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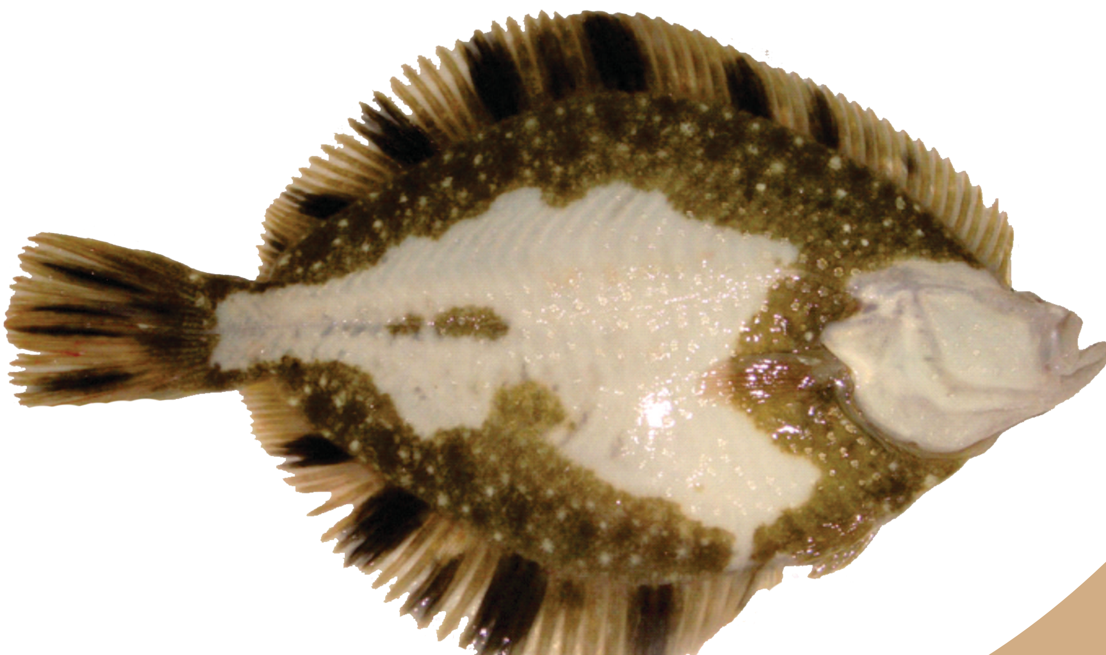

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Humid thermal ratio as a tool to assess mango thrips dynamics under subtropical climatic condition

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Abstract

Weather factors play an important role in occurrence of thrips on mango. Keeping this in view, the present investigation was set out to assess the thrips population dynamics using humid thermal index, based on data sets from 22 fixed plot mango orchards in and around Lucknow. Results revealed that the highest thrips population of 3.36/panicle was recorded in Kakori (Fixed plot -I) orchard, which was followed by 2.4 and 2.06 at CISH III block and Kanar (Fixed II) respectively during the year 2013, whereas corresponding values were 4.05, 3.08 and 2.50 at CISH Block III, CISH Bolck II and Allupur respectively during 2014. The frequency distribution explained that the thrips population of <2 /panicle was widely distributed with highest frequency level. The humid thermal ratio ranged from 1.44 to 2.27 and 1.20 to 2.34 during 2013 and 2014 respectively across standard meteorological weeks. The peak thrips incidence was 6.18 /panicle during 2013 and 4.67/panicle during 2014, the corresponding values of humid thermal ratio were 1.47 and 2.05 respectively. The positive correlation was found between humid thermal ratio and thrips population dynamics during 2013 (r = 0.52**) and 2014 (r = 0.72**). Pooled data showed significant and positive correlation between humid thermal ratio and thrips population. Pooled analysis had explained up to 94 per cent of variation with exponential model (Thrips population = $0.007e^{2.778HTR}$, $R^2 = 0.94^{**}$) and suggested that this index might be used in understanding the mango thrips population dynamics under subtropical environmental condition.

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Humid thermal ratio, Mango thrips, Regression analysis, Seasonal abundance

Introduction

Abiotic factors seem to influence large variation in the thrips population dynamics. In general, growth, development and occurrence of thrips on any crop is temperature and relative humidity driven, and also influenced by factors like growing season, cultivation practices and sampling methods. Chang (1997) observed that the distribution and dynamics, behavior, habits and ecology of thrips was influenced by prevailing weather conditions. Even the variations of single species or different species of thrips population may vary either on same genotypes or on different mango cultivars. Furthermore, within canopy microclimatic conditions have contributed to the wide differences in occurrence of this pest on mango (Aliakbarpour and Rawi, 2012). Thrips attack both vegetative, as well reproductive parts of the mango. Among the phenological stages of mango, blooming, flower maturation and fruiting stages have been identified as crucial phenophases for thrips incidence and its prevention strategies (Lin *et al.,* 2015). Higgins (1992) and Pena *et al*. (2002) also reported that heavy infestation of mango thrips on flower panicles, drastically reduce the fruit production and quality. For management of thrips, growers are routinely practicing indiscriminate use of synthetic insecticides and subsequently, either directly or indirectly posing a threat to environmental safety (Desneux *et al.,* 2007). However, need based application of the insecticides is desirable in order to avoid pollution related hazards (Kandakoor *et al*., 2014).

Phenology models for forewarning the insect pest are being employed because they predict general patterns and time of peak occurrence of insect population (Kim and Lee, 2008; Fand *et al*., 2014). Several studies have been carried out to develop correlation between weather parameters and thrips population, and it has been reported that temperature is the important contributing factor for the thrips population fluctuation (Ananthakrishnan, 1993; McDonald *et al*., 1999). Several temperature driven models for predicting the growth and development of thrips has been developed (Kawai, 1985; McDonald *et al.,* 1999, Murai, 2000). All these models take temperature as prime factor without giving much importance on the effect of relative humidity. Hence, the present study was taken up by considering both temperature and relative humidity in the form of index called humid thermal ratio for quantifying thrips population dynamics under subtropical climatic conditions of Lucknow region.

Materials and Methods

Twenty two mango orchards of cv. *Dashehari ,* 20-35 years age were selected for this study in and around Lucknow region, Uttar Pradesh, India. The trees were planted with a spacing of 10×10 m distance. The orchards were designated as fixed plots and mango thrips population was counted on these orchards during two consecutive seasons of 2013 and 2014. Each orchard had at least 25 trees. Data on thrips population was recorded on weekly basis from five randomly selected trees in four direction of the tree. Thrips count was taken after gently tapping shoot or panicle by holding white paper in the palm. For analysis, mean count per shoot or panicle was taken and expressed as number of thrips per shoot or panicle. Incidence of thrips on mango was reported from 13th to 24th standard meteorological week (SMW) during 2013 and 15th to 28th Standard meteorological week in the next year. These data were used for further analysis and discussion.

The experimental area was characterized as subtropical with hot dry summers and cold winters. Daily weather data of temperature (maximum and minimum), relative humidity (morning and evening), rainfall, wind speed, bright sunshine hours and evaporation rates were recorded in the agromet observatory located within the experimental site. This information was then used for calculating humid thermal ratio using following formulae.

$$HTR = RH_{mean} / T_{mean}$$

Where, HTR is humidity thermal ratio, RH_{mean} is mean relative humidity and T_{mean} is mean temperature

Data analysis : Population dynamics study was plotted against standard meteorological weeks. Logarithmic and non-logarithmic histographic representation of thrips population was carried out by SPSS package (Version 16.0). Linear regression equations were generated by considering weather parameters as independent variables and thrips population as dependent variables. Statistical significance of Pearson's correlation coefficients between dependent and independent variables under the study was drawn using t-test significance. Functional relationship between HTR and thrips population was carried out using MS Excel software.

Results and Discussion

The agro-climatic analysis during the study period is presented in Table 1, and indicated that the weather parameters were responsible for the dynamisms of thrips population across the two seasons. The maximum and minimum temperatures during the thrips incidence were recorded between 31.9 to 43.4°C and 14.1 to 26.5°C, respectively, across standard meteorological weeks (SMW). However, the average temperature ranged from 23.0 to 33.6°C across seasons and SMW. The minimum and maximum relative humidity (RH) was observed to be 20.6 to 88.3%, with an average value of 34.7 to 76.7%. The average temperature was higher in 2014 mango fruiting season as compared to 2013, whereas the average RH was *vice versa*. Sunshine hours were found between 4.2 to 10.8 hr across the seasons. Lowest and highest wind speed of 2.4 to 6.2 km hr^{-1} was also observed. Higher pan evaporation was recorded in 2014 as compared to 2013 with highest value of 12.6 mm day^{-1}. High amount of rainfall was received in 2014 during 24th to 28th SMW.

The mean population density of mango thrips across the consecutive seasons of 2013 and 2014 is presented in Table 2. Results revealed that in general thrips population was higher in 2014 season as compared to 2013. During the year 2013, it was found that the highest thrips population of 3.36 per panicle was recorded in Kakori (Fixed plot -I) orchard, which was followed by 2.4 and 2.06 at CISH III block and Kanar (Fixed II), respectively. Whereas corresponding values were 4.05, 3.08 and 2.50 at CISH Block III, CISH Bolck II and Allupur, respectively, during the year 2014 (Table 2). Univariate statistical analysis showed wide variation (population was ranged between 0.15 to 13.6) in mango thrips population across 20 orchards and seasons. Some of the orchards had lowest thrips population density of 0.88 (Navipana Fixed I) and 1.03 (Hafizkhera Fixed I). The histographic representation depicted that the mean value of mango thrips was 1.66 during the year 2013 (n=264), while in next season it was 1.74 (n=308).

The frequency distribution further explained that the thrip population of <2 per panicle was widely distributed with highest frequency level (Fig 1). Increase in the thrips population from 4.0 to 13.6 showed low frequency level (5 %). To normalize the wide variation in the thrips population,

Table 1 : Meteorological parameters during 2013 and 2014 at experimental site Lucknow, Uttar Pradesh

Std. met. week	Temperature (°C)			Relative humidity (%)			Sunshine (hour / day)	Wind speed (km h^{-1})	Rainfall (mm)	Evaporation in 24 hr (mm)
	Max.	Min.	Avg. Temp	Max.	Min.	Avg.RH				
					2013					
13	31.9	14.1	23.0	73.0	31.7	52.4	8.3	4.2	0.0	3.8
14	34.9	14.2	24.6	58.7	21.3	40.0	10.0	4.8	0.0	7.1
15	38.2	17.2	27.7	59.0	22.7	40.9	8.8	2.9	0.0	7.8
16	37.0	17.8	27.4	63.7	33.1	48.4	7.4	3.6	0.0	8.4
17	36.9	19.3	28.1	71.9	33.4	52.6	10.0	3.6	0.0	6.2
18	40.3	20.2	30.2	69.4	31.0	50.2	10.8	3.7	0.0	8.8
19	40.3	22.5	31.4	81.3	50.1	65.7	9.4	3.7	0.0	9.3
20	39.3	22.6	30.9	69.6	43.6	56.6	10.4	3.1	0.0	9.3
21	40.0	26.8	33.4	77.4	44.7	61.1	9.3	4.5	0.0	8.7
22	37.4	25.6	31.5	76.1	47.4	61.8	8.7	5.5	0.0	8.7
23	35.6	25.3	30.5	81.7	56.3	69.0	7.0	5.0	0.0	5.5
24	34.9	25.2	30.1	76.6	56.7	66.6	5.9	6.2	1.3	4.9
					2014					
15	35.8	14.7	25.3	55.9	20.6	38.2	9.2	3.0	0.0	8.9
16	32.8	16.4	24.6	62.4	38.3	50.4	7.4	3.6	0.0	8.3
17	38.5	17.4	27.9	53.4	23.7	38.6	10.3	4.1	0.0	8.7
18	39.5	19.1	29.3	53.4	26.4	39.9	9.7	3.8	0.0	10.2
19	38.5	21.4	29.9	62.0	30.7	46.4	9.1	3.3	0.0	9.9
20	38.6	20.0	29.3	51.7	24.1	37.9	10.4	3.5	0.0	11.0
21	40.6	20.8	30.7	46.6	22.9	34.7	10.0	4.7	0.0	12.1
22	38.0	23.2	30.6	68.6	37.7	53.1	10.3	4.8	0.0	11.3
23	43.4	23.8	33.6	59.0	28.7	43.9	10.3	2.4	0.0	11.8
24	40.6	24.6	32.6	72.9	38.4	55.6	8.1	5.1	0.4	12.6
25	36.5	25.8	31.1	85.7	57.0	71.4	4.2	3.0	3.0	9.3
26	39.4	26.5	33.0	76.0	45.3	60.6	8.5	3.2	0.0	11.9
27	34.6	25.7	30.2	82.7	58.3	70.5	4.3	3.8	1.6	11.8
28	34.4	26.5	30.4	88.3	65.1	76.7	4.4	2.7	8.4	8.9

the data was subjected to logarithmic transformation which revealed that the mean of thrips population was 0.23 and 0.46 during the year 2013 and 2014 respectively. The potential for successful establishment and completion of the life cycle of insect pests in different orchards is often limited by temperature and host plant availability (Kannan and Rao, 2006 a, b). Although the differences may be due to various factors, highest variation in thrip population is attributed to difference in the prevailing temperature. A wide variation across season is pertaining to the fact that growth and development of thrips is temperature driven. Insect development occurs within a definite temperature range (Wagner *et al.,* 1984). Park *et al*. (2010) inferred that the thrips developmental time decreased with increasing temperatures up to 32.5°C. In this study low thrips population was recorded as the mean temperature increased up to 33.6°C with mean RH of 77.6%.

Growth and development of mango are profoundly influenced by biotic and abiotic factors since it is cultivated in open field conditions and affected by biotic and abiotic factors. Crop weather interaction and associated pest population dynamics are thus, the function of ambient temperature, relative humidity and precipitation. Kumar *et al.* (2014) observed that the population dynamics of mango thrips was significantly impacted by prevailing weather conditions. Lin *et al*. (2015) opined that even in an identical environment, the population dynamics was influenced by various mango cultivars. He also suggested that relative humidity and temperature are the most crucial factors that influenced thrips population. Thus, in the present study ratio of two important environmental factors mean temperature and mean relative humidity were taken to know the functional relationship with thrips population dynamics. Humid thermal ratios ranged from 1.44 to 2. 27 during the year 2013, whereas during 2014 humid thermal ratio ranged from 1.20 to 2.34. Thrips population was recorded between 13th SMW to 24th SMW during 2013, whereas in the next year it was found from 15th SMW to 28th SMW. The peak thrips incidence was 6.18 /panicle during 2013 and 4.67/panicle during 2014, the corresponding values of humid thermal ratio 1.47 and 2.05, respectively (Fig 2).

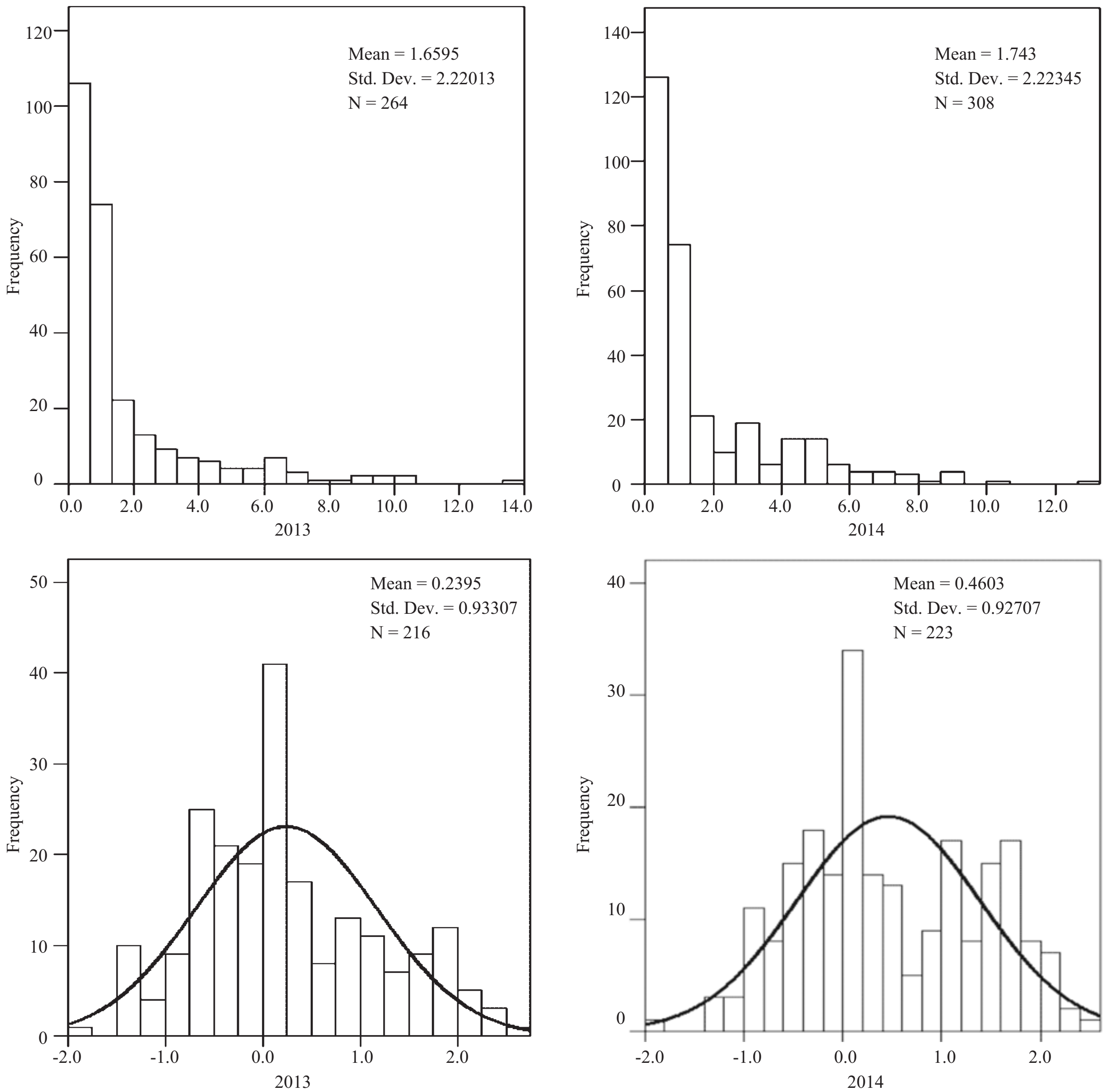

Fig. 1 : Histograms depicting frequency distribution of thrips

A significant positive correlation was found between humid thermal ratio and thrips population dynamics during 2013 (r= 0.523**; p<0.001) and 2014 (r= 0.720**; p<0.001). When two year data was pooled significant positive correlation was found between humid thermal ratio and thrips population. A linear regression between humid thermal ratio and thrips population had explained up to 85 % of variation (Thrips population = 3.971×HTR-5.45; *F*=144.11; p<0.000). This clearly indicates that humid thermal ratio serve as a useful tool in understanding the thrips population dynamics with prevailing weather conditions. Similar results were also observed in mustard, where population of mustard aphids was positively correlated with humid thermal ratio (Narjary *et al*., 2013).

Researchers across the world have employed regression analysis to investigate the population change of thrips under the influence of temperature, humidity, precipitation, wind velocity, sampling method, and location of the installed monitoring facilities (Li, 2010; Kumar *et al*., 2014). In the present study, linear and non linear regression was carried out to quantify the functional relationship

Table 2 : Univariate statistical analysis for the population of mango thrips during 2013 and 2014 at Lucknow, Uttar Pradesh

	2013					2014				
Location	**Mean**	**Range**	**CV**	**Skewness**	**Kurtosis**	**Mean**	**Max**	**CV**	**Skewness**	**Kurtosis**
Malihabad (Fixed I)	1.63 ± 0.59	9.15 - 0.4	61.6	2.54	6.44	1.48 ± 0.20	4.90 - 0.4	89.3	1.26	0.24
Malihabad (Fixed II)	1.65 ± 0.67	9.45 - 0.25	58.3	2.33	5.35	1.63 ± 0.32	6.95 - 0.4	76.8	1.72	2.02
Navipana (Fixed I)	0.88 ± 0.15	3.95 - 0.25	64.7	1.79	2.10	1.41 ± 0.31	6.90 - 0.4	68.1	2.03	3.50
Navipana (Fixed II)	1.57 ± 0.42	6.2 - 0.5	69.5	1.54	1.04	1.70 ± 0.36	6.75 - 0.65	76.1	1.79	2.29
Methe Nagar (Fixed I)	1.44 ± 0.23	5.65 - 0.15	86.7	1.78	3.14	1.20 ± 0.24	6.40 - 0.6	65.7	2.11	4.63
Methe Nagar (Fixed II)	1.54 ± 0.20	5.6 - 0.55	98.8	1.74	3.72	1.46 ± 0.26	5.50 - 0.25	77.0	1.23	0.20
Hafizkhera (Fixed I)	1.38 ± 0.24	5.3 - 0.25	81.8	1.72	2.10	1.03 ± 0.18	5.70 - 0.15	64.4	2.32	5.63
Hafizkhera (Fixed II)	1.36 ± 0.20	4.8 - 0.45	87.2	1.63	1.74	1.80 ± 0.20	5.30 - 0.6	108.2	0.67	-0.54
Mahmood Nagar (Fixed I)	1.83 ± 0.44	6.9 - 0.4	79.8	1.63	1.59	1.84 ± 0.42	8.75 - 0.4	75.6	2.06	4.51
Mahmood Nagar (Fixed II)	1.27 ± 0.36	7.55 - 0.25	61.1	2.96	9.37	1.28 ± 0.23	5.20 - 0.4	70.6	1.52	1.23
Kakori (Fixed I)	3.36 ± 1.67	13.6 - 0.65	75.1	1.58	1.50	1.20 ± 0.35	7.30 - 0.4	54.4	2.08	3.87
Kakori (Fixed II)	1.78 ± 0.44	8.15 -0.25	77.1	2.36	5.55	2.16 ± 0.24	5.95 - 0.9	118.5	1.05	-0.11
Ulrapur (Fixed I)	1.11 ± 0.11	3.95 - 0.25	97.5	1.55	2.77	1.97 ± 0.39	7.85 - 0.4	84.6	1.46	1.81
Ulrapur (Fixed II)	1.45 ± 0.33	6.45 - 0.25	73.2	1.85	2.96	1.68 ± 0.42	8.85 - 0.35	68.9	2.22	5.62
Kanar (Fixed I)	1.57 ± 0.27	5.8 - 0.4	87.8	1.78	2.29	1.41 ± 0.24	5.05- 0.25	77.0	1.38	0.31
Kanar (Fixed II)	2.06 ± 0.76	9.4 - 0.55	68.4	2.02	3.03	1.33 ± 0.19	4.85 - 0.5	81.9	1.33	0.56
NB Dhanewa (Fixed I)	2.01 ± 0.61	10.3 - 0.5	74.3	3.04	9.89	1.71 ± 0.36	8.20 - 0.4	76.5	2.35	5.48
NB Dhanewa (Fixed II)	1.65 ± 0.26	6.6 - 0.55	92.6	2.18	5.73	1.24 ± 0.29	5.95 - 0.65	60.8	1.85	2.34
CISH Block-III (Fixed I)	2.40 ± 0.41	7.15 - 0.25	107.5	1.31	0.96	4.05 ± 0.93	9.30 - 0.4	112.1	0.15	-1.85
CISH Block-II (Fixed II)	1.92 ± 0.28	6.2 - 0.6	104.6	1.17	1.40	3.08 ± 0.76	13.00 - 0.9	94.0	2.30	6.82
Allupur (Fixed I)	1.06 ± 0.14	4.9 -0.4	82.8	2.82	9.00	1.19 ± 0.14	5.15 - 0.35	86.1	2.01	4.82
Allupur (Fixed II)	1.60 ± 0.54	8.8 - 0.5	63.3	2.50	6.45	2.50 ± 0.52	10.10 - 0.75	93.1	1.97	4.39

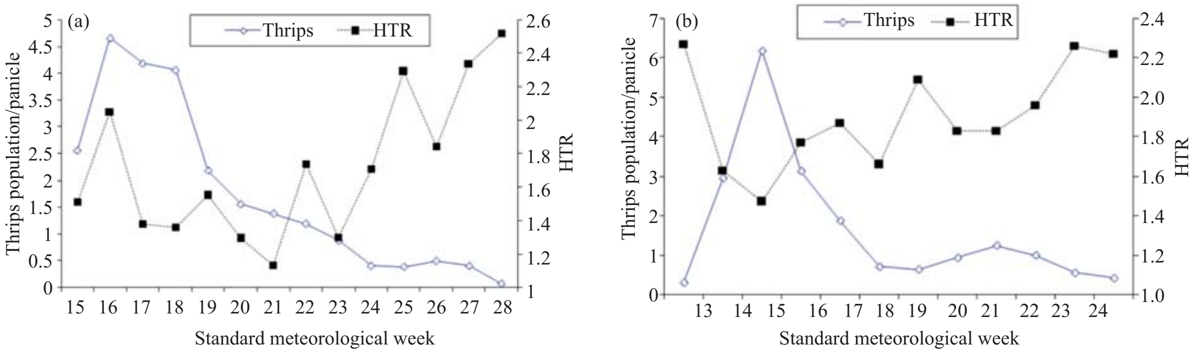

Fig. 2 : Dynamics of thrips and humid thermal ratio across meteorological week (a) 2013 (b) 2014

between humid thermal ratio and thrips population. It was inferred that different regression equation (Linear, Logarithmic and exponential) explained good amount of variation. During the year 2013 exponential model explained highest variation for humid thermal ratio (Thrips population = $0.001e^{3.367HTR}$; R^2 = 0.95**) as compared to linear and logarithmic models. During the year 2014, as compared to exponential and logarithmic models, linear models for humid thermal ratio (Thrips population = 3.545HTR - 4.338; R^2 = 0.98**) explained highest variation (Table 3). Pooled analysis explained up to 94 % variation with exponential model (Thrips population = $0.007e^{2.778HTR}$; R^2 = 0.94**) (Fig 3). Narjary *et al.* (2013) used growing degree days and humid thermal ratio to develope a linear regression model for mustard aphid, which explained 60-70 % of variation in aphid population. Thus, it indicated that humid thermal ratio might be considered as an important tool for understanding the mango thrips population dynamics.

The present study indicated that weather parameters particularly temperature and relative humidity played a pivotal role on the incidence and variations in mango thrips across the seasons and standard meteorological weeks. The population recorded was higher in 2014 fruiting season as

Table 3: Different models for mango thrips using humid thermal index.

Model	2013			2014		
	Equation	**R²**	**r**	**Equation**	**R²**	**r**
Linear	y = 5.434x - 8.697	0.69	0.834	y = 3.545x - 4.338	0.98	0.989
Logarithmic	y = 9.963ln(x) - 4.678	0.65	0.810	y = 6.119ln(x) - 1.380	0.94	0.972
Exponential	$y = 0.001e^{3.367x}$	0.95	0.978	$y = 0.013e^{2.556x}$	0.84	0.916

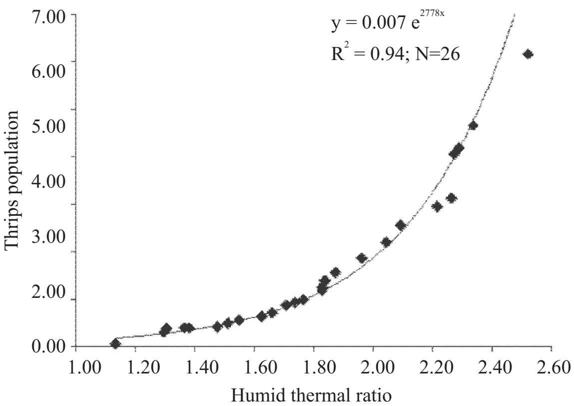

Fig. 3 : Relationship between thrips population and humid thermal ratio

compared to 2013, of course the maximum/peak incidence was found during emergence of new flushes and fruit development stages of mango. Thus, phenological events of the tree played a crucial role in thrips population occurrence. A positive correlation of thrips population with humid thermal ratio suggested the role of this index in understanding the mango thrips population dynamics. Henceforth, this HTR might serve as a tool for understanding crop- weather-pest behavior.

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