (1.52)	2.00^{e} (1.58)	1.59^{b} (1.44)	1.84^{bc} (1.52)	1.80^{c} (1.51)	1.62^{c} (1.46)	1.44^{b} (1.39)	1.71^{b} (1.48)	30.33
T_{10}- Untreated control (UTC)	-	2.33 (1.68)	2.29^{f} (1.67)	2.51^{f} (1.74)	2.60^{c} (1.76)	2.29^{c} (1.67)	2.24^{d} (1.66)	2.42^{d} (1.71)	2.69^{c} (1.78)	2.46^{c} (1.72)	-
S.E.M ±		NS	0.07	0.04	0.07	0.20	0.07	0.05	0.04	0.04	-
CD @ 5%			0.22	0.13	0.20	0.60	0.20	0.15	0.13	0.14	-

Note: Values in parenthesis are √ (x + 0.5) transformed,

In a column, means followed by same alphabet(s) do not differ significantly by DMRT (P=0.05) DBS – Day before spraying DAS– Day after spraying DBSS – Day before second spraying DASS - Day after second spraying NS – Non significant

Table 3: Bio efficacy of insecticides against bud damage by flea beetle in grape cv. Thompson Seedless during 2021-22

Treatments	Dose/l	Bud damage (%) / shoot (1st Spray)				Bud damage (%) / shoot (2nd Spray)				Average	Per cent reduction over untreated control
		DBS	1DAS	3 DAS	5 DAS	DBSS	1DASS	3 DASS	5 DASS		
T1- Fipronil 80 WG	0.06g	15.93 (23.50)	14.99^{a} (22.76)	13.12^{ab} (21.22)	9.62^{a} (17.97)	14.53^{abcd} (22.39)	13.64^{abc} (21.67)	7.63^{abc} (16.00)	4.91^{ab} (12.76)	10.65^{a} (19.03)	52.00
T2- Flonicamid 50 WG	0.30g	17.40 (24.56)	22.02^{b} (27.73)	18.01^{cd} (25.05)	12.73^{ab} (20.78)	19.99^{d} (26.50)	15.68^{cd} (23.30)	9.45^{abc} (17.87)	4.74^{ab} (12.54)	13.77^{bcd} (21.71)	37.93
T3- Spinosad 45 SC	0.25ml	18.12 (25.15)	15.61^{a} (23.26)	14.56^{abc} (22.32)	12.52^{ab} (20.10)	17.82^{bcd} (24.96)	10.33^{a} (18.70)	7.02^{a} (15.14)	3.83^{a} (11.19)	10.65^{a} (18.99)	52.03
T4- Thiamethoxam 25 WG	0.25g	16.21 (23.65)	16.42^{a} (23.88)	12.78^{ab} (20.89)	11.43^{a} (19.76)	11.75^{a} (20.01)	13.71^{abc} (21.73)	9.23^{abc} (17.60)	6.87^{abc} (15.12)	11.74^{ab} (20.04)	47.09
T5- Lambda cyhalothrin 5 EC	0.50ml	16.68 (23.74)	15.40^{a} (23.02)	11.29^{a} (19.57)	9.93^{a} (18.05)	14.22^{abc} (22.10)	15.25^{c} (22.95)	11.72^{c} (20.02)	8.47^{bc} (16.88)	12.01^{abc} (20.27)	45.87
T6- Lambda cyhalothrin 4.9 CS	0.50ml	16.33 (23.76)	13.53^{a} (21.58)	15.53^{bc} (23.18)	11.16^{a} (19.47)	11.86^{a} (20.15)	11.35^{ab} (19.54)	8.27^{abc} (16.64)	4.22^{a} (11.52)	10.68^{a} (19.06)	51.89
T7- Alphamethrin 10 EC	0.50ml	18.02 (25.01)	18.00^{ab} (25.09)	17.86^{cd} (24.93)	12.49^{ab} (20.56)	12.47^{ab} (20.53)	15.16^{c} (22.86)	10.77^{bc} (19.10)	7.24^{abc} (15.60)	13.59^{bcd} (21.62)	38.78
T8- Cyantraniliprole 10.26 OD	0.70ml	17.18 (24.43)	17.66^{ab} (24.85)	11.93^{ab} (20.09)	17.32^{b} (24.52)	12.89^{abc} (20.92)	18.89^{de} (25.76)	11.29^{c} (19.63)	9.16^{c} (17.45)	14.38^{cd} (22.27)	35.21
T9- Azadirachtin 1 EC	2.00ml	16.24 (23.76)	14.09^{a} (22.03)	14.37^{abd} (22.26)	13.49^{ab} (21.53)	14.37^{abc} (22.28)	14.78^{bc} (22.58)	17.35^{d} (24.57)	18.23^{d} (25.24)	15.39^{d} (23.09)	30.66
T10- Untreated control (UTC)	-	19.43 (26.10)	22.96^{b} (28.61)	21.32^{d} (27.48)	23.88^{c} (29.15)	18.12^{d} (25.16)	20.52^{e} (26.96)	20.65^{d} (27.10)	23.81^{e} (29.12)	22.19^{e} (28.09)	-
S.E.M ±		NS	1.79	1.33	1.88	1.85	1.20	1.15	1.42	0.83	-
CD @ 5%			5.32	3.94	5.58	5.57	3.56	3.42	4.22	2.48	-

Note: Values in parenthesis are arcsine transformed,
In a column, means followed by same alphabet(s) do not differ significantly by DMRT (P=0.05) DBS – Day before spraying
DAS– Day after spraying DBSS – Day before second spraying DASS - Day after second spraying NS – Non significant

Table 4: Economics of flea beetle management in grapes during 2021-22

Treatments	Dosage / l	Grape yield (t/ha)	Gross return (Rs./ha)	Total cost of cultivation (Rs./ha)	Treatment cost (Rs./ha)	Net returns (Rs./ha)	B:C ratio
T1- Fipronil 80 WG	0.06g	38.95	1090600	257640	1640	832960	3.23
T2- Flonicamid 50 WG	0.30g	35.42	991760	256750	750	735010	2.86
T3- Spinosad 45 SC	0.25ml	36.49	1021720	263500	7500	758220	2.88
T4- Thiamethoxam 25 WG	0.25g	38.12	1067360	256600	600	810760	3.16
T5- Lambda cyhalothrin 5 EC	0.50ml	40.68	1139040	256380	380	882660	3.44
T6- Lambda cyhalothrin 4.9 CS	0.50ml	44.35	1241800	256440	440	985360	3.84
T7- Alphamethrin 10 EC	0.50ml	38.72	1084160	256300	300	827860	3.23
T8- Cyantraniliprole 10.26 OD	0.70ml	44.32	1240960	265450	9450	975510	3.67
T9- Azadirachtin 1 EC	2.00ml	32.02	896560	258380	2380	638180	2.47
T10- Untreated control (UTC)	-	24.4	683200	250000	-	433200	1.73

Note: Fruit rate: 28Rs/kg
B: C ratio: Benefit cost ratio

Flea beetle incidence and bud damage a one day after spray (1 DAS)

At one day after spray, there was a significant difference among treatments with respect to number of flea beetle. Among the treatments, Lambda cyhalothrin 5 EC @ 0.50ml / l (0.76 Flea beetle / shoot) recorded significantly lowest population of the flea beetle and was statistically on par with Lambda cyhalothrin 4.9 CS @ 0.50ml / l, Thiamethoxam 25 WG @ 0.25g / l, Alphamethrin 10 EC @ 0.5ml / l and Cyantraniliprole 10.26 OD @ 0.7ml / l (0.80, 0.87, 0.93 and 0.96 Flea beetle / shoot, respectively). Further, the next best treatment which recorded less number of flea beetle was Spinosad 45 SC @ 0.25ml / l, Fipronil 80 WG @ 0.06 g / l and Flonicamid 50 WG @ 0.3g / l (1.02, 1.09 and 1.13 Flea beetle / shoot, respectively) treatment and it was statistically on par with each other. The next best treatments which recorded moderate number of flea beetle were and Azadirachtin 1 EC @ 2.0ml / l (1.82 Flea beetle / shoot, respectively). However, significantly highest population of grape flea beetle was recorded in untreated control (2.29 Flea beetle / shoot) (Table 2).

There was a significant difference among the treatments with respect to bud damage at DAS. Among the treatments, Lambda cyhalothrin 4.9 CS @ 0.50ml / l (13.53 %) recorded significantly lowest bud damage and was statistically on par with Azadirachtin 1 EC @ 2.0ml / l, Fipronil 80 WG @ 0.06 g / l, Lambda cyhalothrin 5 EC @ 0.50ml / l, Spinosad 45 SC @ 0.25ml / l, Thiamethoxam 25 WG @ 0.25g / l, Cyantraniliprole 10.26 OD @ 0.7ml / l and Alphamethrin 10 EC @ 0.5ml / l (14.09, 14.99, 15.40, 15.61, 16.42, 17.66 and 18.00 %, respectively). However, significantly highest bud damage was recorded in untreated control and Flonicamid 50 WG @ 0.3g / l (22.96 and 22.02 %, respectively) and they are statistically on par with each other (Table 3).

Flea beetle incidence and bud damage at three days after spray (3 DAS)

At three DAS, Lambda cyhalothrin 5 EC @ 0.50ml / l (0.13 Flea beetle / shoot) recorded significantly lowest population of the flea beetle and was statistically on par with Alphamethrin 10 EC @ 0.5ml / l, Fipronil 80 WG @ 0.06 g / l, Cyantraniliprole 10.26 OD @ 0.7ml / l and Thiamethoxam 25 WG @ 0.25g / l (0.20, 0.22, 0.22 and 0.24 Flea beetle / shoot, respectively). Further, the next best treatment which recorded less number of flea beetle was Lambda cyhalothrin 4.9 CS @ 0.50ml / l, Spinosad 45 SC @ 0.25ml / l and

Flonicamid 50 WG @ 0.3g / l (0.27, 0.31 and 0.36 Flea beetle / shoot, respectively) and they are statistically on par with each other. The next best treatments which recorded moderate number of flea beetle was Azadirachtin 1 EC @ 2.0ml / l (2.00 Flea beetle / shoot). However, significantly highest population of grape flea beetle was recorded in untreated control (2.51 Flea beetle / shoot) (Table 2).

In case of bud damage per shoot, there was a significant difference among the treatments at three DAS. Among the treatments, Lambda cyhalothrin 5 EC @ 0.50ml / l (11.29 %) recorded significantly lowest bud damage and it was followed by Cyantraniliprole 10.26 OD @ 0.7ml / l, Thiamethoxam 25 WG @ 0.25g / l, Fipronil 80 WG @ 0.06 g / l, Azadirachtin 1 EC @ 2.0ml / l, and Spinosad 45 SC @ 0.25ml / l (11.93, 12.78, 13.12, 14.37 and 14.56 %, respectively) and they are statistically on par with each other. The next best treatments which recorded moderate bud damage was Lambda cyhalothrin 4.9 CS @ 0.50ml / l (15.53 %). However, significantly highest bud damage was recorded in untreated control (21.32 %) and it was statistically on par with Flonicamid 50 WG @ 0.3g / l and Alphamethrin 10 EC @ 0.5ml / l (18.01 and 17.86 %, respectively) (Table 3).

Flea beetle incidence and bud damage at five days after spray (5 DAS)

At Five DAS, Fipronil 80 WG @ 0.06 g / l and Cyantraniliprole 10.26 OD @ 0.7ml / l (0.00 and 0.00 Flea beetle / shoot, respectively) recorded significantly zero population of the flea beetle and was statistically on par with Lambda cyhalothrin 5 EC @ 0.50ml / l, Thiamethoxam 25 WG @ 0.25g / l, Flonicamid 50 WG @ 0.3g / l, Spinosad 45 SC @ 0.25ml / l, Alphamethrin 10 EC @ 0.5ml / l and Lambda cyhalothrin 4.9 CS @ 0.50ml / l (0.04, 0.07, 0.09, 0.09, 0.11, 0.13 and 0.13 Flea beetle / shoot, respectively). Further, next best treatments which recorded moderate number of flea beetle was Azadirachtin 1 EC @ 2.0ml / l (1.59 Flea beetle / shoot). However, significantly highest population of grape flea beetle was recorded in untreated control (2.60 Flea beetle / shoot) (Table 2).

In case of bud damage, there was a significant difference among the treatments at five DAS. Among the treatments, Fipronil 80 WG @ 0.06 g / l (9.62 %) recorded significantly lowest bud damage and it was followed by Lambda cyhalothrin 5 EC @ 0.50ml / l, Lambda cyhalothrin 4.9 CS @ 0.50ml / l, Thiamethoxam 25 WG @ 0.25g / l, Alphamethrin 10 EC @ 0.5ml / l, Spinosad 45 SC @ 0.25ml / l, Flonicamid 50 WG @ 0.3g / l and Azadirachtin 1 EC @ 2.0ml / l (9.93, 11.16, 11.43, 12.49, 12.52, 12.73 and 13.49 %, respectively) and they are statistically on par with each other. The next best treatments which recorded moderate bud damage were Cyantraniliprole 10.26 OD @ 0.7ml / l (17.32 %). However, significantly highest bud damage was recorded in untreated control (23.88 %) (Table 3).

Second Spray

Flea beetle incidence and bud damage after second spray.

Flea beetle incidence and bud damage a one day before second spray (1 DBSS)

At one day before second spray, there was a significant difference among treatments with respect to number of flea beetle. Among the treatments, Flonicamid 50 WG @ 0.3g / l (1.20 Flea beetle / shoot) recorded significantly lowest population of the flea beetle and was statistically on par with Alphamethrin 10 EC @ 0.5ml / l, Spinosad 45 SC @ 0.25ml / l, Lambda cyhalothrin 4.9 CS @ 0.50ml / l, Lambda cyhalothrin 5 EC @ 0.50ml / l, Fipronil 80 WG @ 0.06 g / l, Thiamethoxam 25 WG @ 0.25g / l and Cyantraniliprole 10.26 OD @ 0.7ml / l (1.24, 1.33, 1.38, 1.40, 1.53, 1.58 and 1.58 Flea beetle / shoot, respectively). However, significantly highest population of grape flea beetle was recorded in untreated control and Azadirachtin 1 EC @ 2.0ml / l (2.29 and 1.84 Flea beetle / shoot, respectively) (Table 2).

There was a significant difference among the treatments with respect to bud damage at one DBSS. Among the treatments, Thiamethoxam 25 WG @ 0.25g / l (11.75 %) recorded significantly lowest bud damage and was statistically on par with Lambda cyhalothrin 4.9 CS @ 0.50ml / l, Alphamethrin 10 EC @ 0.5ml / l, Cyantraniliprole 10.26 OD @ 0.7ml / l, Lambda cyhalothrin 5 EC @ 0.50ml / l, Azadirachtin 1 EC @ 2.0ml / l and Fipronil 80 WG @ 0.06 g / l (11.86, 12.47, 12.89, 14.22, 14.37 and 14.53 %, respectively). However, significantly highest bud damage was recorded in Flonicamid 50 WG @ 0.3g / l (19.99%) and it was followed untreated control and Spinosad 45 SC @ 0.25ml / l (18.12 and 17.82 %, respectively) (Table 3).

Flea beetle incidence and bud damage a one day after second spray (1 DASS)

At one day after second spray, there was a significant difference among treatments with respect to number of flea beetle. Among the treatments, Spinosad 45 SC @ 0.25ml / l and Fipronil 80 WG @ 0.06 g / l (0.36 and 0.36 Flea beetle / shoot, respectively) recorded significantly lowest population of the flea beetle and was statistically on par with Flonicamid 50 WG @ 0.3g / l, Lambda cyhalothrin 4.9 CS @ 0.50ml / l, Lambda cyhalothrin 5 EC @ 0.50ml / l, Thiamethoxam 25 WG @ 0.25g / l and Cyantraniliprole 10.26 OD @ 0.7ml / l (0.38, 0.38, 0.40, 0.42 and 0.51 Flea beetle / shoot, respectively). Further, the next best treatment which recorded less number of flea beetle was Alphamethrin 10 EC @ 0.5ml / l (0.67 Flea beetle / shoot) treatment. The next best treatments which recorded moderate number of flea beetle was Azadirachtin 1 EC @ 2.0ml / l (1.80 Flea beetle / shoot). However, significantly highest population of grape flea beetle was recorded in untreated control (2.24 Flea beetle / shoot) (Table 2).

There was a significant difference among the treatments with respect to bud damage at one DASS. Among the treatments, Spinosad 45 SC @ 0.25ml / l (10.33 %) recorded significantly lowest bud damage and was statistically on par with Lambda cyhalothrin 4.9 CS @ 0.50ml / l, Fipronil 80 WG @ 0.06 g / l and Thiamethoxam 25 WG @ 0.25g / l (11.35, 13.64 and 13.71 %, respectively). The next best treatments which recorded moderate bud damage were Azadirachtin 1 EC @ 2.0ml / l, Alphamethrin 10 EC @ 0.5ml / l, Lambda cyhalothrin 5 EC @ 0.50ml / l and Flonicamid 50 WG @ 0.3g / l (14.78, 15.16, 15.25 and 15.68 %, respectively) and they are statistically on par with each other. However, significantly highest bud damage was recorded in untreated control (20.52 %) and it was followed by and statistically on par with Cyantraniliprole 10.26 OD @ 0.7ml / l (18.89 %) (Table 3).

Flea beetle incidence and bud damage at three day after second spray (3 DASS)

At three DAS, Thiamethoxam 25 WG @ 0.25g / l (0.04 Flea

beetle / shoot) recorded significantly lowest population of the flea beetle and was statistically on par with Alphamethrin 10 EC @ 0.5ml / l, Lambda cyhalothrin 5 EC @ 0.50ml / l, Lambda cyhalothrin 4.9 CS @ 0.50ml / l, Cyantraniliprole 10.26 OD @ 0.7ml / l and Fipronil 80 WG @ 0.06 g / l, (0.09, 0.09, 0.11, 0.11 and 0.18 Flea beetle / shoot, respectively). The next best treatment which recorded lowest population of flea beetle was Flonicamid 50 WG @ 0.3g / l and Spinosad 45 SC @ 0.25ml / l (0.22 and 0.22 Flea beetle / shoot, respectively) and they are statistically on par with each other. The next best treatments which recorded moderate number of flea beetle was Azadirachtin 1 EC @ 2.0ml / l (1.62 Flea beetle / shoot). However, significantly highest population of grape flea beetle was recorded in untreated control (2.42 Flea beetle / shoot) (Table 2).

In case of bud damage, there was a significant difference among the treatments at three DAS. Among the treatments, Spinosad 45 SC @ 0.25ml / l (7.02 %) recorded significantly lowest bud damage and it was followed by Fipronil 80 WG @ 0.06 g / l, Lambda cyhalothrin 4.9 CS @ 0.50ml / l, Thiamethoxam 25 WG @ 0.25g / l and Flonicamid 50 WG @ 0.3g / l (7.63, 8.27, 9.23 and 9.45 %, respectively) and they are statistically on par with each other. The next best treatments which recorded less bud damage was and Alphamethrin 10 EC @ 0.5ml / l, Cyantraniliprole 10.26 OD @ 0.7ml / l and Lambda cyhalothrin 5 EC @ 0.50ml / l (10.77, 11.29 and 11.72 %, respectively). However, significantly highest bud damage was recorded in untreated control (20.65 %) and it is statistically on par with Azadirachtin 1 EC @ 2.0ml / l and (17.35 %) (Table 3).

Flea beetle incidence and bud damage at five day after second spray (5 DASS)

At Five DASS, Lambda cyhalothrin 5 EC @ 0.50ml / l, Lambda cyhalothrin 4.9 CS @ 0.50ml / l, Fipronil 80 WG @ 0.06 g / l, Thiamethoxam 25 WG @ 0.25g / l, Spinosad 45 SC @ 0.25ml / l, Alphamethrin 10 EC @ 0.5ml / l and Flonicamid 50 WG @ 0.3g / l has recorded significantly nil population of the flea beetle and they are statistically on par with Cyantraniliprole 10.26 OD @ 0.7ml / l (0.09 Flea beetle / shoot). Further, next best treatments which recorded moderate number of flea beetle was Azadirachtin 1 EC @ 2.0ml / l (1.44 Flea beetle / shoot). However, significantly highest population of grape flea beetle was recorded in untreated control (2.69 Flea beetle / shoot) (Table 2).

In case of bud damage, there was a significant difference among the treatments at five DASS. Among the treatments, Spinosad 45 SC @ 0.25ml / l (3.83 %) recorded significantly lowest bud damage and it was followed by Lambda cyhalothrin 4.9 CS @ 0.50ml / l, Flonicamid 50 WG @ 0.3g / l, Fipronil 80 WG @ 0.06 g / l, Thiamethoxam 25 WG @ 0.25g / l and Alphamethrin 10 EC @ 0.5ml / l (4.22, 4.74, 4.91, 6.87 and 7.24 %, respectively) and they are statistically on par with each other. The next best treatments which recorded less bud damage was Lambda cyhalothrin 5 EC @ 0.50ml / l (8.47 %) and it was statistically on par with and Cyantraniliprole 10.26 OD @ 0.7ml / l (14.38 %). Further, next best treatments which recorded moderate bud damage was Azadirachtin 1 EC @ 2.0ml / l (18.23 %). However, significantly highest bud damage was recorded in untreated control (23.81 %) (Table 3).

Mean population of flea beetle and bud damage (after 1st and 2nd spray)

In the table 2, the mean number of flea beetles has differed significantly after treatment imposing. Among the treatments, Lambda cyhalothrin 5 EC @ 0.50ml / l (0.24 Flea beetle / shoot) was recorded lowest number of flea beetle population and it was statistically on par with Thiamethoxam 25 WG @ 0.25g / l, Lambda cyhalothrin 4.9 CS @ 0.50ml / l, Fipronil 80 WG @ 0.06 g / l, Cyantraniliprole 10.26 OD @ 0.7ml / l, Spinosad 45 SC @ 0.25ml / l, Alphamethrin 10 EC @ 0.5ml / l and Flonicamid 50 WG @ 0.3g / l (0.27, 0.28, 0.31, 0.31, 0.33, 0.33 and 0.36 Flea beetle / shoot, respectively). Further, next best treatments which recorded moderate number of flea beetle was Azadirachtin 1 EC @ 2.0ml / l (1.71 Flea beetle / shoot). However, significantly highest population of grape flea beetle was recorded in untreated control (2.46 Flea beetle / shoot).

There was a significant difference among the treatments with respect to bud damage at average. Among the treatments, Spinosad 45 SC @ 0.25ml / l and Fipronil 80 WG @ 0.06 g / l (10.65 and 10.65 %, respectively) recorded significantly lowest bud damage and it was followed by Lambda cyhalothrin 4.9 CS @ 0.50ml / l, Thiamethoxam 25 WG @ 0.25g / l and Lambda cyhalothrin 5 EC @ 0.50ml / l (10.68, 11.74 and 12.01 %, respectively) and they are statistically on par with each other. The next best treatments which recorded lower bud damage were Alphamethrin 10 EC @ 0.5ml / l and Flonicamid 50 WG @ 0.3g / l (13.59 and 13.77 %, respectively) and it was statistically on par with each other. Further, next best treatments which recorded moderate bud damage was Cyantraniliprole 10.26 OD @ 0.7ml / l and Azadirachtin 1 EC @ 2.0ml / l (14.38 and 15.39 %, respectively). However, significantly highest bud damage was recorded in untreated control (22.19 %) (Table 3).

Per cent reduction of flea beetle and bud damage over untreated control

The order of efficacy of treatments against flea beetle population based on per cent reduction over untreated control was Lambda cyhalothrin 5 EC @ 0.50ml / l (90.36%) > Thiamethoxam 25 WG @ 0.25g / l (88.86%) > Lambda cyhalothrin 4.9 CS @ 0.50ml / l (88.56%) > Fipronil 80 WG @ 0.06 g / l (87.50%) > Cyantraniliprole 10.26 OD @ 0.7ml / l (87.20%) > Spinosad 45 SC @ 0.25ml / l (86.45%) > Alphamethrin 10 EC @ 0.5ml / l (86.45%) > Flonicamid 50 WG @ 0.3g / l (85.25%) > Azadirachtin 1 EC @ 2.0ml / l (30.33%) (Table 2).

The order of efficacy of treatments for bud damage by flea beetle based on per cent reduction over untreated control was Spinosad 45 SC @ 0.25ml / l (52.03%) > Fipronil 80 WG @ 0.06 g / l (52.00%) > Lambda cyhalothrin 4.9 CS @ 0.50ml / l (51.89%) > Thiamethoxam 25 WG @ 0.25g / l (47.09%) > Lambda cyhalothrin 5 EC @ 0.50ml / l (45.87%) > Alphamethrin 10 EC @ 0.5ml / l (38.78%) > Flonicamid 50 WG @ 0.3g / l (37.93%) > Cyantraniliprole 10.26 OD @ 0.7ml / l (35.21%) > Azadirachtin 1 EC @ 2.0ml / l (30.66%) (Table 3).

In the present study, newer formulations of insecticides *viz.*, Lambda cyhalothrin 4.9 CS, Lambda cyhalothrin 5 EC, Fipronil 80 WG, Spinosad 45 SC, Thiamethoxam 25 WG, Alphamethrin 10 EC, Flonicamid 50 WG and Cyantraniliprole 10.26 OD were found effective in minimizing flea beetle population and was mainly due to their

unique mode of action, broad spectrum action, anti-feeding and repellent against grape flea beetle to these insecticides. Whereas, Azadirachtin was less effective against grape flea beetle which may be due to their slow action which needed repeated applications compared to other insecticides.

The present study is in line with Tansey *et al.* (2009) [11] who reported that, neonicotinoid compounds, thiamethoxam, imidacloprid and fipronil treatments reduced feeding damage to canola seedlings by increasing mortality of flea beetles and thus caused less feeding damage. Similarly, Kwaifa *et al.* (2015) [8] reported that Lambda-cyhalothrin killed insects by contact, ingestion and ovicidal action and it offers rapid knockdown and residual control while anti-feeding and repellence properties extend the biological effect against some pests and author confirmed that synthetic insecticide (Lambda-cyhalothrin) conferred more protection on okra against flea beetles.

Grape yield and economics

The grape yield is presented in table 4 and the yield varied from 24 to 44.35 tonne per hectare. Among the treatments, Lambda cyhalothrin 4.9 CS @ 0.50ml / l (44.35 t / ha) followed by Cyantraniliprole 10.26 OD @ 0.7ml / l, Lambda cyhalothrin 5 EC @ 0.50ml / l, Fipronil 80 WG @ 0.06 g / l, Alphamethrin 10 EC @ 0.5ml / l, Thiamethoxam 25 WG @ 0.25g / l, Spinosad 45 SC @ 0.25ml / l, Flonicamid 50 WG @ 0.3g / l and Azadirachtin 1 EC @ 2.0ml / l (44.32, 40.68, 38.95, 38.72, 38.12, 36.49, 35.42 and 32.02 t / ha, respectively). However, untreated control (24.00 t / ha) recorded significantly lowest yield. Present study is in close agreement with experiment conducted by Kulkarni and Adsule (2006) [7] that in the experiment conducted against flea beetle, the increased fruit yield was obtained in fipronil treated plots when compared to untreated check. Kulkarni and Patel (2012) [6] reported that Thiamethoxam 25 WG recorded the highest grape yield of 14.05 kg/vine compared to other treatments and untreated control.

Highest benefit cost ratio was obtained in Lambda cyhalothrin 4.9 CS (3.84) followed by Cyantraniliprole 10.26 OD (3.67) and Lambda cyhalothrin 5 EC (3.44). Further, the next best treatment which got higher B: C ratio was Fipronil 80 WG (3.23), Alphamethrin 10 EC (3.23), Thiamethoxam 25 WG (3.16), Spinosad 45 SC (2.88) and Flonicamid 50 WG (2.86). However, lowest B: C ratio was recorded in untreated control (1.73) and Azadirachtin 1 EC (2.47).

Conclusion

The present investigation concluded that, among the insecticides, Lambda cyhalothrin 5 EC @ 0.50ml / l was recorded lowest number of flea beetle and bud damage followed by Lambda cyhalothrin 4.9 CS, Fipronil 80 WG, Spinosad 45 SC, Cyantraniliprole 10.26 OD, Thiamethoxam 25 WG, Flonicamid 50 WG, and Alphamethrin 10 EC during study.

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