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IMPACT OF CLIMATE VARIABILITY AND CROP PHENOLOGY ON ABUNDANCE OF MANGO HOPPER

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ABSTRACT

Impact of climate and crop phenology on abundance of mango hopper was studied in mango cv. Alphonso under field conditions from 1997 to 2007 at Agriculture Experimental Station, Navsari Agricultural University, Paria, Gujarat. Overall average hopper population (irrespective of crop stages) was 1.31/twig or panicle. During peak activity year (2005-2006), highest hopper population was 5.74 (peak 29.70 at 8th Standard week)/twig or panicle when maximum, minimum and average temperatures were 31.19, 18.73 and 24.96 °C, respectively. Relative humidities during the same year were 89.16 (morning), 59.55 (evening) and 74.35 (average) per cent, respectively. Rainfall, rainfall days, sun shine and wind velocity were 60.99 mm, 1.60, 7.55 hours and 3.72 km/hours, respectively. During this period, hopper population exhibited significant positive correlation with maximum temperature ('r' = 0.3864) and sun shine ('r' = 0.4351). While, hopper population indicated significant negative correlation with minimum and average temperature ('r' = - 0.4652 and – 0.3031), evening and average relative humidity ('r' = -0.5102 and -0.4737) and rainfall days ('r' = -0.4181). Total contribution of all the abiotic factors on fluctuation of hopper population during 2005-2006 was 35.71 per cent (R= 0.6673 significant at 1 % level). Hopper population during the peak activity year peaked on pea cum marble stage of the crop (25.99/panicle) followed by 13.76 hoppers at stone sized fruit stage of the crop. So, it may be concluded that most critical weather condition for peak abundance of hopper population during peak activity year was 33.74 (maximum), 12.14 (minimum) and 22.94 °C (average) temperature, 41.42 (evening) and 65.21 per cent (average) relative humidity and 9.80 hours of sun shine. Slight increase in temperature (minimum and average) (0.06 and 0.29 °C), relative humidity (1.32-3.20 %) and rainfall (17.09 mm) and slight decrease in rainfall days (0.06), sunshine (0.12 hours/day) and wind velocity (0.50 kms/hour) are conducive for sharp rise in hopper population.

Key words: Crop stage, hopper, weather

INTRODUCTION

Mango (*Mangifera indica L.*) is one of the most important fruit crops of the tropics and sub-tropics. In India, it is cultivated in 23.12 lakh hectares with annual production of 150.25 lakh metric tonnes. In Gujarat, it is cultivated in 1.25 lakh hectares with 8.56 lakh tonnes of fruit production. Mango cultivation is principally distributed in South Gujarat as well as in pockets of Junagadh; however, in recent years, its area and distribution has spread to as far as Kutch in North Gujarat and Dahod in Eastern part of the state. The popular varieties grown in Gujarat are Alphonso, Kesar, Rajapuri and Banarasi Langra. Though, there has been a tremendous increase in area and distribution of mango at the national level and in the state of Gujarat too, the level of productivity has not reached the expected level of 10 t/ha. There are many reasons attributed and one of the main reasons is incidence of major pests and diseases. Among major insect-pests, the abundance of sucking pests *viz;* mango hopper in South Gujarat, in particular, is a threat to the mango industry. In addition to direct damage, hoppers excrete honey dew on the infested plant parts which encourages growth of the fungal pathogen like *Capnodium* species which forms sooty mould on the infested area (Srivastava, 1998). The hopper complex (*Amritodus atkinsoni, Idioscopus clypealis, I. nitidulus* and *Amrasca splendens*) remain in the mango ecosystem of South Gujarat almost throughout the year and damage every crop stage (from emergence of new flush to fruiting stage). Significant impact of major abiotic factors and appropriate crop stages on their dominance as well as continuation of their respective life cycles inflict severe damages resulting into enormous crop losses. Due to these reasons, a study was planned to establish relationship between major abiotic factors and abundance of hopper on mango and to workout relationship between appropriate crop stages and pest abundance.

MATERIALS AND METHODS

Seasonal abundance of mango hopper was studied in relation to weather factors and crop stages or crop phenology in mango cv. Alphonso under field conditions

from July 1997 to June 2007 at Agriculture Experimental Station, Gujarat Agricultural University (part of which is now known as Navsari Agricultural University), Paria, Valsad, Gujarat.

For recording hopper population, ten trees of mango cv. Alphonso were selected randomly in 1 hectare plot in "W" design representing every part of the orchard. The trees were kept unsprayed during the period of investigation (1997-2007). Hopper population was recorded at standard week wise interval from 27th standard week of 1997 to 26th standard week of 2007. Ten twigs from lower canopy of each tree were selected for recording hopper population during vegetative, emergence of new flush, new twigs, fruiting, initiation of ripening, ripening cum harvest and harvest stages of the crop. Similarly, hoppers were also recorded on ten panicles per tree during bud/bud burst stage, initiation of flowering, peak flowering, pea/marble and stone sized fruit stages of the crop. Hoppers were counted on each randomly selected twig or panicle by visual count method without disturbing the plant part. Weather parameters *viz;* temperature (maximum, minimum and average), relative humidity (morning, evening and average), rainfall, rainfall days, sun shine and wind velocity of the preceding week (26th standard week of 1997 to 25th standard week of 2007) was observed at standard week wise interval. Relationship of abundance of hopper in relation to major weather factors was studied using correlation and regression method. Similar studies were also carried out on abundance of hopper in relation to crop stages.

RESULTS AND DISCUSSION

Impact of major abiotic factors as well as appropriate crop stages on abundance of hopper complex has been studied during ten years spread over 1997-2007 i.e. July 1997-June 2007. The whole period was divided into three distinct crop stage regions *viz*; vegetative which on an average spread over 21 standard weeks (27-47) followed by bud burst cum flowering cum fruit set spread over 23 standard weeks (48-18) and fruiting cum harvest stage spread over 8 standard weeks (19-26).

(I) Seasonal abundance of mango hopper (Ten years impact)

(a) Seasonal abundance. Hopper population was monitored from 27 standard week of 1997 to 26 SW of 2007 at standard week wise interval wherein it varied from 0.18 hoppers during 1999-2000 and 2001-2002 to 5.74 hoppers per twig or panicle during 2005-2006. The year 2005-2006 was considered as highest activity period of the pest during the experimental period (1997-2007). Overall, the average hopper population was 1.31 per twig or panicle wherein it peaked (5.00 hoppers/panicle) on 9th SW (26 February – 4 March) followed by another period of higher activity (4.88) on 8th standard week (Table 1).

(b) Impact of weather factors. Average hopper population (1.31/twig or panicle) was noticed during ten years of experimental period wherein it peaked (5/panicle) at 9th standard week. The average population was noticed when the weather witnessed temperatures (maximum, minimum and average) of 32.04, 18.67 and 24.67 °C, relative humidity (morning, evening and average) of 87.84, 57.89 and 71.15 per cent, rainfall of 43.90 mm, rainy days of 1.66, sunshine of 7.67 hours and wind velocity of 4.07 kms/hr (Table 3). The overall average hopper population indicated significant positive correlation with sunshine ('r' = 0.2167) and significant negative correlation with temperature (minimum and average) ('r' = -0.3018 and -0.2664), relative humidity (evening and average) ('r' = -0.2672 and – 0.1679), rainfall ('r' = -0.1488), rainfall days ('r' = -0.2449) and wind velocity ('r' = -0.1133) (Table 4). The total contribution of all the abiotic factors was 11.18 per cent (Table 5).

Regression equation of overall hopper population was:

$$\hat{Y} = 3.3642 - 0.0361\ (X_2) - 0.1534\ (X_3) - 0.0349\ (X_5) + 0.0605\ (X_6) + 0.0008\ (X_7) - 0.1246\ (X_8) + 0.0654\ (X_9) - 0.0162\ (X_{10})$$

Where,

Y = Hoppers/twig or panicle

X_2 = Minimum temperature

X_3 = Average temperature

X_5 = Evening Relative humidity

X_6 = Average temperature

X_7 = Rainfall

X_8 = Rainfall days

X_9 = Sun shine

X_{10} = Wind velocity

During ten years of experimental period, the highest hopper population was noticed during 2005-2006 which was thus considered as period or year of highest activity.

(II) Seasonal abundance of mango hopper (Peak activity year)

(a) Seasonal abundance. Hopper population varied from 0 to 29.70 hoppers per panicle (average 5.74/panicle) during peak year of activity. The highest hoppers (29.70/panicle) were noticed on 8th standard week followed by 29.00 and 26.11 during 9th and 10th standard weeks, respectively (Table 2).

(b) Impact of weather factors. Overall hopper population during peak year of activity (2005-2006) was noticed when weather variables indicated temperature (maximum, minimum and average) of 31.19, 18.73 and 24.96 °C, relative humidity (morning, evening and average) of 89.16, 59.55 and 74.35 per cent, rainfall of

Table 1. Overall abundance of mango hopper (1997-2007)

Standard week	Standard Period	Av. No. of Hopper / twig or Panicle*										Mean
		1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	
27	July 2-8	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
28	9-15	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
29	16-22	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
30	23-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	30-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	Aug 6-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	13-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	20-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	27-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	Sept 3-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	10-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	17-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	24-30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	Oct 1-7	0.00	0.00	0.00	0.00	0.00	0.00	2.26	0.96	0.00	0.00	0.32
41	8-14	0.00	0.00	0.00	0.00	0.00	0.00	2.31	1.03	1.04	0.78	0.52
42	15-21	0.00	0.00	0.00	0.00	0.00	0.00	1.94	1.94	1.19	1.27	0.63
43	22-28	0.00	0.00	0.00	0.00	0.00	0.27	1.68	2.30	1.34	1.34	0.69
44	29-4	0.22	2.98	0.19	0.00	0.45	0.00	1.14	2.44	0.00	1.79	0.92
45	Nov 5-11	0.24	4.24	1.14	0.02	0.00	5.41	2.71	2.91	0.96	1.63	1.93
46	12-18	0.28	2.70	1.43	0.00	0.00	3.75	2.99	2.14	0.00	2.23	1.55
47	19-25	0.44	3.26	2.07	0.00	0.00	5.03	3.10	2.03	1.12	2.71	1.98
48*	26-2	0.97	2.40	0.00	0.00	0.00	1.80	3.50	2.74	1.41	2.97	1.58
49*	Dec. 3-9	1.08	1.82	0.90	0.02	0.04	0.00	2.98	0.00	2.60	3.03	1.25
50*	10-16	1.30	3.16	1.10	0.12	0.30	0.00	1.74	0.00	3.29	4.00	1.50
51*	17-23	2.09	0.02	0.00	0.17	0.00	0.00	0.62	0.00	4.16	4.47	1.15
52*	24-31	2.90	0.25	0.04	0.11	0.00	0.00	0.40	0.00	5.96	4.33	1.40
01*	Jan 1-7	3.71	1.84	0.08	0.79	0.40	0.15	1.27	0.00	5.99	4.92	1.92
02*	8-14	3.67	1.44	0.15	0.86	0.50	0.63	9.22	0.01	6.01	5.13	2.76
03*	15-21	2.46	2.56	0.09	0.33	0.09	0.26	4.50	1.79	6.47	5.57	2.41
04*	22-28	2.05	1.87	0.14	0.56	0.22	0.19	5.60	2.41	7.17	6.02	2.62
05*	29-4	4.71	0.10	0.08	0.23	0.30	1.23	5.90	3.04	8.17	7.27	3.10
06*	Feb 5-11	4.93	0.24	0.08	0.27	0.12	1.34	4.80	3.41	8.07	9.47	3.27
07*	12-18	2.83	2.01	0.12	1.46	1.55	0.95	9.22	0.28	19.17	9.38	4.70
08*	19-25	2.20	1.99	0.16	0.36	1.28	0.51	4.50	0.01	29.70	8.07	4.88
09*	26-4	1.71	2.54	0.12	1.27	0.26	1.17	6.58	0.03	29.00	7.33	5.00
10*	Mar 5-11	0.69	0.64	0.11	1.16	2.35	0.19	5.50	0.23	26.11	5.41	4.24
11*	12-18	0.98	0.73	0.14	0.28	0.07	0.11	4.10	0.00	23.17	3.03	3.26
12*	19-25	0.44	0.64	0.19	0.00	0.14	0.06	2.70	0.50	19.16	2.13	2.60
13*	26-1	0.49	0.78	0.20	0.00	0.34	0.00	1.90	0.00	18.13	2.17	2.40
14*	Apr 2-8	0.32	0.02	0.36	0.00	0.00	0.15	0.71	0.05	11.10	2.05	1.48
15*	9-15	0.00	0.02	0.04	0.00	0.14	0.11	0.56	0.56	10.17	1.71	1.33
16*	16-22	0.00	0.00	0.30	1.20	0.08	0.00	0.09	0.41	10.94	1.31	1.43
17*	23-29	0.00	0.00	0.11	3.57	0.11	0.00	0.06	0.09	9.17	1.08	1.42
18*	30-6	0.00	0.00	0.14	3.81	0.02	0.00	0.03	0.03	8.30	0.98	1.33
19	May 7-13	0.00	0.00	0.00	1.88	0.00	0.00	0.03	0.03	4.17	0.64	0.68
20	14-20	0.00	0.00	0.00	1.14	0.33	0.00	0.00	0.00	3.99	0.57	0.60

Standard week	Standard Period	Av. No. of Hopper / twig or Panicle*										Mean
		1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	
21	21-27	0.00	0.00	0.00	0.58	0.38	0.00	0.00	0.00	4.13	0.49	0.56
22	28-3	0.00	0.00	0.00	0.64	0.00	0.00	0.00	0.00	2.67	0.22	0.35
23	June 4-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.67	0.00	0.17
24	11-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.00	0.13
25	18-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.96	0.00	0.10
26	Jun 25- Jul 01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.07
	Average	0.78	0.74	0.18	0.40	0.18	0.45	1.82	0.60	5.74	2.22	1.31

*** Observations on 10 panicles on 10 trees**

Y_1: Av. No. of Hopper / twig or Panicle **(Dependent variable)**

X_1: Maximum Temperature (°C)
X_2: Minimum Temperature (°C)
X_3: Average Temperature (°C)
X_4: Morning Relative Humidity (%)
X_5: Evening Relative Humidity (%)
Independent variables

X_6: Average Relative Humidity (%)
X_7: Rainfall (mm)
X_8: Rain Day
X_9: Sunshine Hour
X_{10}: Wind Velocity (km / hr)
Independent variables

Table 2. Abundance of mango hopper during peak year of activity in relation to major weather factors (2005-06)

Standard week	Standard Period	Dependent variable	Independent variables									
		Y_1	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
27	July 2-8	0.00	27.50	23.51	25.51	97.71	92.71	95.21	1137.00	7.00	5.81	7.78
28	9-15	0.00	28.05	25.11	26.58	92.85	89.57	91.21	346.40	6.00	3.33	6.15
29	16-22	0.00	29.88	26.00	27.94	94.42	81.14	87.78	11.20	3.00	3.31	4.36
30	23-29	0.00	30.71	25.00	27.86	94.28	80.00	87.14	88.30	6.00	4.62	1.68
31	30-5	0.00	29.34	25.68	27.51	93.50	83.71	88.61	44.00	5.00	2.65	5.26
32	Aug 6-12	0.00	26.91	23.74	25.33	97.71	94.71	96.21	324.00	7.00	0.48	3.49
33	13-19	0.00	28.14	24.77	26.46	95.00	89.00	92.00	77.00	7.00	1.80	8.81
34	20-26	0.00	28.85	24.62	26.74	96.14	85.00	90.57	47.00	7.00	4.35	4.32
35	27-2	0.00	27.85	23.43	25.64	97.00	88.00	92.50	163.00	7.00	3.75	3.20
36	Sept 3-9	0.00	28.11	23.31	25.71	94.71	79.00	86.86	9.00	2.00	5.28	1.40
37	10-16	0.00	30.83	24.26	27.55	94.00	82.00	88.00	125.00	4.00	3.12	1.40
38	17-23	0.00	28.48	24.20	26.34	97.00	85.71	91.36	197.50	7.00	3.17	3.94
39	24-30	0.00	27.91	21.01	24.46	96.14	90.42	93.28	434.00	7.00	0.51	12.48
40	Oct 1-7	0.00	28.77	22.71	25.74	94.85	79.57	87.21	1.00	1.00	2.07	3.30
41	8-14	1.04	30.26	22.46	26.36	92.57	76.00	84.29	1.00	1.00	7.31	1.39
42	15-21	1.19	34.17	19.08	26.63	85.00	64.57	74.79	0.00	0.00	10.00	1.41
43	22-28	1.34	32.97	21.77	27.37	90.85	63.42	77.14	0.00	0.00	9.40	2.17
44	29-4	0.00	33.37	17.14	25.26	78.00	53.28	65.64	0.00	0.00	9.44	1.79
45	Nov 5-11	0.96	32.63	15.82	24.23	89.00	57.85	73.43	0.00	0.00	9.50	1.65
46	12-18	0.00	32.34	12.05	22.20	86.00	35.28	60.64	0.00	0.00	9.80	1.79
47	19-25	1.12	32.25	12.08	22.17	91.71	33.14	62.43	0.00	0.00	9.60	1.72
48*	26-2	1.41	33.02	12.25	22.64	82.42	35.71	59.07	0.00	0.00	9.80	1.79
49*	Dec. 3-9	2.60	31.60	15.00	23.30	82.28	42.57	62.43	0.00	0.00	6.40	1.80
50*	10-16	3.29	31.82	14.14	22.98	87.57	45.28	66.43	0.00	0.00	9.20	2.28
51*	17-23	4.16	30.91	10.45	20.68	85.42	41.26	63.34	0.00	0.00	9.10	1.88
52*	24-31	5.96	28.82	7.68	18.25	90.57	39.42	65.00	0.00	0.00	8.70	2.07
1*	Jan 1-7	5.99	29.31	9.22	19.27	90.12	41.50	65.81	0.00	0.00	8.80	2.63

Standard week	Standard Period	Dependent variable	Independent variables									
		Y_1	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
2*	8-14	6.01	28.97	11.14	20.06	92.85	45.00	68.93	0.00	0.00	7.92	2.30
3*	15-21	6.47	31.61	11.30	21.46	91.14	41.85	66.50	0.00	0.00	9.50	1.94
4*	22-28	7.17	31.63	12.85	22.24	89.00	43.80	66.40	0.00	0.00	9.50	2.50
5*	29-4	8.17	28.80	8.40	18.60	88.28	36.71	62.50	0.00	0.00	9.78	3.17
6*	Feb 5-11	8.07	33.97	11.05	22.51	90.00	40.85	65.43	0.00	0.00	9.60	1.92
7*	12-18	19.17	33.40	10.48	21.94	91.71	41.42	66.57	0.00	0.00	9.65	2.39
8*	19-25	29.70	33.74	12.14	22.94	89.00	41.42	65.21	0.00	0.00	9.80	2.26
9*	26-4	29.00	34.20	14.72	24.46	91.42	48.85	70.14	0.00	0.00	9.50	2.43
10*	Mar 5-11	26.11	33.45	15.31	24.38	86.57	43.57	65.07	0.00	0.00	9.00	3.13
11*	12-18	23.17	29.42	14.94	22.18	89.00	58.14	73.57	3.00	1.00	8.08	2.64
12*	19-25	19.16	30.08	16.20	23.14	89.20	48.42	68.81	0.00	0.00	9.02	2.65
13*	26-1	18.13	34.42	16.70	25.56	85.85	40.57	63.21	0.00	0.00	9.70	2.95
14*	Apr 2-8	11.10	34.45	15.08	24.77	76.00	31.80	53.90	0.00	0.00	9.78	3.48
15*	9-15	10.17	34.22	18.40	26.31	84.71	42.57	63.64	0.00	0.00	9.92	3.67
16*	16-22	10.94	32.97	19.48	26.23	87.42	46.42	66.92	0.00	0.00	9.50	3.32
17*	23-29	9.17	34.00	20.88	27.44	84.85	54.28	69.57	0.00	0.00	10.20	3.70
18*	30-6	8.30	32.45	22.48	27.47	84.00	60.14	72.07	0.00	0.00	10.50	3.70
19	May 7-13	4.17	33.65	23.02	28.34	85.00	60.85	72.93	0.00	0.00	10.84	5.60
20	14-20	3.99	34.23	23.62	28.93	85.28	51.71	68.50	0.00	0.00	10.70	6.98
21	21-27	4.13	33.48	25.28	29.38	80.00	61.14	70.57	0.00	0.00	10.27	5.99
22	28-3	2.67	24.57	22.65	23.61	79.71	64.00	71.86	0.00	0.00	10.34	9.37
23	June 4-10	1.67	32.20	25.20	28.70	87.00	68.71	77.86	160.00	3.00	4.40	7.73
24	11-17	1.30	31.28	25.97	28.63	89.00	67.00	78.00	0.00	0.00	9.62	7.05
25	18-24	0.96	32.45	24.68	28.57	83.42	63.85	73.64	0.00	0.00	9.94	6.34
26	Jun 25- Jul 01	0.67	33.48	25.74	29.61	88.85	63.85	76.35	3.00	2.00	4.42	4.31
	Average	5.74	31.19	18.73	24.96	89.16	59.55	74.35	60.99	1.60	7.55	3.72

Table 3. Overall abundance of mango hopper during in relation to major weather factors (1997-2007)

Standard week	Standard Period	Dependent variable	Independent variables									
		Y_1	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
27	July 2-8	0.01	30.31	24.76	27.25	91.90	80.87	83.92	295.80	5.40	5.01	6.92
28	9-15	0.01	29.70	24.62	26.93	92.25	83.81	85.16	239.20	5.40	3.07	6.16
29	16-22	0.01	29.42	24.87	26.90	92.00	82.80	84.07	152.10	5.50	3.14	9.20
30	23-29	0.00	30.13	24.69	27.18	92.83	81.33	84.16	149.80	6.00	3.01	6.99
31	30-5	0.00	29.53	24.40	26.71	93.16	83.67	85.73	144.10	6.00	3.07	7.24
32	Aug 6-12	0.00	29.14	24.23	26.40	94.14	86.27	87.50	174.20	5.50	2.30	7.13
33	13-19	0.00	28.42	24.11	26.08	94.96	88.34	88.70	252.00	6.80	1.83	6.71
34	20-26	0.00	28.83	24.13	26.25	93.71	83.41	85.71	100.60	5.80	3.71	6.65
35	27-2	0.00	29.40	23.72	26.27	94.51	82.27	85.45	123.90	6.10	3.49	4.91
36	Sept 3-9	0.00	29.50	23.75	26.36	92.81	81.22	83.99	69.80	4.30	4.53	4.87
37	10-16	0.00	29.80	23.25	26.22	93.95	78.84	83.36	47.90	4.00	4.72	2.83
38	17-23	0.00	29.55	23.04	25.89	93.63	80.31	84.18	52.20	3.70	4.87	3.36
39	24-30	0.00	30.11	22.77	26.07	93.29	78.51	83.43	98.10	3.40	4.66	3.49
40	Oct 1-7	0.32	31.55	23.07	26.83	93.32	73.44	81.55	42.80	3.10	6.40	2.04

Standard week	Standard Period	Dependent variable	Independent variables									
		Y_1	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
41	8-14	0.52	32.83	22.47	27.33	91.34	66.92	77.18	11.20	1.40	7.59	1.97
42	15-21	0.63	33.30	21.94	27.19	90.02	64.48	74.60	11.30	0.80	8.42	1.88
43	22-28	0.69	33.92	19.46	26.01	88.83	54.70	70.11	1.30	0.20	9.18	1.82
44	29-4	0.92	34.30	16.95	24.66	86.22	49.70	66.03	0.00	0.00	9.60	1.90
45	Nov 5-11	1.93	34.32	17.71	25.09	85.76	50.35	66.61	0.00	0.00	8.81	2.12
46	12-18	1.55	34.22	16.87	24.59	88.34	45.26	65.82	0.00	0.00	9.09	1.58
47	19-25	1.98	33.61	15.48	23.49	87.10	43.89	64.33	0.00	0.00	9.33	1.45
48	26-2	1.58	32.03	13.82	21.85	85.93	40.53	62.20	0.00	0.00	8.98	1.52
49	Dec. 3-9	1.25	31.89	13.59	21.71	83.87	40.50	61.23	0.00	0.00	8.81	1.75
50	10-16	1.50	32.34	12.88	21.57	85.30	39.34	61.82	0.00	0.00	8.72	1.98
51	17-23	1.15	31.95	11.07	20.43	85.75	46.34	63.26	0.00	0.00	8.80	2.03
52	24-31	1.40	31.30	10.39	19.75	88.65	42.44	64.47	0.00	0.00	8.86	1.62
1	Jan 1-7	1.92	30.68	11.42	20.04	88.53	47.21	66.46	0.00	0.00	9.02	1.94
2	8-14	2.76	29.82	10.92	19.32	88.34	42.11	63.56	0.00	0.00	8.77	2.09
3	15-21	2.41	30.68	10.74	19.69	88.34	46.64	66.04	0.00	0.00	9.06	2.11
4	22-28	2.62	30.68	10.44	19.66	87.27	39.92	62.96	0.00	0.00	9.32	2.03
5	29-4	3.10	29.60	10.67	19.15	88.15	40.21	63.39	0.00	0.00	9.25	2.57
6	Feb 5-11	3.27	30.32	10.84	19.49	85.14	41.32	61.99	0.00	0.00	9.12	2.53
7	12-18	4.70	30.93	10.80	19.84	87.60	41.41	64.14	0.00	0.00	9.77	2.67
8	19-25	4.88	31.89	11.97	20.90	87.33	43.24	64.48	0.00	0.00	9.51	2.51
9	26-4	5.00	31.85	12.35	21.08	86.13	43.81	64.12	0.50	0.10	9.78	2.67
10	Mar 5-11	4.24	33.43	13.09	22.12	84.49	39.48	61.14	0.00	0.00	9.83	3.13
11	12-18	3.26	32.50	12.92	21.67	84.16	41.38	61.51	0.30	0.10	9.31	2.93
12	19-25	2.60	33.51	13.99	22.76	84.83	40.42	61.74	0.50	0.20	9.32	3.22
13	26-1	2.40	34.38	15.09	23.80	84.00	40.75	61.26	0.00	0.00	9.77	2.93
14	Apr 2-8	1.48	35.35	16.15	24.90	81.16	38.92	59.14	0.00	0.00	9.48	3.05
15	9-15	1.33	35.59	18.24	26.24	84.18	44.72	64.21	0.10	0.10	9.25	3.57
16	16-22	1.43	35.17	18.39	25.89	82.03	44.50	62.93	0.00	0.00	10.06	3.64
17	23-29	1.42	34.56	19.81	26.41	83.65	49.44	65.38	0.00	0.00	10.08	3.83
18	30-6	1.33	34.94	21.75	27.47	84.24	52.18	67.21	0.00	0.00	10.30	5.61
19	May 7-13	0.68	34.88	22.10	27.70	84.17	56.48	68.62	0.00	0.00	10.55	5.70
20	14-20	0.60	35.03	23.02	28.52	83.51	56.40	68.58	3.20	0.40	10.12	5.45
21	21-27	0.56	33.70	24.40	28.73	82.37	60.57	69.89	6.00	0.80	9.87	7.04
22	28-3	0.35	33.25	24.42	28.36	81.60	61.59	70.28	5.90	0.60	10.34	7.90
23	June 4-10	0.17	34.09	24.84	29.08	82.34	62.31	70.49	24.00	1.30	9.01	8.09
24	11-17	0.13	33.70	25.06	28.94	84.51	63.27	72.07	32.20	1.30	8.56	6.45
25	18-24	0.10	33.03	24.96	28.53	86.68	68.01	74.36	108.70	3.60	5.92	6.31
26	Jun 25- Jul 01	0.07	31.32	24.62	27.58	89.55	74.29	79.41	136.60	4.60	4.24	6.21
	Average	1.31	32.04	18.67	24.67	87.84	57.89	71.15	43.9	1.66	7.67	4.07

60.99 mm, rainy days of 1.60, sunshine of 7.55 hours per day and wind velocity of 3.72 kms/hour (Table 2). The hopper population during peak year exhibited significant positive correlation with maximum temperature ('r' = 0.3864) and sunshine ('r' = 0.4351) while, it was significant and negative with temperature (minimum and average) ('r' = -0.4652 and -0.3031), relative humidity (evening and average) ('r' = -0.5102 and 0.4737) and rainfall days ('r' = -0.4181) (Table 4). The total contribution of all the factors on fluctuation of hopper population was 35.71 per cent (R= 0.6673 significant at 1 %) (Table 5).

Regression equation of hopper population during peak activity year was:

Table 4. Correlation coefficients of abundance of hopper in relation to major abiotic factors during 1997-2007

Observation period	Correlation coefficient ('r) /Abiotic factors									
	Temperature (°C)			Relative humidity (%)			Rainfall (mm)	Rainfall days	Sunshine (hrs)	Wind velocity (km/hr)
	Maximum	Minimum	Average	Morning	Evening	Average				
1997-1998	-0.2625	-0.7562**	-0.7538**	0.0944	-0.3987**	-0.2791*	-0.2792*	-0.4198**	0.2851*	-0.3614**
1998-1999	-0.0134	-0.4840**	-0.4484**	-0.0220	-0.3711**	-0.2965*	-0.2706	-0.4297**	0.3798**	-0.3667**
1999-2000	0.2737*	-0.3534**	-0.2444	0.2538	-0.4023**	-0.3920**	-0.2122	-0.3299*	0.2754*	-0.3632**
2000-2001	0.3198	-0.0863	0.0542	-0.2503	-0.3222*	-0.1793	-0.1662	-0.3151*	0.3868**	-0.0499
2001-2002	0.0785	-0.4116**	-0.3529*	-0.1768	-0.4035**	-0.3775**	-0.1564	-0.2613	0.3097*	-0.1574
2002-2003	0.0728	-0.2819*	-0.2242	-0.2729*	-0.2908*	-0.3021*	-0.1310	-0.2114	0.1652	-0.1203
2003-2004	0.0041	-0.7989**	-0.7489**	-0.0174	-0.5742**	-0.5031**	-0.3920**	-0.4597**	0.4234**	-0.5625**
2004-2005	0.0680	-0.3599**	-0.2929*	-0.0930	-0.4404**	-0.3855**	-0.2011	-0.2898*	0.2008	-0.3217*
2005-2006	0.3864**	-0.4652**	-0.3031*	-0.1956	-0.5102**	-0.4737**	-0.2458	-0.4181**	0.4351**	-0.2315
2006-2007	0.0649	-0.8606**	-0.8155**	-0.4016**	-0.6646**	-0.6836**	-0.3751**	-0.5542**	0.4351**	-0.4997**
Mean (Av. of ten years)	0.0395	-0.3541**	-0.3349*	-0.0673	-0.3401*	-0.2146	-0.2917*	-0.3249*	0.2830*	-0.2504
Overall (Pooled over ten years)	0.0282	-0.3018**	-0.2664**	-0.0214	-0.2672**	-0.1679**	-0.1488**	-0.2449**	0.2167**	-0.1133*

* Significant at 5 % level

** Significant at 1 % level

Table 5. Regression coefficients of abundance of hopper in relation to major abiotic factors during 1997-2007

Abiotic factors	Observation period										Mean (Av. of ten years)	Overall (Pooled over ten years)
	1997-98	1998-99	1999-2000	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07		
Max. temp.(X_1)	--	--	0.0512	0.0423	--	--	--	--	584.8001	--	--	--
Min. temp. (X_2)	-0.3426	-0.4295	-0.0089	--	0.0172	-0.0459	-0.2823	0.3216	583.5968	0.0044	0.8497	-0.0361
Av. temp. (X_3)	0.1161	0.0671	--	--	-0.0514	--	-0.1536	-0.3295	-1167.7489	-0.6617	-1.2509	-0.1534
Mor. R.H. (X_4)	--	--	--	--	--	-9.5489	--	--	--	-58.7940	--	--
Eve. R.H. (X_5)	-0.0239	-0.1017	-0.0024	-0.0044	--0.0080	-9.4981	0.0408	-0.1789	-0.4131	-58.7721	-0.1247	0.0349
Av. R.H. (X_6)	0.1084	0.2280	-0.0068	--	0.0017	19.0013	-0.0551	0.1798	0.6794	117.5211	--	0.0605
Rainfall (X_7)	-0.0028	--	--	--	--	--	0.0020	--	--	0.0098	-0.0031	0.0008
Rainy days (X_8)	0.0976	-0.1638	-0.0223	0.0583	--	--	0.1254	0.0543	0.7244	-0.1105	-0.5522	-0.1246
Sun shine (X_9)	0.1026	0.0645	-0.0409	0.1128	0.0130	--	0.1311	--	1.0928	0.0748	-0.3000	0.0654
Wind velocity (X_{10})	0.0852	-0.0020	-0.0159	--	--	--	-0.0814	-0.0460	--	-0.098	--	-0.0162
R^2	0.5981	0.3413	0.1039	0.0981	0.1088	0.0355	0.5861	0.2980	0.3571	0.7492	0.0491	0.1118
Variation Explained (%)	59.82	34.13	10.39	9.81	10.88	3.55	58.61	29.80	35.71	74.92	4.91	11.18
R value	0.8131**	0.6571*	0.4763	0.4109	0.4429	0.3334	0.8069**	0.6169*	0.6673*	0.8908**	0.4012	0.3344**
Constant (A value)	-3.3339	-8.9027	-0.2759	-1.6565	1.4025	5.3016	11.7992	0.1601	-50.7822	22.4937	27.7464	3.3642

* Significant at 5 % level ** Significant at 1 % level

Table 6. Impact of various crop stages on abundance of mango hopper during 1997-2007

Crop stages	Observation period/Hopper population/twig or panicle										Pooled
	1997-98	1998-99	1999-2000	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	
Vegetative	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.003
Emergence of new flush	0.00	0.00	0.00	0.00	0.00	0.04	0.04	1.03	0.59	0.57	0.240
New twigs	0.28	3.29	1.20	0.005	0.11	3.54	3.54	2.38	0.52	2.09	1.590
Bud/bud burst	1.66	1.53	0.41	0.08	0.06	0.36	0.36	0.54	3.59	3.76	1.37
Initiation of Flowering	2.97	1.92	0.11	0.63	0.301	0.30	0.30	1.05	6.41	5.41	2.428
Peak flowering	4.82	0.17	0.08	0.25	0.21	1.28	1.28	3.22	8.12	8.37	3.18
Pea/marble	1.85	1.79	0.12	1.06	1.36	0.70	0.70	0.13	25.99	7.55	4.70
Stone size	0.27	0.27	0.18	1.10	0.11	0.05	0.05	0.20	13.76	1.81	1.906
Fruiting	0.00	0.00	0.00	1.51	0.16	0.00	0.00	0.015	4.08	0.61	0.639
Initiation of Ripening	0.00	0.00	0.00	0.61	0.19	0.00	0.00	0.00	3.40	0.36	0.45
Ripening/harvest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.67	0.00	0.167
Harvest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.98	0.00	0.09
'r'	-0.2250**	-0.3988**	-0.3563**	0.2090**	0.0296	-0.3562**	-0.3562**	-0.5787**	0.1104*	-0.2179**	0.1056*
Constant (A)	7.1055	7.5208	7.2068	6.0085	6.4443	7.1244	7.1244	8.1705	6.2470	7.2258	4.8934
Regression coefficient	-0.1785	-0.3182	-0.8947	0.2831	0.0706	-0.3214	-0.3214	-0.6390	0.0102	-0.0754	0.1105

* Significant at 5 % level ** Significant at 1 % level

$\hat{Y}$ = -50.7822 + 584.8001 **(X_1)** 583.5968 **(X_2)** -1167.7489 **(X_3)** -0.4131 **(X_5)** + 0.6794 **(X_6)** + 0.7244 **(X_8)** + 1.0928 **(X_9)**

(III) Overall assessment of hopper population v/s peak year activity

It is evident from the above results that slight increase in minimum temperature from 18.67 to 18.73 °C(0.06), average temperature from 24.67 to 24.96 °C (0.29), morning relative humidity from 87.84 to 89.16 per cent (1.32), evening relative humidity from 57.89 to 59.55 per cent (1.66), average relative humidity from 71.15 to 74.35 per cent (3.20), rainfall from 43.90 to 60.99 mm (17.09) and with slight decrease in maximum temperature from 32.04 to 31.19 °C (0.85), rainfall days from 1.66 to 1.60 (0.06), sunshine from 7.67 to 7.55 hours (0.12) and wind velocity from 4.07 to 3.72 kms per hour (0.50) indicated sharp rise in hopper population from 1.31 to 5.74 i.e. a rise of 4.43 which is almost near to the threshold value (5.00 hoppers) of the pest under consideration.

Tandon *et al.* (1983) indicated peak of *Idioscopus clypealis* during March-April. Similarly, Baro *et al*. (1998) observed maximum population of *Amritodus* and *Idioscopus* during March-April and minimum during December-January. Likewise, Kudagamage *et al.* (2001) noticed peak population of *Idioscopus niveosparsus* and *Amrasca brevistylus* in March-April. Pehzman and Radjabi (2002) reported maximum density of mango hopper during March-April. Rehman and Singh (2004) reported lowest hopper population during first week of February; however, population gradually increased from March and reached its peak during April, then later decreased. Vijaya *et al.* (2010) reported peak incidence of mango hopper during 8th and 9th standard weeks. The results obtained by the above workers indicate peak incidence of hopper during 8 and 9th standard weeks which was also observed in the present findings (5.00 and 4.88 during respective weeks), thus conform the present investigation.

It can be concluded that slight increase of temperature (minimum and average) (0.06 and 0.29 °C), relative humidity (1.32-3.20 %) and rainfall (17.09 mm), which in turn increased dampness in the environmental conditions were conducive for sharp rise in hopper population. These results are also supplemented by results based on decrease in rainfall days (0.06) and sunshine (0.12 hours/day). If wind velocity decreased even by 0.50 km per hour, settling of hopper on trees increased leading to higher multiplication and its oriented damage.

(IV) Abundance of hopper in relation to various crop stages

Hopper population was noticed at various stages of crop growth *viz;* vegetative, emergence of new flush, new twigs, bud/bud burst stage, initiation of flowering, peak flowering, pea cum marble sized fruit, stone sized fruit, fruiting, initiation of ripening, ripening cum harvest and harvest stages of the crop. The hopper (average of 10 years) population varied from 0.003 to 4.70 hoppers per panicle at various stages of crop growth wherein it peaked (4.70/panicle) at pea cum marble sized fruit stage of the crop. Highest hopper population (25.99/panicle) was observed at pea cum marble sized fruit stage of the crop during 2005-2006 followed by 13.76 at stone sized crop stage.

Correlation of hopper in relation to various crop stages was significant and positive ('r' = 0.1056) implying that population increased with the advancement of crop growth. So, as the crop growth advanced from new flush to new twig, the hopper oviposition and multiplication increased, which might have led to increased population and subsequently higher damage. Similarly, from new twig to bud or bud burst stage, the pest population increased further which ultimately reached to its peak either during peak flowering or marble sized fruit stage. As the annual crop cycle was near to its completion i.e. from flowering to fruiting or ripening, the pest population increased initially but later on decreased to its minimum at harvest stage. This clearly proves that succulent crop stages like new flush, twigs, bud, flowering and marble sized fruit stage were preferred most by the pest under consideration whereas, hard crop stages like mature or ripened fruits were preferred less by the pest.

Idioscopus niveosparsus has been found to breed throughout the flowering season. *Amritodus atkinsoni* on the other hand has been reported to be a shy breeder found on vegetative shoots rarely on blossoms (Anonymous, 1917) under North Indian conditions. Similar trend of this pest species was reported in middle Gujarat by Patel *et al.* (1994). Verghese and Rao (1987) reported population of this pest at post bloom stage. Similarly, higher population build-up and rapid multiplication of mango hoppers, *A. atkinsoni* and *Idioscopus* spp. have been reported during flower initiation and full-bloom stage of the crop (Srivastava, 1998; Bharat Babu *et al;* 2001 and Sushil Kumar *et al;* 2002).

In the above reports higher hopper population has been recorded during flower initiation or post bloom stage. In the present investigation, highest incidence of hopper has been observed at marble sized fruit stage (25.99/panicle) which is nearly the same as reported earlier, thus conform the ongoing discussion.

Talpur *et al.* (2002) reported that population density of mango hopper had positive correlation with inflorescence phenology in all the mango cultivars;

however population of hoppers had negative correlation with fruit development. In the present investigation, hopper population dipped from 4.70 at marble stage of the crop to 0.09 hoppers at harvest stage. This trend is almost similar to the above reports, thus conforms the present investigation.

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