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Spatial Distribution of *Thrips tabaci* Lindeman on *rabi* Onion in North Western Himalayan

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Abstract: Spatial distribution of *Thrips tabaci* Lindeman on *rabi* onion was assessed in mid-hill regions of Himachal Pradesh, representing north-western Indian Himalayas. Thrips followed negative binomial distribution in onion. Based on the Lewis index, Index of dispersion, Morisita coefficient of dispersion, Lloyd's mean crowding and Index of patchiness, in early crop growth stages of *rabi* onion, thrips were distributed randomly whereas in later crop stages, thrips distribution was aggregated/ over dispersed/ clumped. Aggregated distribution of thrips was also confirmed by Taylor's power law and Iwao's patchiness regression index with the corresponding values of 1.29 and 2.65. For estimation of thrips population in vegetative, bulb initiation and bulb development stage, the mean number of samples needed were 15476, 760 and 270, respectively at P=0.1 (precision level of 90%),whereas at 80% (P=0.2), relatively small number of samples were needed (869, 190 and 68) for corresponding crop stages.

Keywords: Spatial distribution, *Rabi* onion, Population indices, Population estimation

Onion (*Allium cepa* L.) is one of the major crops grown in different parts of the world mainly in 170 countries for culinary purpose and have medicinal value (Singh et al 2017, FAO 2018). India ranks first in onion production followed by China and accounts for about 25.57 per cent of the world's onion production (FAO 2020). Onion is considered as the most preferred host crop of *Thrips tabaci* Lindeman globally (Gill et al 2015, Pal et al, 2019, Ain et al 2021, Shiberu 2022) and is one of the limiting factors posing serious threat to onion production in all the onion growing regions of the country (Sekine et al 2021). Being polyphagous in nature, feed on around 391 plant species belonging to 64 different families including Asteraceae, Brassicaceae, Fabaceae, Solanaceae and Poaceae (Loredo and Fail 2022). The losses inflicted by *T. tabaci* ranges between 18 to 90 per cent in onion (Pandey et al 2011, Shiberu et al 2013, Tadele and Mulugeta 2014, Soumia et al 2017) in different onion growing regions. Population level of 5 to 30 thrips per plant have been established as the Economic Threshold Level (ETL) in different parts of the world (Tadele and Amin 2014, Tiwari et al 2017). In an ecosystem, individual insect population can change seasonally in response to the availability of resources, behavioral patterns and environment. Comprehensive understanding of insect distribution and the factors that impact utilization of available resources are crucial to establish appropriate sampling plans. Knowledge of dispersion patterns of the pest (random, aggregate or uniform) has wider application in ecological studies, sampling theories as well as in formulation of pest management strategies. Pandey et al (2008) from Jammu and Kashmir (India) observed the clumped distribution of thrips. Since, the distribution parameters of an insect species vary with respect to different factors, the number of sampling units required to estimate the mean density will also vary. Considering this, the present study was aimed to determine the spatial distribution of onion thrips and the samples required for its population estimation which in turn form the basis for decision making in forecasting and thrips management strategies in mid-hill regions of Himachal Pradesh representing north-western Indian Himalayan regions.

MATERIAL AND METHODS

Present investigations were conducted during 2016-17 and 2017-18 at CSK Himachal Pradesh Agricultural University, Palampur, Himachal Pradesh, India (altitude 1290 m amsl; 32°1'N latitude and 76°5' E longitude). All the recommended agronomic practices were followed in raising the crop excluding plant protection measures. One month old seedlings of Palam Lohit variety were transplanted during second fortnight of December for raising the crop in plot size of 3×3 m with row to row and plant to plant spacing of 15×6 cm, respectively. In-situ observations on population buildup of thrips were recorded following random sampling method by placing a quadrate of 1 m in onion plot and 10 plants were randomly selected from each quadrate. In total, 300 plants were observed. Observations were recorded at weekly interval starting from first appearance of thrips infestation till final harvesting of the crop.

Analysis of spatial distribution: Spatial distribution of *T. tabaci* was determined by working out various indices of dispersion during two cropping seasons as detailed below:

Variance to mean ratio (VMR): Variance to mean ratio was utilized to determine the thrips distribution as suggested by Patil and Stiteler (1974).

$VMR = S^2/\bar{x}$, where, S^2 = variance, $\bar{x}$ = Mean

The value of VMR = 1, <1 and > 1 for 'Poisson' distribution, positive binomial and negative binomial distribution, respectively. Additionally, VMR provides detail on population dispersion, with the value ranging from <1 (regular) to =1 (random) to >1 (contagious distribution).

Index of clumping of David and Moore (I_{DM}): The distribution of *T. tabaci* was confirmed by estimating the index of clumping (I_{DM}) suggested by David and Moore (1954):

$$I_{DM} = \frac{S^2}{\bar{X}} - 1$$

I_{DM} results in value of zero for Poisson, positive for negative binomial and negative for positive binomial distribution.

Lewis index: Lewis index was worked to determine the dispersion of *T. tabaci* as:

$$\sqrt{\frac{S^2}{\bar{X}}}$$

The value of this index being <1: regular, >1: contagious and =1: random distribution.

Morisita's coefficient of dispersion (I_δ): The following equation was proposed by Morisita (1962) in order to evaluate the uneven distribution coefficient of I_δ.

$$I_\delta = \frac{n \quad Xi\,(Xi-1)}{N\,(N-1)}$$

where, n is the number of sample units, N is the total number of individuals in sample n and Xi is the number of individual in each sample. Large sample test of significance was utilized to determine whether the sampled population varied significantly from random.

$$Z = \frac{(I_\delta - 1)}{\sqrt{\frac{2}{\bar{X}^2}}}$$

Spatial distribution is random if the value of Z is 1.96 ≥ Z ≥ -1.96, >1.96 for aggregated and < -1.96 indicated regular distribution (Pedigo and Buntin 1994).

Index of dispersion (I_D): Index of Dispersion was calculated to further confirm the distribution pattern of onion thrips as suggested by Patil and Stiteler (1974).

$$I_D = (n-1)\ \frac{S^2}{\bar{X}}$$

where, I_D: index of dispersion, n: the number of samples drawn

To test its significance, the I_D coefficient was also worked out as given below:

$$Z = \sqrt{2I_D} - \sqrt{(2v-1}$$

Lloyd's mean crowding ($\bar{X}$*): It is used to highlight the possible effect of mutual interference or competition among individuals as suggested by Lloyd (1967). The sample estimate of mean crowding ($\bar{X}$) for *T. tabaci* was calculated as

$$\bar{X}^* = \bar{X} + \frac{S^2}{\bar{X}} - 1$$

Index of patchiness ($\bar{X}$*/$\bar{X}$): The ratio of mean crowding to mean density ($\bar{X}$*/X) is known as patchiness index. In a dispersed, random, and clumped distribution, respectively, the values of the function ($\bar{X}$*/X) are 1, =1, and >1 (Lloyd 1967). The value of ($\bar{X}$*/X) >2 suggests that clumping being due to environmental factors as well as insect behavior; the value being <2 reveals only environmental factors to influence clumping (Iwao 1968).

Taylor's power law: According to Taylor's power law, population variance (S^2) is proportional to the fractional power of arithmetic mean ($\bar{X}$)*. The log function of $S^2 = a(X)^b$ was used in following form:

$\log S^2 = \log a + b \log (\bar{X})$

where, a: sampling factor, b: aggregation parameter

In which 'a' is sample size-related scaling factor; slope b index of aggregation which in turns recalls (b<1), random (b=1) and aggregated (b>1) dispersion of a population (Taylor 1961).

Iwao's patchiness regression index: This index (Iwao 1968) quantifies the relationship between mean crowding index ($\bar{X}$)* and mean ($\bar{X}$) using the following equation:

$(\bar{X})^* = \alpha + \beta\,(X)$

Here, α denotes the tendency of crowding (positive) or dispersion (negative). The constant β is related to the pattern in which the insect utilizes its habit and is called density contiguosness coefficient and its interpretation is equivalent to Taylor's power law 'b' (Iwao 1968). The distribution with β>1 corresponds to negative binomial series and the distribution with β=1 to models of randomly distributed colonies were used to test the distribution pattern of thrips.

Desired sample size for population estimation: The number of samples to be taken for estimating thrips population was worked out as suggested by Rojas (1964). Analysis was done at weekly interval starting from the appearance of thrips on crop till the final harvest of the crop.

$$N=\frac{\frac{1}{\bar{x}}+\frac{1}{k}}{D^2}$$

where, N: Number of samples to be drawn, ($\bar{X}$): mean population, k: dispersion parameter worked out as $(\bar{X})^2/(S^2-\bar{X})$ S^2: variance, D: the desired level of accuracy and was taken as 0.1 and 0.2.

RESULTS AND DISCUSSION

Population dynamics: During cropping season 2016-17, thrips appeared first in 7 standard week (SW) (18 February, 2017). The population density remained low up to 12 SW and peak population of 4.93 thrips/plant was observed on April 22, 2017 (16SW) (Fig. 1). Thereafter, population abruptly declined to 0.09 thrips per plant at final harvest of the crop (May 20, 2017). Whereas, during 2017-18 thrips infestation initiated in second fortnight of February (7-8 SW) and persisted till final harvesting of the crop during mid-May (20 SW). The population levels remained low up to 12 SW and resulted in peak population of 4.65 thrips/plant in third week of April (17 SW).

Spatial distribution: Variance to mean ratio (VMR) to vary between 0.99 to 6.60 (Table 1). The value of VMR was unity on 7 SW and less than unity up to 9SW depicting the population to follow Poisson and positive binomial distribution, respectively. For subsequent observations (10SW onwards) the population followed negative binomial distribution. This was further confirmed by the index of clumping of David and Moore (I_{DM}) which revealed the values being greater than zero and positive in most of the cases, on and after 13 SW depicting the distribution of thrips following negative binomial distribution in later stages of crop growth. The value of index of dispersion (I_D) revealed *T. tabaci* tofollow random distribution with the values ranging between 1.96 ≥ Z ≥ -1.96 from 7 to 9 SW. Thereafter, the population trend became aggregated (Z>1.96) for all the values. Morisita coefficient of dispersion (I_δ) also revealed the thrips population to be distributed randomly in early growth stages and aggregated in later stages (10 SW onwards). The hypothesis of aggregation was also confirmed by Lewis index which resulted in the value >1, being aggregated. The values of Lloyd's mean crowding (X*) more than zero (13SW onwards) further confirmed the clumped distribution of thrips. The values of index of patchiness (X*/X*) for most of the observations were greater than unity which revealed that the clumping of thrips on onion being influenced by both the environmental factors as well as insect behaviour.

In early stages of crop growth of *rabi* onion, thrips followed random distribution. But in later crop growth stages, thrips distribution was aggregated/ over dispersed/ clumped. Aggregated distribution of thrips in all the cropping seasons was further confirmed by Taylor's power law and Iwao's patchiness regression in which the value of aggregation parameter (b) and β being positive and > 1, respectively (Fig. 2). The estimates of mean to variance ratio and other dispersion parameters shows that the *T. tabaci* population in onion fields followed the negative binomial distribution. In early

Table 1. Dispersion indices of *Thrips tabaci* in *rabi* onion (Pooled for 2017 and 2018)

SW	Mean population/ plant	Variance	Variance to mean ratio	David & Moore's Index of clumping	Lewis Index	Index of dispersion		Morisita coefficient of dispersion		Lloyd's mean crowding	Index of patchiness
	($\bar{X}$)	(S^2)	(VMR)	(I_{DM})		(I_D)	Z	(I_δ)	Z	($\bar{X}$*)	($\bar{X}$*/$\bar{X}$)
7	0.00	0.00	1.00	0.00	1.00	598.00	-0.01	0.00	-0.06	0.00	0.50
8	0.01	0.01	0.99	-0.01	1.00	596.00	-0.07	0.00	-0.12	0.00	0.25
9	0.01	0.01	0.99	-0.01	1.00	594.00	-0.13	0.00	-0.17	0.00	0.17
10	0.03	0.04	1.78	0.78	1.33	1065.00	11.55	34.29	14.41	0.80	32.12
11	0.09	0.15	1.66	0.66	1.29	994.00	9.99	8.18	11.61	0.75	8.07
12	0.15	0.20	1.39	0.39	1.18	830.10	6.15	3.69	6.76	0.53	3.66
13	0.82	3.14	3.84	2.84	1.96	2301.26	33.24	4.47	49.24	3.66	4.47
14	1.02	2.55	2.51	1.51	1.59	1506.27	20.29	2.49	26.23	2.53	2.49
15	1.43	7.12	4.98	3.98	2.23	2984.54	42.66	3.79	68.95	5.41	3.79
16	3.62	22.21	6.13	5.13	2.48	3670.89	51.09	2.41	88.72	8.75	2.42
17	2.81	18.55	6.60	5.60	2.57	3955.28	54.34	2.99	96.94	8.41	2.99
18	2.23	12.95	5.82	4.82	2.41	3486.12	48.90	3.16	83.41	7.04	3.17
19	1.09	3.83	3.51	2.51	1.87	2103.80	30.27	3.30	43.41	3.60	3.30
20	0.70	1.79	2.55	1.55	1.60	1527.22	20.67	3.21	26.86	2.25	3.21

SW: Standard week

Table 2. Number of samples required for estimating *Thrips tabaci* population in *rabi* onion (Pooled for 2017 and 2018 cropping season)

Crop stage	SW	Number of samples at desired level of precision		Mean number of samples for crop stage at desired level of precision	
		P=0.1	P=0.2	P=0.1	P=0.2
Vegetative	7	29950	7487	15476	3869
	8	14925	3731		
	9	9917	2479		
	10	7112	1778		
Bulb initiation	11	1778	444	760	190
	12	954	239		
	13	469	117		
	14	248	62		
Bulb development to maturity	15	349	87	270	68
	16	169	42		
	17	235	59		
	18	262	65		
	19	322	81		
	20	363	91		

growth stages, the distribution was random which became aggregated during later growth stages. The random distribution at early growth stages of crop can be due to the initial invasion of low number of thrips populations on the crop which later changed to aggregated. At later stages, clumped or aggregated dispersion of *T. tabaci* is common as they are weak and passive fliers which largely depend upon the wind for their dispersion from one plant to another. Thrips colonize for several generations in the same host and their ability to shift and disperse to other host mainly depends on the reproductive success of adults. Other factors such as availability of food resource, adult behavior, protection against natural enemies might contribute their aggregate behavior. Quartey (1982) in Michigan also observed that onion thrips randomly distributed in the beginning of season and clumped subsequently. Pandey et al (2008) also observed the thrips population becoming over dispersed as density increased above one thrips per plant.

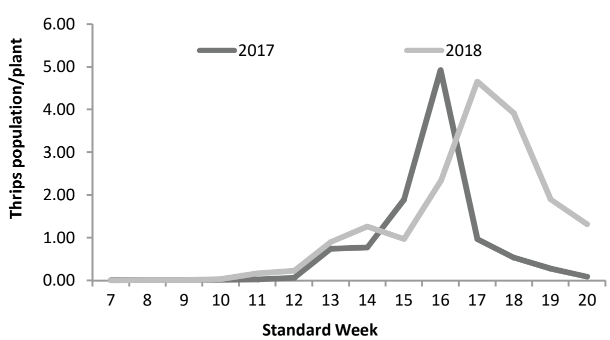

Fig. 1. Mean population of *Thrips tabaci* on onion during 2017 and 2018

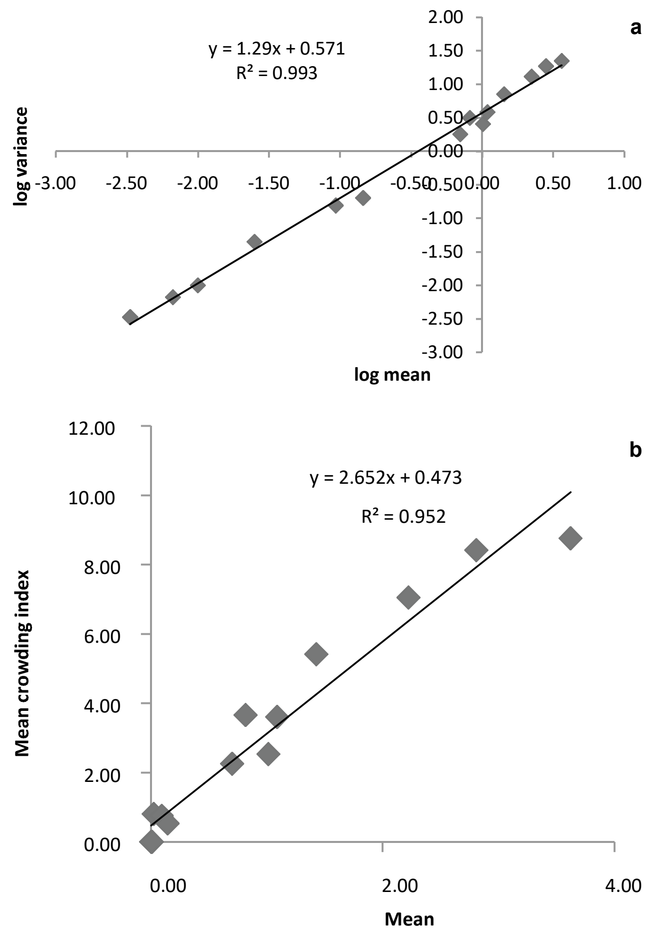

Fig. 2. Parameters for the distribution of *Thrips tabaci* on onion: (a) Taylor's power law; (b) Iwao's patchiness regression index

Desired sample size for population estimation: The desired number of samples required for estimating *T. tabaci* population in *rabi* onion ranged from 169 to 29950 and 42 to 7487 at 10 and 20 per cent precision level, respectively (Table 2). The number of samples required during vegetative stage was more and reduced drastically after 11 SW, coinciding with bulb initiation stage. On the basis of mean number of samples needed for estimating population, the sample size of 15476, 760 and 270 (P=0.1) and 3869, 190 and 68 (P=0.2) was appropriate for vegetative, bulb initiation and bulb development stage of *rabi* onion, respectively. The minimum sample size for thrips estimation utilized at different precision level showed that more samples were needed in early crop stages as distribution of thrips being random in the early crop stages.With the increase in population, distribution became clumped in later crop growth stages resulting the number of samples to be drawn for population estimation to reduce considerably. Deligeorgidis et al (2002) also reported the increase in thrips population caused exponential decrease in sample size.

CONCLUSION

In mid-hill regions of Himachal Pradesh representing north-western Himalayan region, onion thrips infestation initiated during first week of February and persisted till harvesting of the crop to mid of May with peak population occurring during third week of April. The values of all the dispersion indices revealed that thrips follow random distribution during early crop growth stages, whereas, clumped/aggregated/over dispersed in the later stages. The number of samples required for their population estimation were comparatively more in early crop stages as compared to later stages.

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