Indian Journal of Agricultural Sciences **93** (12): 1308–1313, December 2023/Article
https://doi.org/10.56093/ijas.v93i12.138123

Integrated pest management strategy for striped flea beetle, *Phyllotreta striolata* infesting radish (*Raphanus sativus*)

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Received: 21 June 2023; Accepted: 22 September 2023

ABSTRACT

In recent past, striped flea beetle, *Phyllotreta striolata* (Fabricius) was found to be very serious on radish (*Raphanus sativus* L.) across Haryana state and Delhi NCR in India and farmers suffered a huge economic loss. In the present study, an experiment was conducted during winter (*rabi*) seasons of 2020 and 2021 in predominant radish producing village of Haryana to investigate the influence of weather parameters on pest damage and validation of IPM strategy against *P. striolata* in radish. Results revealed that, among the different weather parameters, both maximum and minimum temperature had a significant negative relationship with leaf damage by adults ($r = -0.35^*$; $P = 0.02$ and $r = -0.62^{**}$; $P = 0.00$, respectively) and root damage by grubs of *P. striolata* ($r = -0.91^{**}$; $P = 0.00$ and $r = -0.86^{**}$, $P = 0.00$, respectively) in radish. The IPM strategy evaluated against *P. striolata* was effective with less leaf (10.99%) and root (12.93%) damage due to *P. striolata* compared to Farmers practice with 20.47% leaf and 39.43% root damage and also recorded 5.98 t/acre yield with cost: benefit ratio of 1:3.83 compared to Farmers practice (4.00 t/acre yield and 1:1.60 C: B ratio). IPM strategy also reduced average number of insecticide sprays from 6.11 to 3.57 sprays (41.51% reduction), which clearly evince that the IPM strategy so validated can be adopted by the farmers as an economically viable option for management of *P. striolata* in radish.

Keywords: IPM strategy, *Phyllotreta striolata*, Radish, Striped Flea beetles

Cruciferous (brassicaceae) vegetable crops are abundantly grown throughout the country and occupy a significant niche in the agro-ecosystem due to their economic value (Anonymous 2018). In recent past, with changes in the cropping pattern, climate and wider use of high input intensive cultivars there has been a paradigm shift in spatio-temporal infestation of pests (Bhat *et al.* 2011). Among these insect pests, Flea beetle (*Phyllotreta* sp.), which was considered earlier as a minor pest on vegetable crops has now attained the status of a major pest (Rather *et al.* 2017). flea beetles (Alticinae) of the genus *Phyllotreta* (Chevrolat) (Coleoptera: Chrysomelidae) are specialized herbivores on the brassicaceae and related plant families. Recently, striped flea beetle, *Phyllotreta striolata* (Fabricius) infestation was found to be very serious on radish (*Raphanus sativus* L.). (63.02% leaf and 53.96% root infestation) and mustard crops in different villages of Haryana and Delhi NCR and farmers incurred a huge economic loss (Anooj *et al.* 2020). The adult beetles found to be feeding on leaves causing shot hole symptoms while young stages (grubs) feed on the roots and rootlets of the plants by burrowing grooves, leading to growth retardation and death of plants. Due to the burrowed grooves on radish roots (edible part), the marketability of the produce hampered and these infested radish roots (edible part) fetched reduced price in the market.

Development of resistance to insecticides (Feng *et al.* 2000) and lack of parasitoids or other bio-control measures (Srinivasan *et al.* 2017), have necessitated to have a comprehensive approach by integrating all ecologically feasible methods in crop protection to combat the menace of *P. striolata*. On the contrary, farmers use pesticides as first line of defense and frequently resort to indiscriminate and non-judicious use of insecticides for management of flea beetles on radish and other cruciferous crops, leading to undesired effects (Arora and Gopal 2002). Hence, it was imperative to develop, validate and implement multipronged approach in an integrated manner to manage flea beetles infesting cruciferous crops. Therefore, a study was carried out to synthesize and validate IPM strategy for management of *P. striolata* infesting radish through Farmer Participatory Approach (FPA) during *rabi* 2020 and 2021.

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MATERIALS AND METHODS

The present study was carried out at Samora village of Karnal (29° 49' 16.8"N 77° 00' 41.4"E) District, Haryana. The village is considered to be the leading producer of good quality radish for local markets where the menace of striped flea beetle, *P. striolata* was found to be very serious.

Influence of weather parameters on striped flea beetle, P. striolata *damage in radish*: To study the influence of weather parameters on *P. striolata* damage in radish, a fixed radish field (farmer's holding) was selected during winter (*rabi*) seasons of 2020 and 2021 (October to December). Five randomly selected radish plants from each of five randomly selected spots were observed for radish leaf and root (edible part) damage following destructive sampling. The pooled data (*rabi* 2020 and 2021) were used for correlation and simple linear regression analysis between weather parameters and *P. striolata* damage in radish (Table 1) in a given SMW - Standard Meteorological Week (Gomez and Gomez 1984). The multiple linear regression analysis was also done to assess the degree and extent of influence of weather factors on *P. striolata* damage in radish (Table 2). The data of weather parameters (Table 1 and 2) was collected from automatic weather station installed at ICAR-Central Soil Salinity Research Institute, Karnal for statistical analysis of population dynamics of *P. striolata vis-a-vis* weather parameters. The statistical analysis was carried out using R software (R-Packages1.5) (Reimann *et al.* 2011).

Validation of IPM strategy against P. striolata *in radish:* Extensive literature survey by ICAR-National Research Centre for Integrated Pest Management, New Delhi led to synthesis of the IPM strategy comprising deep summer ploughing to expose overwintering stages of *P. striolata* (adult stage) to intense sunlight and natural enemies; application of well decomposed enriched farmyard manure @1 t/acre, enriched with *Metarhizium anisopliae* Sorokin (Con. = 1×10^8 cfu/g) @2 kg/t; soil application of 2.00–2.50 q of neem cake per acre to the main filed before sowing; growing 5–6 rows of sorghum/maize all around radish field at least 2 months before sowing of radish seeds as a barrier crop; intercropping a bold seeded variety of mustard as a trap crop @10:1 ratio; installation of yellow sticky traps @5 traps/acre, 12–15 cm above the plant canopy; timely intercultural operations for maintaining

Table 1 Correlation Matrix: Influence of weather parameters on striped flea beetle, *P. striolata* damage in radish (*rabi* 2020 and 2021 i.e. 41st to 50th Standard Meteorological Week)

Weather parameter	Per cent damage of *P. striolata* on leaf (Y)			Per cent damage of *P. striolata* on root (Y)		
	Correlation & SLR			Correlation & SLR		
	r	Y = a ± bX	P value	r	Y = a ± bX	P value
Maximum Temperature (ºC) (X_1)	−0.35*	34.73−0.74 X	0.02	−0.91**	208.68−6.27 X	0.00
Minimum Temperature (ºC) (X_2)	−0.62**	33.07−1.51 X	0.00	−0.86**	121.52−6.88 X	0.00
Morning Relative Humidity (%) (X_3)	0.10^{NS}	-13.25+0.29 X	0.51	0.65**	-511.58+5.80 X	0.00
Evening Relative Humidity (%) (X_4)\	-0.15^{NS}	19.36−0.10 X	0.34	0.45**	-15.74+1.02 X	0.00
Rainfall (mm) (X_5)	0.16^{NS}	13.49+0.91 X	0.31	-0.06^{NS}	35.95−1.15 X	0.70
Wind Speed (mph) (X_6)	0.07*	12.74+1.13 X	0.04	0.06^{NS}	31.51+3.19 X	0.68
Sunshine Hours per day (X_7)	-0.05^{NS}	14.32−0.04 X	0.97	−0.59**	146.59−16.91 X	0.00

**Significant at 1% Probability; *Significant at 5% Probability; NS, Non Significant; X, Independent factor (weather parameters; X_1 to X_7); Y, Dependent factor (*P. striolata* damage in radish); SLR, Simple Linear Regression

Table 2 Multiple linear regression model for weather parameters on striped flea beetle, *P. striolata* damage in radish (*rabi* 2020 and 2021 i.e. 41th to 50th Standard Meterological Week)

Per cent damage of *P. striolata* on	No. of observation	Constant	Maximum temperature (ºC)	Minimum temperature (ºC)	Morning relative humidity (%)	Evening relative humidity (%)	Rainfall (mm)	Wind speed (mph)	Sunshine hours per day
			(X_1)	(X_2)	(X_3)	(X_4)	(X_5)	(X_6)	(X_7)
Leaf (Y_1)	40	−17.26*	−0.20*	−1.78**	0.67^{NS}	−0.50*	0.55^{NS}	7.15*	1.81^{NS}
Root (Y_2)	40	−111.17*	−5.29**	−1.18*	3.39**	−0.50*	1.72^{NS}	-2.95^{NS}	2.22*

Multiple Linear regression equation for Y_1:

$Y_1 = -17.26^{*} - 0.20^{*} - 1.78^{**} + 0.67^{NS} - 0.50^{*} + 0.55^{NS} + 7.15^{*} + 1.81^{NS}$

Coefficient of determination (R^2) = 0.68 **Significant at 1% Probability *Significant at 5% probability

X = Independent factor (weather parameters; X_1 to X_7) Y_1= Dependent factor (*P. striolata* damage on leaf)

Multiple Linear regression equation for Y_2:

$Y_2 = -111.17^{*} - 5.29^{**} - 1.18^{*} + 3.39^{**} - 0.50^{*} + 1.72^{NS} - 2.95^{NS} + 2.22^{*}$

Coefficient of determination (R^2) = 0.96 **Significant at 1% Probability *Significant at 5% probability

X = Independent factor (weather parameters; X_1 to X_7) Y_2= Dependent factor (*P. striolata* damage on root) weed free fields; drenching the root zone with biological control agent i.e. entomopathogenic fungi, *Metarhizium anisopliae* (Con. = 1 × 10^8 cfu/ml or g) @8–10 ml or g/litre; spraying of neem oil 0.50% @5 ml/litre or 5% neem seed kernel extract @500 gm of kernels/10 litre or commercial formulation (Azadirachtin 0.03% WSP 300 PPM) @05 ml/litre; need based dusting of malathion 5% D @10 kg/acre or spraying of malathion 50 EC @1.5 ml/litre. The IPM strategy was validated in radish *vis-a-vis* Farmers practice (FP) comprising of sole dependence on synthetic chemical insecticide spray, covering 15 acre area (10 farmer holdings of 1 acre each under IPM and 5 farmer holdings of 1 acre under FP).

Observations were recorded from sowing until harvest of the produce at weekly intervals. The per cent damage intensity on leaves due to adult beetles was calculated on randomly selected five plants from each of five randomly selected spots in a particular farmer field and calculation of the leaf damage was computed (Anooj *et al.* 2020).

$$\text{Per cent leaf damage} = \frac{\text{Number of damaged leaves}}{\text{Total number of leaves per plant}} \times 100$$

The per cent damage intensity on roots due to grubs in the soil was calculated by observing number of infested taproots (edible part) out of five randomly uprooted plants from each of five randomly selected spots in a particular farmer field (Anooj *et al.* 2020).

$$\text{Percent root damage} = \frac{\text{Number of damaged roots}}{\text{Total number of roots sampled}} \times 100$$

The weekly data on leaf and root damage due to *P. striolata* was subjected to statistical analysis using student 't' test. For economic analysis, radish yield per field, cost of cultivation including plant protection, net profit, benefit cost ratio, number of pesticide sprays deployed, reduction in pesticide sprays and reduction in cost of cultivation over FP were computed.

RESULTS AND DISCUSSION

During the present investigation, radish leaf damage due to *P. striolata* adults was first noticed on 42^{nd} SMW (third week of October) while root damage due to grubs appeared in 44^{th} SMW (between last week of October and first week of November) and continued throughout the crop season (up to 50^{th} SMW-second week of December). Initially the radish leaf damage due to *P. striolata* adults was quite low but gradually it increased, reaching its peak (27.23%) during 46^{th} SMW (third week of November) and periodic leaf damage declined gradually thereafter as the crop harvest neared. With respect to root damage due to *P. striolata* grubs, the damage was quite high from the start itself ranging from 10.51–66.63% until final harvest of the crop. However, the peak root damage was observed during 48^{th} to 50^{th} SMW.

Based on correlation studies between weather parameters and *P. striolata* damage in radish (Table 1), wind speed (r = 0.07*; P = 0.04) showed significant positive relationship, whereas maximum temperature (r = −0.35*; P = 0.02) and minimum temperature (r = −0.62**; P = 0.00) showed significant negative relationship with radish leaf damage due to *P. striolata* adults. In case of root damage due to *P. striolata* grubs, morning relative humidity (r = 0.65**; P = 0.00) and evening relative humidity (r = 0.45**; P = 0.00) showed significant positive relationship, while maximum temperature (r = −0.91**; P = 0.00), minimum temperature (r = −0.86**; P = 0.00) and sunshine hours (r = −0.59**; P = 0.00) exhibited significant negative relationship.

From the simple linear regression analysis (Y= a ± bX) (Table 1), it is apparent that an increase in wind speed by 1 mph, resulted in increase in leaf damage due to *P. striolata* adults by 1.13%. Similarly, an increase in maximum and minimum temperature by 1ºC resulted in decrease in leaf damage due to *P. striolata* adults by 0.74 and 1.51%, respectively. Regarding root damage due to *P. striolata* grubs, it is evident that an increase in morning and evening relative humidity by 1% resulted in increase in root damage by 5.80 and 1.02%, respectively. Correspondingly, an increase in maximum, minimum temperature by 1ºC and sunshine hours by 1 h/day resulted in decrease in damage due to *P. striolata* grubs by 6.27, 6.88 and 16.91%, respectively. From the multiple linear regression analysis (Table 2), it was perceivable that the coefficient of determination was significantly high (R^2 = 0.68 and 0.96) with respect to both per cent leaf and root damage, respectively which means that the weather factors together contributes directly towards the leaf and root damage due to *P. striolata* in radish to the extent of 68.00 and 96.00%, respectively.

From the results (Table 3 and Fig 1) it is evident that, there was a significant difference in per cent leaf and root damage between T_1, IPM strategy and T_2, Farmers practice during *rabi* 2020 and 2021. From the pooled mean data it is apparent that T_1, IPM strategy performed better in recording lesser leaf and root damage (10.99 and 12.93%, respectively) in comparison to T_2, Farmers practice (20.47% leaf and 39.43% root damage). There was thus a significant difference between T_1, IPM strategy and T_2, Farmers practice in leaf (9.48%**; P = 0.00) and root (26.50%**; P = 0.00) damage due to *P. striolata*. T_1, IPM strategy also recorded the maximum yield of 5.98 t/acre in comparison to T_2, Farmers practice (4.00 t/Ac) with a significant difference in yield of ~ 2.00 t/acre (1.97 t/acre).

In terms of cost-benefit economics, from the cumulative mean data (Table 3) it was evident that, T_1, IPM strategy recorded the maximum Cost: Benefit ratio of 1:3.83 with 28.71% reduction in cost of cultivation as compared to T_2, Farmers practice (cost: benefit ratio - 1:1.60) indicating that T_1, IPM strategy effectively reduced the pest incidence in the radish crop and contributed to higher yield and enhanced farmers' income by reducing the cost of cultivation and increasing the yield per unit area as compared to T_2, Farmers practice. From the cumulative mean data it is evident that, T_1, IPM strategy also reduced average number of insecticide sprays from 6.11 to 3.57 numbers (41.51% reduction in insecticide spray) as compared to T_2, Farmers practice.

Table 3 Effect of IPM strategy *vis-a-vis* FP against *P. striolata* in radish and their economic analysis (2020 and 2021)

Parameter	Mean per cent damage of *P. striolata* on radish leaf			Mean per cent damage of *P. striolata* on radish root			Yield (t/acre)		
	Rabi-2020	*Rabi*-2021	Pooled mean	*Rabi*-2020	*Rabi*-2021	Pooled mean	*Rabi*-2020	*Rabi*-2021	Pooled mean
A. Effect of IPM strategy *vis-a-vis* FP against *P. striolata*									
T_1 - IPM	11.93	10.04	10.99	13.75	12.11	12.93	5.91	6.04	5.98
T_2 - FP	21.64	19.30	20.47	40.42	38.44	39.43	3.98	4.03	4.00
Difference	9.71**	9.25**	9.48**	26.67**	26.33**	26.50**	1.93**	2.01**	1.97**
Std. Err.	0.15	0.15	0.42	0.36	0.43	0.44	0.07	0.06	0.05
Student 't' value	62.11	60.26	22.29	72.93	60.61	59.37	24.57	32.22	37.04
P value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

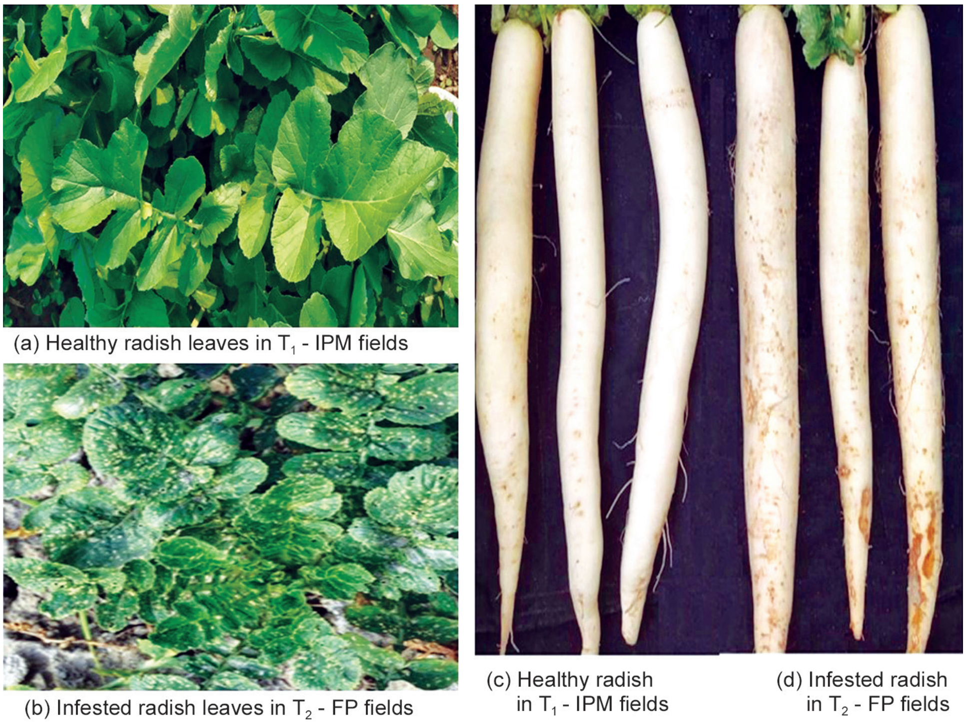
B. Economics of IPM strategy *vis-a-vis* FP

Particular	*Rabi* 2020		*Rabi* 2021		Cumulative mean	
	IPM	FP	IPM	FP	IPM	FP
Cost of cultivation (thousand/acre)	21.18	38.37	32.88	37.63	27.03	38.00
Gross returns (thousand/acre)	98.63	60.48	99.18	61.33	98.91	60.91
Net returns (thousand/acre)	77.45	22.11	66.3	23.7	71.88	22.91
C:B ratio	4.65	1.57	3.01	1.62	3.83	1.60
Number of sprays	3.61	6.33	3.53	5.89	3.57	6.11
Reduction in cost of cultivation (%)	44.80	-	12.62	-	28.71	-
Reduction in spray consumption (%)	42.96	-	40.06	-	41.51	-

**Significant at 1% Probability

Indians' dietary habits include a sizable amount of cruciferous crops (Kumaranag *et al.* 2014). These crops face various challenges every year among which insect pests and diseases cause enormous yield and economic losses (Bhat *et al.* 2011). Among insect pests, flea beetles (*Phyllotreta* sp.) which were considered earlier as minor pests on these crops have now attained the status of a major pest (Pal 2003, Lee *et al.* 2011), which is evident during the course of present investigation.

From the present investigation, the leaf damage due to adults and root damage due to grubs of *P. striolata* in radish clearly illustrates that the *P. striolata* is certainly detrimental for the radish crop as found earlier (Rather *et al.* 2017). Further, it was found that the important weather parameter, temperature (both maximum and minimum) showed a significant negative relationship with leaf damage due to adults and root damage due to grubs of *P. striolata* which is in line with the reports of Shukla and Kumar (2003). However, on the contrary, Rasool and Lone (2022) reported a positive correlation between



(a) Healthy radish leaves in T_1 - IPM fields
(b) Infested radish leaves in T_2 - FP fields
(c) Healthy radish in T_1 - IPM fields
(d) Infested radish in T_2 - FP fields

Fig 1 Impact of IPM strategy on *P. striolata* damage on radish leaf and root (economic part).

temperature and *P. striolata* incidence on radish and cabbage which may be due to the variability in climate and geographical location.

The IPM strategy adopted against *P. striolata* in radish in present study was highly effective in terms of recording lower pest damage, higher economic yield, reduced insecticide consumption and reduced cost of cultivation in comparison to the FP, which clearly indicates the competence of IPM strategy for effective management of *P. striolata* in radish (Raghavendra *et al.* 2022). It has been observed earlier that adults of flea beetles in general overwinter under soil clods and plant debris, therefore, summer or fall ploughing would result in destruction of flea beetle population (Bunn *et al.* 2015). In addition, soil application of farmyard manure enriched with *M. anisopliae* and drenching of root zone with *M. anisopliae* in the present IPM validation proved effective in undermining the damage of radish roots (economical part) due to *P. striolata* grubs similar to report of Li *et al.* (2022). Likewise, neem cake application to the soil plays a significant role in managing the grubs and overwintering stages of flea beetles due to active ingredient Azadirachtin (Saxena *et al.* 1988).

Sorghum or maize have been proved as effective pest barrier crop against insect movements (Root 1973, Fereres 2000) and therefore proved effective in the present study too in reducing the damage of *P. striolata* in radish. It was also observed that bold seeded mustard used as trap crop inter-cultured with radish played a significant role along with the other IPM interventions in reducing the damage of *P. striolata* in radish (main crop) as it lured flea beetles away from main crop in the present study. Chinese southern giant mustard (*Brassica juncea* var. *crispifolia*) was effectively used for protecting crucifer crops from flea beetle damage and a diverse trap crop containing Pacific Gold mustard (*B. juncea*), Dwarf Essex rape (*B. napus*), and pac choi (*B. campestris* L. var. *chinensis*) successfully protected broccoli from the crucifer flea beetle (Parker *et al.* 2012).

In the present study, yellow sticky traps were observed to be an effective monitoring tool against flea beetles. It has also been found previously that yellow coloured sticky traps were predominantly used for detecting first emergence and population peaks of *Phyllotreta* spp. enabled to take necessary management action in time. In our study dusting of malathion 5% D was followed as final resort resulted in reduction of leaf damage due to *P. striolata* in radish when used in combination with other IPM interventions as malathion belonging to organophosphates acts as nerve poisons (acetylcholinesterase inhibitor) resulting in lethality in insect pests.

To conclude with, the present study highlights that IPM strategy comprising of cultural, mechanical, biological and chemical practices was found economically viable option for management of *P. striolata* in radish. The effectiveness of IPM strategy was validated and proved efficient in tackling the menace of the pest in comparison to the Farmers practice. As a result of reduction in pest incidence due to IPM strategy despite less synthetic chemical insecticide use, farmers were benefitted through production of higher yield and higher market price for radish. The validated IPM practice is thus recommended as pest management strategy against flea beetles for sustainable production of radish crop.

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