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Seasonal occurrence of major insect pests of mango

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Abstract
Investigations on seasonal occurrence of major insect pests of mango in relation to weather parameters were carried out at Horticulture Farm, B. A. College of Agriculture, Anand Agricultural University, Anand during September, 2013 to August, 2014 and September, 2014 to August, 2015. The results showed that hopper population showed two peaks with highly significant positive association between Evapotranspiration (EP), Bright Sunshine hours (BSS) and Maximum Temperature (MaxT) whereas highly significant negative association between Morning Relative Humidity (RH_1) and Evening Relative Humidity (RH_2). Thrips showed three-four peaks during course of investigations and showed highly significant positive association between EP and BSS whereas highly significant negative association between rainfall (RF), RH_1, RH_2 and Evening Vapour Pressure (VP_2). Comparatively higher incidence due to leaf webber was noticed during first year than second year and showed negative association with EP, BSS, RF, WS, MaxT, Minimum Temperature (MinT) and Morning Vapour Pressure (VP_1) while positive association with RH_1, RH_2 and VP_2 showed positive effect on the pest activity. The higher incidence of *P. matteiana* was observed during 1st week of November and 2nd week of May during first year, while it was during 2nd week of November and 2nd week of May during second year. Gall midge showed highly significant positive association with MaxT during first year, whereas highly significant negative association with RH_2 during second year. The activity of fruit fly commenced from 1st week of April and reached its peak on 3rd week of May during first year while its peak activity was noticed on 3rd week of May during second year and BSS and MaxT showed significant positive impact on the fluctuation of the fruit fly population whereas EP, RH_1 and RH_2 showed highly significant negative association during both the years. Comparatively higher mean incidence of termite was noticed during first year than the second year. It showed highly significant positive association with EP, BSS, MaxT and MinT whereas highly significant negative association with RH_1. The higher activity of natural enemies *viz*., spiders and coccinellids (adults) was recorded from February to April in mango ecosystem.

Keywords: Mango, seasonal occurrence, major insect pests, weather parameters, correlation

Introduction
Mango (*Mangifera indica* Linnaeus) is known to be the most important tropical fruit of Asia and known as 'king of fruits'. Uttar Pradesh, Andhra Pradesh, Bihar, Karnataka, Himachal Pradesh, Maharashtra, Orissa, Tamil Nadu, Gujarat and West Bengal are the major mango producing states of India. Valsad, Kheda, Junagadh, Surat and Banaskantha are the known districts of Gujarat for cultivation of this fruit crop. The popular varieties grown in Gujarat are Kesar, Rajapuri, Langra and Alphonso. In recent years, mango is gaining more and more importance in the national as well as international markets. There is a great demand for fresh fruits as well as processed products prepared from mangoes. This has created the demand for increasing the yield as well as quality of the mango fruits. The crop is attacked by about 492 species of insects, 17 species of mites and 26 species of nematodes at the world level. Of these, 188 species of insects have been reported from India (Tandon and Verghese, 1985) [18]. Srivastava (1997) [15] reported various insect-pests *viz*., hoppers, mealybugs, gall midges, shoot gall psylla, fruit flies, fruit-sucking moth, thrips, ant, termites, grey weevil, flea weevil, leaf-cutting weevil, whiteflies, stone weevil, bark-eating caterpillar, shoot borers, stem borer, scale insects, leaf webbers and leaf miner on mango. Apparently, the population fluctuation as well as the distribution of the pests depends largely upon the prevailing environmental factors, as this pest known to multiply tremendously during favourable weather conditions leading to population outbreaks. Environmental factors also influence natural enemy populations such as parasitoids and predators either directly or indirectly (Thomson *et al*., 2010) [19]. For developing an early warning weather based system for any pest in a specific agro-ecosystem, it is necessary to have basic information regarding population dynamics/seasonal occurrence of pests in relation to prevalent weather parameters. This will help in determining appropriate times for intervention and application of suitable methods for pest management.

In this study, the effect of weather parameters on population fluctuation of different pests of mango was carried out through correlation analysis under middle Gujarat agro-climatic condition.

Materials and Methods

To study the seasonal occurrence of major insect pests on mango, investigations were carried out at Horticulture Farm, B. A. College of Agriculture, AAU, and Anand during September, 2013 to August, 2014 and September, 2014 to August, 2015 on Kesar variety. The experiment was laid out by selecting more or less equal age (15 years) trees having similar size and canopy. The observations of different pests were recorded from three randomly selected trees from orchard at weekly interval (Standard Meteorological Week wise) from 1st week of September, 2013 (36th SMW) to 4th week of August, 2014 (35th SMW) and 1st week of September, 2014 (36th SMW) to 4th week of August, 2015 (35th SMW). The experimental trees were kept free from any insecticidal applications during the course of investigations.

Method of recording observations of different insect pests

Mango hopper

Number of nymphs and adults on a single panicle (10 cm)/inflorescence from each direction (East, West, South and North) of selected tree were visually counted during season. During off season, standard sweep net (4 sweeps/tree, one sweep in each direction) was used to sample the adult hoppers resting on tree trunk after disturbance by using net. Sweeps were made across the zone of flight of hoppers. The net was emptied after each sweep and hoppers were counted (Anon., 2012) [1].

Thrips

Ten terminal twigs from lower canopy of each of experimental tree were selected randomly for counting thrips population.

Leaf webber

The number of webs/tents formed by the pest was counted from each direction by covering the whole tree.

Leaf gall midge

On each selected and tagged trees, four leaves from terminal twig were selected randomly from each direction. On visual observations, galling index (0-5) was given. To standardize the scale, 100 leaves were randomly selected and brought to the laboratory. Collected leaves were categorized into the following index looking to the per cent leaf area covered based on number of galls counted.

Galling Index

Index	Leaf area covered (%)	Average number of gall (s)	Standard deviation (±)
0	No galls (completely free)	0	0
1	20% leaf area covered	6.9	2.02
2	40% leaf area covered	16.6	1.17
3	60% leaf area covered	26.8	3.19
4	80% leaf area covered	47.9	4.38
5	More than 80% leaf area covered	129.6	5.58

Fruit fly

For recording the observations of mango fruit fly, five methyl eugenol traps were placed in mango orchard after initiation of inflorescence. From each trap, numbers of male fruit flies were recorded at weekly interval from flowering to end of mango season.

Termite

A total of five spots on ten trees of each (all four corners and at centre of orchard) were examined for termite infestation in the orchard. Number of trees with symptoms of termite out of ten trees in each spot was noted.

Natural enemies

The population of predatory spiders and coccinellids were recorded from four twigs of each selected tree at weekly interval.

Correlation Analysis

In order to study the instantaneous effect of weather parameters on population fluctuation of various pests, the data of physical factors of environment *viz.*, bright sunshine (BSS), evapotranspiration (EP), rainfall (RF), wind speed (WS), maximum (MaxT) and minimum (MinT) temperature, morning (RH_1) relative humidity, evening (RH_2) relative humidity, morning vapour pressure (VP_1) and evening vapour pressure (VP_2) were correlated. Standard Week-wise data on various parameters were recorded in Department of Agricultural Meteorology, B. A. College of Agriculture, AAU, Anand during September, 2013 to August, 2014 (first year) and September, 2014 to August, 2015 (second year) [Table 2].

In order to determine the population fluctuation of insect pests and their natural enemies, the periodic mean incidence of the major insect pests and their natural enemies were worked out. The mean values of individual year were pooled and used for discussing seasonal occurrence of insect pests. Simple correlation was worked out between various pests and their natural enemies using their weekly mean population by adopting a standard statistical procedure (Steel and Torrie, 1980) [16].

Result and Discussion

Seasonal occurrence of major insect pests of mango

Mango hopper

The results presented in Table 1 revealed that hopper population was observed from 1st week of September (36th SMW) during first year with two peaks, first during 2nd week of April (15th SMW) (28.33 hoppers per panicle/ inflorescence/ tree trunk) and second during 4th week of August (35th SMW) (18.70) with highly significant positive association between EP, BSS and MaxT with hopper population (r = 0.443**, 0.398** and 0.467**, respectively) whereas highly significant negative association between RH_1 and RH_2 (r = -0.469** and 0.430**, respectively) [Table 3]. The results presented in Table 1 revealed that activity of hoppers was noticed from 1st week of September (36th SMW) during second year with two peaks, 3rd week of March (12th

SMW) (24.75) and 4th week of August (35th SMW) (11.33). The activity of hoppers showed highly significant positive association with EP (r = 0.368**) [Table 4]. BSS and MaxT exhibited significant positive correlation with population of hoppers. RH_1 and RH_2 exhibited significant negative association with the activity of hoppers population (r = -0.275* and -0.289*, respectively).

The population of hopper was recorded from January to April on flowering flush, also noticed during June-August on vegetative flush (Chowdhury, 2015) [5]. Temperature was positively correlated with the incidence of mango hopper and relative humidity was negatively correlated with the activity of mango hopper (Sarode and Mohite, 2016) [13]. Increase in temperature and decrease in humidity resulted in increase in population of *I. clypealis* and rain fall had less impact on the activity of hoppers on mango (Sathe and Kamble, 2015) [14]. The present findings are more or less in close agreement with the earlier reports.

Thrips

The results presented in Table 1 revealed that during first year, the population of thrips was gradually increased from 1st week of October (40th SMW) and reached its first (7.20 thrips/ twig), second and third peak on 3rd week of January (3rd SMW), 3rd week of April (16th SMW) (8.50) and 2nd week of June (24th SMW) (11.66), respectively. There was highly significant positive association between EP and BSS with thrips population (r = 0.585** and 0.588**, respectively) whereas highly significant negative association between Rainfall (RF), RH_1, RH_2 and Evening Vapour Pressure (VP_2) (r = -0.445**, -0.580**, -0.671** and -0.480**, respectively) [Table 3]. The results presented in Table 1 revealed that during second year, the first (6.33), second (6.30), third (4.33) and fourth (7.90) peak were attained during 52nd, 8th, 14th and 23rd SMW, respectively. EP, BSS and MaxT had positive whereas; RF, MinT, RH_1, RH_2, VP_1 and VP_2 had highly significant negative association with the activity of thrips (Table 4).

Table 1: Seasonal occurrence of major insects pests and their natural enemies on mango

Month/ Week	SMW	No. of mango hopper/ panicle (10 cm)/ Inflorescence/ swipe		No. of thrips/ twig		No. of webs/ tree due to leaf webber		Gall midge incidence (0-5 index)		Fruit fly/ trap		No. of trees infested by termite		No. of natural enemies/ twig			
														Spiders		Coccinellids (adult)	
		1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
September I	36	15.73	17.50	1.20	0.00	2.30	3.33	1.67	1.33	-	-	0.00	0.00	0.10	0.15	0.00	0.10
II	37	12.30	15.50	2.33	0.60	2.66	3.50	2.00	1.67	-	-	0.00	0.00	0.15	0.15	0.30	0.15
III	38	9.20	13.10	0.70	0.70	2.85	3.66	2.11	1.80	-	-	0.00	0.00	0.20	0.15	0.22	0.20
IV	39	7.13	11.33	0.00	1.70	3.03	3.80	2.44	2.11	-	-	0.00	0.00	0.20	0.10	0.15	0.20
October I	40	5.30	9.70	0.33	1.30	3.66	3.90	2.67	2.33	-	-	0.00	0.00	0.15	0.20	0.10	0.20
II	41	5.03	7.33	0.20	1.77	4.66	4.10	2.99	2.67	-	-	0.00	0.00	0.15	0.20	0.10	0.15
III	42	4.20	5.40	1.10	2.33	5.33	4.33	3.11	2.80	-	-	0.00	0.00	0.10	0.20	0.00	0.15
IV	43	2.50	5.10	3.33	3.10	5.77	4.66	3.22	3.00	-	-	0.00	0.00	0.10	0.15	0.10	0.15
V	44	2.33	4.77	3.70	3.66	6.33	5.10	3.50	3.11	-	-	0.00	0.00	0.10	0.10	0.10	0.10
November I	45	1.53	3.33	4.33	4.13	6.70	5.50	3.89	3.22	-	-	0.00	0.00	0.00	0.10	0.10	0.15
II	46	1.13	2.33	5.00	2.10	7.20	5.80	3.67	3.44	-	-	0.00	0.00	0.00	0.10	0.10	0.10
III	47	0.85	1.77	5.66	3.33	7.77	6.33	2.67	3.22	-	-	0.00	0.00	0.00	0.00	0.00	0.10
IV	48	0.00	1.03	5.33	3.50	8.50	6.77	1.67	2.33	-	-	0.00	0.00	0.00	0.00	0.00	0.00
December I	49	0.70	0.77	4.50	4.33	9.33	7.33	1.44	2.11	-	-	0.00	0.00	0.00	0.00	0.00	0.00
II	50	1.00	0.50	5.33	5.66	8.33	8.66	1.44	1.67	-	-	0.00	0.00	0.00	0.00	0.00	0.00
III	51	1.15	0.00	6.33	5.80	6.40	5.80	1.33	1.60	-	-	0.00	0.20	0.00	0.00	0.00	0.00
IV	52	1.70	0.00	6.77	6.33	4.30	3.50	1.22	1.44	-	-	0.20	0.40	0.10	0.15	0.00	0.10
January I	1	2.10	0.90	6.50	4.50	2.50	1.77	1.22	1.44	-	-	0.60	0.00	0.10	0.10	0.10	0.10
II	2	3.30	1.77	6.66	5.10	1.03	1.33	1.22	1.33	-	-	0.60	0.20	0.10	0.10	0.10	0.15
III	3	4.55	3.90	7.20	5.50	0.80	1.10	1.11	1.30	-	-	0.00	0.40	0.10	0.15	0.10	0.15
IV	4	4.90	5.50	3.30	3.90	0.60	0.77	1.11	1.22	-	-	0.00	0.00	0.15	0.10	0.10	0.20
V	5	5.77	6.77	2.10	4.33	0.50	0.66	1.00	1.22	-	-	0.60	0.00	0.15	0.10	0.15	0.15
February I	6	6.80	8.33	3.50	4.66	0.33	0.50	0.67	1.00	-	-	1.60	0.80	0.20	0.15	0.10	0.20
II	7	7.77	12.33	4.33	5.33	0.20	0.20	0.67	1.00	-	-	1.80	1.20	0.25	0.20	0.15	0.30
III	8	11.70	15.50	4.50	6.30	0.00	0.20	0.99	0.67	-	-	2.20	1.40	0.33	0.25	0.20	0.25
IV	9	13.75	17.33	4.70	2.20	0.00	0.10	1.00	0.80	-	-	2.80	0.40	0.35	0.25	0.30	0.35
March I	10	15.50	21.80	5.33	3.33	0.00	0.00	1.33	1.11	-	-	3.20	0.40	0.40	0.30	0.33	0.45
II	11	18.70	22.77	6.33	2.33	0.00	0.00	1.67	1.44	-	-	3.60	0.20	0.45	0.35	0.40	0.30
III	12	23.50	24.75	6.77	2.66	0.00	0.00	1.99	1.67	-	-	4.20	0.40	0.45	0.33	0.35	0.33
IV	13	25.70	21.70	7.33	3.66	0.00	0.00	2.22	1.77	-	-	4.40		1.60	0.35	0.30	0.40

Month/ Week	SMW	No. of mango hopper/ panicle (10 cm)/ Inflorescence/ swipe		No. of thrips/ twig		No. of webs/ tree due to leaf webber		Gall midge incidence (0-5 index)		Fruit fly/ trap		No. of trees infested by termite		No. of natural enemies/ twig			
														Spiders		Coccinellids (adult)	
		1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
April I	14	27.50	20.33	7.66	4.33	0.10	0.10	2.44	2.11	55	75	5.40	2.40	0.40	0.35	0.20	0.45
II	15	28.33	18.33	8.33	2.00	0.30	0.10	2.67	2.22	110	150	2.80	1.20	0.35	0.40	0.15	0.25
III	16	23.50	17.50	8.50	2.50	0.40	0.20	2.67	2.50	155	220	0.60	1.00	0.30	0.40	0.10	0.20
IV	17	17.10	15.33	3.30	3.10	0.50	0.33	3.00	2.70	210	250	0.80	1.80	0.30	0.33	0.10	0.20
V	18	15.50	13.40	5.60	3.90	0.60	0.33	3.22	2.85	230	285	0.60	2.80	0.20	0.30	0.10	0.15
May I	19	13.10	11.33	7.90	4.33	0.50	0.50	3.33	3.00	270	300	0.00	3.20	0.15	0.25	0.10	0.15
II	20	10.70	9.77	3.33	5.66	0.66	0.66	3.50	3.22	280	325	0.00	3.60	0.10	0.20	0.10	0.15
III	21	9.70	7.33	6.66	7.33	0.77	0.80	2.67	3.11	315	350	0.40	2.40	0.10	0.15	0.10	0.10
IV	22	8.33	6.50	8.90	7.50	0.70	0.80	1.99	2.44	250	330	0.80	1.60	0.10	0.15	0.10	0.10
June I	23	7.10	5.77	9.33	7.90	0.90	1.03	1.80	2.11	210	270	0.40	0.60	0.10	0.15	0.10	0.15
II	24	6.77	4.33	11.66	4.50	1.10	1.10	1.67	2.00	170	217	0.00	0.20	0.00	0.10	0.10	0.15
III	25	6.33	4.00	5.30	3.70	1.30	1.10	1.67	1.80	166	180	0.00	0.00	0.00	0.10	0.10	0.10
IV	26	5.77	3.77	5.80	1.50	1.33	1.30	1.50	1.67	140	177	0.00	0.00	0.00	0.00	0.00	0.10
July I	27	5.33	2.70	6.33	2.33	1.45	1.33	1.44	1.50	131	150	0.00	0.00	0.00	0.00	0.00	0.00
II	28	4.33	2.33	7.33	3.30	1.60	1.50	1.33	1.22	110	110	0.00	0.00	0.00	0.00	0.00	0.00
III	29	3.33	2.03	3.50	0.30	1.66	1.66	1.11	0.80	95	70	0.00	0.00	0.00	0.00	0.00	0.00
IV	30	3.10	1.77	0.70	0.70	1.80	1.80	0.80	0.67	70	50	0.00	0.00	0.00	0.00	0.00	0.00
V	31	2.50	1.50	0.10	0.50	2.03	1.90	1.11	0.99	60	40	0.00	0.00	0.00	0.00	0.00	0.00
August I	32	1.10	1.33	0.30	1.33	2.25	2.03	1.67	1.22	-	-	0.00	0.00	0.00	0.00	0.00	0.00
II	33	0.70	0.77	0.50	0.70	2.66	2.70	1.99	1.50	-	-	0.00	0.00	0.00	0.00	0.00	0.00
III	34	0.33	0.20	1.10	1.33	2.90	3.03	2.33	1.80	-	-	0.00	0.00	0.00	0.00	0.00	0.00
IV	35	18.70	11.33	0.50	2.50	3.00	3.50	2.44	2.11	-	-	0.00	0.00	0.00	0.00	0.00	0.00
Mean ± SD		8.36 ± 7.68	7.98 ± 6.98	4.56 ±2.86	3.37 ±1.97	2.49 ±2.62	2.32 ±2.24	1.99 ±0.86	1.91 ±0.77	168.17 ±79.36	197.17 ±101.42	0.72 ±1.34	0.55 ±0.92	0.13 ±0.14	0.14 ±0.12	0.10 ±0.10	0.15 ±0.12

Note: SMW = Standard Meteorological Week

Table 2: Weekly meteorological data recorded at Meteorological observatory, Anand Agricultural University, Anand

SMW	Evapotranspiration (mm) [EP]		Bright Sunshine, hr/ day [BSS]		Rainfall (mm) [RF]		Wind Speed (km/ hr) [WS]		Maximum Temperature (^{0}C)[(MaxT]		Minimum Temperature (^{0}C) [MinT]		Morning Relative Humidity (%) [RH_1]		Evening Relative Humidity (%) [RH_2]		Morning Vapour Pressure, (mm of Hg [VP_1]		Evening Vapour Pressure (mm of Hg [VP_2]	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
36	0.8	2.8	7.3	3.1	62.4	245.2	5.2	7.3	33.4	30.9	24.7	24.5	96.3	97	58.9	84	24.3	24.8	21.7	25.0
37	4.8	2.9	8.9	2.5	3.8	47.2	3.8	4.3	35.1	29.9	25.4	26.0	92.7	97	60.9	83	24.3	24.8	24.6	24.8
38	5.4	4.3	6.6	7.9	45.4	36.8	6.0	4.2	34.4	32.8	25.7	26.2	89.7	97	70.7	66	24.3	23.9	25.0	23.8
39	2.2	4.4	1.3	8.3	288.8	0.0	7.2	2.4	29.1	35.1	24.4	26.8	97.0	93	83.6	56	23.9	23.9	24.5	22.2
40	3.2	5.2	6.3	9.2	1.4	0.8	3.2	3.0	32.9	36.9	25.0	24.1	97.9	86	71.0	46	25.1	23.1	24.3	20.5
41	2.0	5.3	5.1	9.4	18.7	0.0	2.4	2.4	31.2	37.3	23.7	21.4	98.4	93	73.6	39	24.1	21.4	23.5	17.5
42	4.7	5.2	8.9	9.6	0.0	0.0	2.1	1.8	36.0	37.0	23.1	19.2	104.4	100	43.9	40	22.1	18.8	17.2	15.9
43	5.4	4.1	10.0	7.4	0.0	0.0	3.0	2.1	35.0	36.0	19.4	18.8	81.6	89	36.3	43	16.4	17.1	14.1	16.9
44	3.6	3.8	8.4	7.2	0.0	0.0	1.4	1.6	34.4	35.9	17.9	19.4	93.9	88	45.3	37	17.3	17.8	16.9	15.6
45	3.3	4.0	7.6	9.2	0.0	0.0	2.1	2.1	33.7	35.0	18.9	17.7	88.1	86	43.0	38	16.9	15.8	15.5	14.9
46	3.9	3.5	8.2	6.5	0.0	3.6	2.7	2.3	30.5	34.4	16.0	22.6	76.9	87	41.3	52	12.4	19.7	13.1	20.1
47	4.0	3.5	9.6	9.1	0.0	0.0	2.2	1.5	31.8	33.5	14.9	16.5	82.7	93	35.6	36	12.2	14.4	12.7	13.3
48	3.7	3.0	9.0	9.0	0.0	0.0	2.5	1.3	32.0	32.6	16.7	15.6	78.7	97	41.9	40	12.8	14.1	14.1	14.0
49	3.3	3.7	8.4	9.2	0.0	0.0	2.0	2.4	31.0	31.2	13.7	14.6	92.1	84	39.6	42	12.6	11.8	12.6	10.7
50	3.2	3.1	9.1	8.3	0.0	0.0	1.7	2.4	30.1	28.6	11.1	12.3	94.6	89	37.7	69	10.8	10.7	11.1	18.4
51	2.9	2.6	8.8	7.7	0.0	0.0	1.9	3.1	28.6	26.3	10.1	10.3	95.1	94	39.6	49	10.4	9.7	10.7	10.1
52	2.6	2.6	3.9	8.0	0.0	0.0	3.1	2.5	23.5	23.8	12.4	8.6	75.6	75	50.9	31	10.1	7.8	12.5	7.6
1	3.0	2.6	5.1	7.5	0.0	0.8	3.6	3.6	26.4	26.3	13.1	12.1	95	96	52	50	12.4	12.4	13.3	13.3
2	3.3	2.9	7.0	9.2	0.0	0.0	3.8	1.4	26.2	29.8	11.1	9.2	91	99	49	36	10.1	10.1	12.3	12.3
3	2.8	2.9	7.9	8.8	7.4	0.0	3.1	3.0	26.3	26.9	11.2	11.9	93	88	54	58	10.8	10.8	11.8	11.8
4	2.2	2.8	5.3	6.1	9.2	1.0	4.0	3.3	24.6	25.7	15.5	12.6	97	93	67	53	14.2	14.2	16.0	16.0
5	3.3	3.2	9.7	9.8	0.0	0.0	1.8	2.6	30.3	28.2	13.2	10.5	94	92	42	39	11.7	11.7	13.4	13.4
6	4.1	3.8	9.8	9.3	0.0	0.0	2.7	3.4	29.6	29.4	12.6	13.4	87	85	42	44	11.5	11.5	11.9	11.9
7	3.8	4.3	8.7	9.9	0.0	0.0	2.9	2.3	27.7	31.8	12.6	12.7	94	90	45	36	11.8	11.8	11.7	11.7
8	4.1	4.5	8.1	9.7	0.0	0.0	3.2	2.3	29.9	35.3	15.1	16.3	90	87	43	36	13.3	13.3	13.3	13.3
9	4.8	4.2	8.4	8.1	0.0	25.4	3.1	3.7	30.4	27.8	13.5	14.0	86	89	33	50	12.3	12.3	10.5	10.5
10	5.6	5.2	9.8	9.7	0.0	0.0	2.8	3.1	33.5	32.2	16.8	16.0	79	82	38	34	13.2	13.2	13.9	13.9
11	6.1	5.6	9.8	9.0	0.0	3.6	3.3	3.7	36.3	32.8	18.6	16.8	82	82	25	42	14.7	14.7	10.7	10.7

12	7.5	7.0	10.1	10.3	0.0	0.0	3.6	2.4	35.6	38.3	16.9	19.0	80	72	29	23	13.8	13.8	11.6	11.6
13	8.1	6.7	10.0	8.3	0.0	0.0	4.1	3.4	37.3	38.7	20.9	21.6	62	77	27	34	13.9	13.9	13.2	13.2

SMW	Evapotranspiration (mm) [EP]		Bright Sunshine, hr/ day [BSS]		Rainfall (mm) [RF]		Wind Speed (km/ hr) [WS]		Maximum Temperature (^{0}C) [(MaxT]		Minimum Temperature (^{0}C) [MinT]		Morning Relative Humidity (%) [RH_1]		Evening Relative Humidity (%) [RH_2]		Morning Vapour Pressure, (mm of Hg [VP_1]		Evening Vapour Pressure (mm of Hg [VP_2]	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
14	8.3	7.4	9.8	8.7	0.0	0.0	3.8	4.4	38.4	36.2	21.1	21.5	70	82	23	43	16.0	16.0	12.9	12.9
15	8.0	5.9	9.9	9.2	0.0	18.8	3.3	4.1	38.1	36.0	19.2	21.8	79	90	31	45	16.7	16.7	13.2	13.2
16	8.1	7.4	9.8	10.2	4.6	0.0	4.3	3.1	38.2	40.1	23.4	23.4	86	74	43	24	21.2	21.2	20.0	20.0
17	9.9	8.0	10.9	10.7	0.0	0.0	3.8	5.0	41.5	39.4	24.3	23.1	66	84	21	30	18.7	18.7	12.1	12.1
18	9.5	8.7	10.5	10.4	0.0	0.0	4.5	5.0	40.3	41.1	24.5	24.9	75	86	36	32	20.4	20.4	16.5	16.5
19	9.9	8.2	10.8	10.6	6.0	0.0	5.3	4.9	40.1	40.6	25.3	26.2	70	68	30	29	19.5	19.5	14.7	14.7
20	10.7	9.7	9.8	11.2	0.0	0.0	6.5	5.5	38.4	42.5	26.2	26.7	73	66	38	27	21.5	21.5	18.5	18.5
21	12.1	9.3	11.1	10.8	0.0	0.0	5.4	8.1	41.7	40.8	26.4	27.8	72	80	30	40	21.6	21.6	16.6	16.6
22	10.0	9.5	10.5	11.0	0.0	0.0	6.5	7.2	41.3	41.1	27.9	28.0	84	81	38	38	26.3	26.3	20.9	20.9
23	10.1	9.4	10.4	8.4	0.0	0.0	7.9	5.6	41.2	40.2	28.7	26.3	82	73	37	38	26.3	26.3	19.9	19.9
24	9.6	6.7	9.4	6.4	4.8	11.6	9.4	7.0	37.2	36.5	28.0	25.9	85	84	51	59	26.3	26.3	22.2	22.2
25	9.3	5.6	8.6	6.6	0.0	27.4	10.8	6.9	37.5	36.1	28.4	25.3	82	83	48	63	25.6	25.6	22.1	22.1
26	9.7	5.8	9.5	5.9	0.0	53.0	10.1	8.6	38.5	33.8	27.7	25.2	77	88	42	55	23.8	23.8	19.8	19.8
27	10.5	6.9	8.7	6.6	0.0	0.0	9.1	10.7	38.5	35.7	28.3	26.2	76	82	45	54	23.6	23.6	20.9	20.9
28	7.3	6.7	6.5	4.7	41.0	0.0	7.4	8.8	37.2	35.7	27.6	26.3	84	78	55	50	25.2	25.2	23.3	23.3
29	3.3	4.7	2.5	2.9	150.4	1.1	4.5	7.1	33.2	34.3	25.3	25.9	95	86	75	66	25.8	25.8	25.6	25.6
30	2.4	1.9	1.6	0.6	217.8	296.2	7.0	8.4	30.5	29.6	25.3	23.6	98	95	90	88	25.1	25.1	25.7	25.7
31	2.3	3.8	2.2	3.2	81.6	12.8	6.4	8.0	31.0	31.9	25.2	24.2	99	92	84	72	25.9	25.9	26.0	26.0
32	3.2	4.4	4.6	4.6	61.8	0.0	5.5	5.8	31.6	33.6	25.1	25.1	95	88	79	63	24.5	24.5	25.2	25.2
33	4.1	3.1	5.2	3.4	10.6	8.4	6.3	4.7	33.1	32.2	24.7	24.6	94	92	73	71	24.5	24.5	25.0	25.0
34	4.3	5.0	5.9	7.0	8.6	0.0	3.5	6.7	34.4	33.8	25.7	24.3	91	89	65	59	25.3	25.3	24.6	24.6
35	3.2	4.7	4.3	6.8	61.0	0.0	4.0	5.2	33.0	34.2	24.0	24.4	97	91	72	61	24.9	24.9	25.8	25.8

Note: SMW = Standard Meteorological Week

Table 3: Correlation coefficient (r) between insect pests infesting mango and weather parameters (1st year)

Weather parameters	Mango hopper	Thrips	Leaf webber	Gall midge	Fruit fly$	Termite#	Spiders	Coccinellids
Evapotranspiration (mm) [EP]	0.443**	0.585**	-0.454**	0.294*	-0.750**	0.038	0.216	0.203
Bright Sunshine, hr/ day [BSS]	0.398**	0.588**	-0.133	0.275*	0.680**	0.250	0.368**	0.359**
Rainfall (mm) [RF]	-0.112	-0.445**	-0.25	-0.146	-0.519*	-0.399	-0.161	-0.175
Wind Speed (km/ hr) [WS]	0.006	0.149	-0.406**	-0.139	-0.028	-0.326	-0.264	-0.164
Maximum Temperature (^{0}C) [MaxT]	0.467**	0.315*	-0.289*	0.494**	0.736**	0.153	0.157	0.130
Minimum Temperature (^{0}C) [MinT]	0.138	-0.123	-0.271	0.315*	0.308	-0.106	-0.198	-0.157
Morning Relative Humidity (%) [RH_1]	-0.469**	-0.580**	0.277*	-0.302*	-0.562*	-0.300*	-0.353*	-0.295*
Evening Relative Humidity (%) [RH_2]	-0.430**	-0.671**	0.094	-0.232	-0.565*	-0.564**	-0.459**	-0.381**
Morning Vapour Pressure (mm of Hg) [VP_1]	-0.100	-0.285*	-0.186	0.205	-0.082	-0.248	-0.324*	-0.267
Evening Vapour Pressure (mm of Hg) [VP_2]	-0.179	-0.480**	-0.063	0.055	-0.391	-0.451*	-0.435**	-0.337*
Note: * Correlation is significant at 0.05 level; ** Correlation is significant at 0.01 level; $: n = 18 (r at 16 e.d.f. = 0.468 and 0.590 at 5 and 1 per cent, respectively); #: n = 28; (r at 26 e.d.f = 0.374 and 0.478 at 5 and 1 per cent, respectively); remaining characters n = 52 (r at 50 e.d.f. = 0.273 and 0.372 at 5 and 1 per cent, respectively.								

Table 4: Correlation coefficient (r) between insect pests infesting mango and weather parameters (2nd year)

Weather parameters	Mango hopper	Thrips	Leaf webber	Gall midge	Fruit fly$	Termite#	Spiders	Coccinellids
Evapotranspiration (mm) [EP]	0.368**	0.314*	-0.499**	0.421**	-0.864**	0.729**	0.465**	0.258
Bright Sunshine, hr/ day [BSS]	0.325*	0.600**	-0.140	0.453**	0.839**	0.639**	0.550**	0.465**
Rainfall (mm) [RF]	0.043	-0.384**	0.000	-0.277*	-0.400	-0.186	-0.131	-0.153
Wind Speed (km/ hr) [WS]	-0.136	-0.193	-0.366**	-0.220	-0.282	0.487*	-0.276*	-0.161
Maximum Temperature (^{0}C) [MaxT]	0.316*	0.079	-0.255	0.614**	0.906**	0.733**	0.392**	0.156
Minimum Temperature (^{0}C) [MinT]	0.121	-0.358**	-0.183	0.301*	0.546*	0.689**	-0.004	-0.172
Morning Relative Humidity (%) [RH_1]	-0.275*	-0.403**	0.411**	-0.222	-0.629**	-0.542**	-0.390**	-0.245
Evening Relative Humidity (%) [RH_2]	-0.289*	-0.546**	0.227	-0.434**	-0.752**	-0.471*	-0.550**	-0.457**
Morning Vapour Pressure (mm of Hg) [VP_1]	-0.093	-0.445**	-0.096	0.135	-0.130	0.461*	-0.237	-0.362**
Evening Vapour Pressure (mm of Hg) [VP_2]	-0.231	0.540**	0.086	-0.065	-0.460	0.285	-0.449**	-0.496**
Note: * Correlation is significant at 0.05 level; ** Correlation is significant at 0.01 level; $: n = 17 (r at 15 e.d.f. = 0.482 and 0.606 at 5 and 1 per cent, respectively); #: n = 26; (r at 24 e.d.f. = 0.388 and 0.496 at 5 and 1 per cent, respectively); remaining characters n = 52 (r at 50 e.d.f. = 0.273 and 0.372 at 5 and 1 per cent, respectively.								

The activity of thrips on mango was found more or less throughout the year (Bhut *et al*., 2017) [3]. The highest thrips population density during 15th SMW in 2013 while in 2014, it was from 17th to 20th SMW and thrips population was found significantly negatively correlated with minimum temperature, minimum relative humidity and maximum relative humidity (Gundappa *et al*., 2016) [6]. The present findings are in close conformity with earlier reports.

Leaf webber

The results presented in Table 1 revealed that leaf webber incidence was noticed from 1st week of September (36th SMW) during first year with its peak activity on 1st week of December (49th SMW) (9.33 webs/ tree). The pest showed highly significant negative association with EP (r = -0.454**) and WS (-0.406**). MaxT (r = -0.289*) had significant negative association with the pest (Table 3). The results presented in Table 1 revealed that during second year, the population was gradually increased from 1st week of September (36th SMW) up to 2nd week of December (50th SMW) and reached on peak (8.66 webs/ tree). There was highly significant negative association between leaf webber incidence and EP and WS (r = -0.499** and -0.366**, respectively) whereas highly significant positive association with RH_1 (r = 0.411**) [Table 4].

The activity of mango leaf webber during June-December (Bana *et al*., 2018) [2]. The leaf webber infestation began from April and continued up to December (Chowdhury, 2015) [5]. August to December is the most active period for mango leaf webber, *O. exvinacea* and also found that maximum and minimum temperature as well as rainfall had negative association whereas morning relative humidity had positive association with the pest (Kasar *et al*., 2017) [8]. Thus, the results of present investigation followed more or less similar trend with the earlier reports.

Gall midge

The results presented in Table 1 revealed that during first year, 2014, gall midge incidence was gradually increased from 1st week of September (36th SMW) and attained its first peak (3.89) during 1st week of November (45th SMW) and second peak (3.50) during 2nd week of May (20th SMW). Gall midge showed highly significant positive association with MaxT (r = 0.494**). EP, BSS and MinT had significant positive association with gall midge incidence whereas RH_1 had significant negative association. The results presented in Table 1 revealed that during second year, first and second peak were noticed on 2nd week of November (46th SMW) (3.44) and 2nd week of May (20th SMW) (3.22), respectively. Highly significant positive association was observed between EP, BSS as well as MaxT and gall midge incidence (r = 0.421**, 0.453** and 0.614**, respectively) whereas highly significant negative association with RH_2 (r = -0.434**) [Table 4].

Two peaks of gall midge population were observed every year first in March/April and second in September/October (Rehman *et al*., 2013) [12]. The infestation of *P. matteiana* throughout the year (Bana *et al*., 2018) [2]. Highly significant positive correlation of sunshine hours with infestation of mango gall midge (Kumar and Patel, 2012) [9]. More or less the results of the present investigations are in close conformity with earlier reports.

Fruit fly

The results presented in Table 1 revealed that the activity of fruit fly is concerned in terms of number of fly catches per trap, the activity commenced from 1st week of April (14th SMW) and reached on peak (315 fruit flies/ trap) during 3rd week of May (21st SMW) during first year. The population of fruit fly coincided with fruiting and harvesting stages of the crop. It showed highly significant positive association with BSS and MaxT (r = 0.680** and 0.736**, respectively) whereas highly significant negative association with EP (r = -0.750**) [Table 3]. The results presented in Table 1 revealed that the number of fruit flies/ trap during second year ranged from 40 to 350 per trap with its peak on 3rd week of May (21st SMW) (350 fruit flies/ trap).

Maximum catches of fruit fly were observed during April-July using methyl eugenol impregnated fruit fly trap which coincided with fruiting and harvesting stages of the crop (Bana *et al*., 2018) [2]. The emergence of fruit fly started from April onwards and maximum population was recorded during May-July, which coincides with fruit maturity (Chowdhury, 2015) [5]. Trap catches of *B. dorsalis* exhibited negative relationship with relative humidity and rainfall whereas significant positive relationship with minimum temperature (Verghese *et al.*, 2006) [20]. Correlation between incidence and temperature (maximum and minimum) was significant and positive while it was negative with rainfall and relative humidity (Kannan and Rao, 2006) [7]. The findings of present investigations are in close conformity with earlier reports.

Termite

The results presented in Table 1 revealed that the number of trees infested due to termite was exhibited to the tune of 0.20 to 5.40 with peak incidence on 1st week of April (14th SMW) (5.40 infested trees) during first year. Whereas, it was in range of 0.20 to 3.60 with first (2.40 infested trees) and second peak (3.60 infested trees) on 1st week of April (14th SMW) and 2nd week of May (20th SMW), respectively during second year. Termite showed highly significant positive association with EP, BSS, MaxT and MinT (r = 0.729**, 0.639**, 0.733** and 0.689**, respectively) whereas highly significant negative association with RH_1 (r = -0.542**) [Table 4].

Termite damage was not found from August to December and again, its activity commenced from first week of January at lower level, gradually increased in subsequent months and reached to a peak during June (Rathod, 2011) [11].

Natural enemies

The results presented in Table 1 revealed that the population of spiders observed on the crop from 1st week of September (36th SMW) which ranged from 0.10 to 0.45 spider/ twig with highest activity during 2nd week of March (11th SMW) during first year whereas it was ranged from 0.10 to 0.40 spider per twig during second year with the highest activity observed on 2nd and 3rd week of April (15th - 16th SMW) (Table 1). EP, BSS and MaxT had highly significant positive association with spider population whereas RH_1, RH_2 and VP_2 had highly significant negative association (Table 4).

The peak activity of spiders during March-April (Purohit and Sushil Kumar, 2008) [10]. The highest population of spiders during14th SMW (Sushil Kumar, 2006) [17]. The findings of the present investigations are in close agreement with the earlier reports.

The results presented in Table 1 revealed that the adults of coccinellids appeared on the crop during 2nd week of September (37th SMW) with the tune of 0.10 to 0.40 beetle

per twig and 0.10 to 0.45 beetle per twig during first and second year, respectively. The higher activity of this natural enemy was recorded during 42nd week of March (11th SMW) during first year. In the next year, its first peak (0.45 beetle/ twig) and second peak (0.45 beetle/ twig) were observed on 1st week of March (10th SMW) and 1st week of April (14th SMW), respectively (Table 1). Coccinellids showed significant positive association with BSS whereas highly significant negative association with RH_2, VP_1 and VP_2 (Table 4).

The highest population of coccinellids during 15th SMW (Sushil Kumar, 2006) [17]. The peak period of coccinellids activity (second fortnight of February and first fortnight of March) generally coincided with the peak abundance of their prey (hopers and thrips) in mango and RF and RH had negative association with the population of coccinellids (Chaudhary *et al*., 2014) [4] . Thus, results of the present investigations are more or less in close conformity with earlier reports.

Conclusion

In nutshell, hopper population showed two peaks with highly significant positive association between EP, BSS and MaxT whereas highly significant negative association between RH_1 and RH_2. Thrips showed three-four peaks during course of investigations and showed highly significant positive association between EP and BSS whereas highly significant negative association between RF, RH_1, RH_2 and VP_2. Comparatively higher incidence due to leaf webber was noticed during first year than second year and showed negative association with EP, BSS, RF, WS, MaxT, MinT and VP_1 while positive association with RH_1, RH_2 and VP_2 showed positive effect on the pest activity. The higher incidence of *P. matteiana* was observed during 1st week of November and 2nd week of May during first year, while it was during 2nd week of November and 2nd week of May during second year. Gall midge showed highly significant positive association with MaxT during first year, whereas highly significant negative association with RH_2 during second year. The activity of fruit fly commenced from 1st week of April and reached its peak on 3rd week of May during first year while its peak activity was noticed on 3rd week of May during second year and BSS and MaxT showed significant positive impact on the fluctuation of the fruit fly population whereas EP, RH_1 and RH_2 showed highly significant negative association during both the years. Comparatively higher mean incidence of termite was noticed during first year than the second year. It showed highly significant positive association with EP, BSS, MaxT and MinT whereas highly significant negative association with RH_1. The higher activity of natural enemies *viz*., spiders and coccinellids (adults) was recorded from February to April in mango ecosystem.

All these information, may be useful to develop region specific crop simulation dynamics models to predict and forecast the insect pests population so that farmers can adopt control measures well in advance to save the fruit crop being lost.

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