Indian Journal of Ecology (2017) 44(2): 369-374

Manuscript Number: 2530
NAAS Rating: 4.96

Population Diversity and Cyclicityof Fruit Fly (*Bactrocera* spp.) in Sapota Orchard under South Gujarat Condition

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Abstract: An investigation on population diversity and cyclicity of fruit fly, *Bactrocera spp.* was carried out in sapota orchards by using modified "Nauroji Stonehouse" fruit fly trap throughout the year from 2013 to 2015. *Bactocera dorsalis* was the dominating species with more than 95% population over *B. correcta* and *B. zonata*. The fruit fly activity observed low at early period of fruit maturity in December to February (14.33-66.00 males/trap). However, population reached at its peak during April (306.67-520.67 males/trap) and May (535.67-1099.33 males/trap) with the late fruiting phase, which coincided with the mango fruiting stage under South Gujarat agro-ecological situation. The correlation study revealed that the temperature and evaporation had positive role in the increasing population build up of fruit fly with declining morning relative humidity during summer period with significant regression effect of minimum temperature, evening relative humidity, bright sunshine hours and evaporation. The mass trapping campaign can be initiated February onwards to bring down the male adult fruit fly population below decisive level and to escape advance fruit damage during fruiting phase.

Keywords: Fruit fly, *Bactrocera spp.*, Population diversity, Cyclicity, Sapota

In South Gujarat agro-ecological region, sapota or Chiku *[Manilkara achras* (Mill.) Forsberg] is an important fruit crop, which showed a phenomenal growth and attained the status of major fruit crop after mango and banana. Navsari, Valsad and Surat are major sapota growing districts and generally established in mixed orchard diversity with mango. Fruit quality is of prime importance in subsistence and commercial horticulture, which concern with crop cultivation practices as well as infestation of insect pest. With reverence to this, fruit fly, *Bactrocera* spp. (Diptera: Tephritidae) is a vital insect pest in sapota from consumption and export point of fruit quality. Fruit fly is polyphagous pest with wide range of tropical, subtropical fruits and vegetables as well as has high reproductive potential, adaptability to climate and overlapping of generations, management in orchard is difficult through chemical means. The more host diversity in cropping pattern, fruit fly shift from one to another under complimentary ecological factors. Similarly, different fruit fly species exist in same host and causes enormous losses in horticultural crops. Therefore, management of fruit fly is very vital at right time in orchard to avoid subsequent loss. Different types of traps used in integrated pest management and among them, plywood lure traps are highly successful and feasible in mass trapping of fruit flies. Earlier, the major population of *B. dorsalis* over *B. zonata* and *B. correcta* was reported from the same locality in sapota and mango orchard (Anonymous, 2006) and there are no further reports about species diversity study during last one decade. With this, an investigation trial was formulated to supervise the current profusion of fruit fly population diversity and to assess the impact of weather parameters with host availability in sapota orchards for adoption of proper timing of mass trapping.

MATERIAL AND METHODS

The experiment was investigated at sapota (cv. Kalipatti) orchard of Fruit Research Station, Navsari Agricultural University, Gandevi during three consecutive year of 2013, 2014 and 2015 to explore the population cyclicity of fruit fly (*Bactrocera* spp.). For monitoring purpose, one ha orchard area was selected and kept free from insecticidal application. Ten methyl eugenol based modified 'Naurogji Stonehouse traps' (plywood block) developed under Navsari Agricultural University were installed @ 10 traps ha^{-1} round the year at 4-5 feet height from ground level on sapota tree and plywood blocks were changed regularly at two months interval. The observation based on adult male fruit fly catches (Y) was done at each standard meteorological week and coefficient correlation in relation to previous and current weather parameters *viz.*, maximum (X_1) and minimum (X_2) temperature, morning (X_3) and evening (X_4) relative humidity, bright sunshine hrs (X_5), rainfall (X_6) and evaporation (X_7) was analyzed. The trapped male adult population was further examined with regression equation to measure the per cent variability in fruit fly incidence elucidated by each weather variables for previous as well as current weekly weather data. Fruit fly male adult samples were collected and sent to

Division of Entomology and Nematology, ICAR-Indian Institute of Horticultural Research, Bengaluru (Karnataka) for confirmation of the insect species.

RESULTS AND DISCUSSION

On development of fruits, fruit flies deposit their eggs on the physiologically ripen fruits, maggots feed on fruit pulp, which results in softened and discoloration of fruit tissue. The affected fruit drops early prematurely, get distorted and market value affected, which are also not suitable for consumption. The noticed fruit fly species in sapota were *Bactrocera dorsalis*, *B. correcta* and *B. zonata*. Among all these species, *B. dorsalis* was the most dominating with more than 95 per cent of population in sapota orchard. Similar species diversity was also identified in specimens collected from mango orchards. Previously, the similar fruit fly diversity was reported at Gandevi location, wherein *B. dorsalis* was a major species as compare to *B. zonata* and *B. correcta* in sapota and mango orchard of South Gujarat condition (Anonymous, 2006). Currently, the species diversity with more than 90% dominance of *B. dorsalis* over *B. correcta* and *B. zonata* was reported in mango in same ecological region (Anonymous, 2015 & 2016).

The result based on monitoring of adult male fruit fly population at weekly interval in sapota at different crop stage are presented in Table 1. The data on population occurrence indicated that fruit fly was trapped throughout the year in sapota orchard with varying intensity at different crop stages. During 2013, fruit fly adult population exhibiting peak activity during April (442 to 620 males trap^{-1}) and May (830 to 1275 males trap^{-1}), while it was lowest (9 to 66 males trap^{-1}) during January at peak fruiting stage. From June to September, the population trend remains between 150 to 300 males trap^{-1} at overlapping fruit development of sapota, which decline from second fortnight of October and remain below 100 males trap^{-1} till December.

The analogous population catches trend was reported in succeeding years of 2014 and 2015, wherein the crest phase of population was noticed during April and May in a increasing trend and declined later on after July and it was lowest during January. The fruit fly activity during 2015 season was slightly less as compare to earlier seasons. The overall data on the monitoring study of fruit fly adult population indicated that male catches were traced throughout the year in sapota orchard due to round the year fruit availability to pest (Fig. 1). However, population reached at its peak after second fortnight of April (520.67 to 688.33 males trap^{-1}) and May (535.67 to 1099.33 males trap^{-1}) during summer season. From June onwards, the fruit fly population catches were showed turn down tendency and reported between 100 to 250 males/trap till September during monsoon period of fruit development and lower down below 100 males trap^{-1} after October onwards. While the lowest fruit fly activity was noted during peak fruiting phase of January (14.33 to 50.67 males trap^{-1}) to February (42.00 to 66.00 males trap^{-1}) during winter.

The parallel type of population fluctuation of fruit fly catches during April to August was also noticed in earlier reports in same ecological situation (Bansode, 2009; Anonymous, 1998, 2000 & 2010). Besides, the finding is in agreement with the reports of Kumar *et al.* (1997) who reported from South Gujarat that major activity of fruit fly coincided with fruiting season. Recently, Nandre and Shukla (2014) also recorded the highest population of fruit fly during March to August and lower during December to January in sapota as well as Kalipatti variety categories as highly susceptible to *B. dorsalis* under at same location (Nandre and Shukla, 2013). In contrast to this may be due to regional variability and cropping pattern, Ravulapenta *et al.* (2014) reported *B. dorsalis* and *B. zonata* diversity of fruit fly under hill zone of Karnataka and activity was observed during October to January with maximum infestation in December in sapota orchard.

In concern to fruit fly abundance in mango, the adult occurrence was higher during May to July at fruiting stage in Paria having parallel ecosystem. The species diversity was also same with dominance of *B. dorsalis* over *B. correcta* and *B. zonata* (Anonymous, 2015 and 2016). Besides, the peak seasonal activity of the fruit fly was noticed during July in mango orchard under South Gujarat condition of Bharuch (Patel *et al.*, 2014). This indicated that the fruit fly population remains throughout the year in sapota which augmented gradually due to peak fruiting phase of mango. The span between April to June is a peak flowering and late fruiting stage of sapota during summer period, which overlap with fruit ripening phase of mango adjutant to sapota orchard periphery. This may be the reason that fruit fly showed crest activity span in sapota orchard and sapota-mango mixed orchard during May to June under South Gujarat agro-ecological situation. Besides this might be the fruit shape of sapota, which is rounded during summer period provide more volume to fruit fly as compare to elliptical-round shape observed in winter season.

The correlation coefficient data recorded during 2013 and 2014 (Table 2) indicated that the fruit fly population had positive significant relation with preceding and current maximum-minimum temperature along with evaporation, while negative correlation with morning relative humidity. In regard to the correlation coefficient data of 2015, the fruit fly population had positive significant relation with preceding

Table 1. Weekly population cyclicityof fruit fly (*Bactrocera* spp.) during 2013-15

Months	Standard week	Crop stage	Mean fruit fly adult population/trap			
			2013	2014	2015	Avg.
January	01	Peak fruiting	10	20	20	16.67
	02		9	16	18	14.33
	03		26	33	17	25.33
	04		56	46	33	45.00
	05		41	72	39	50.67
	Avg.		28.40	37.40	25.40	30.40
February	06	Peak fruiting	36	48	42	42.00
	07		42	55	47	48.00
	08		41	61	42	48.00
	09		68	91	39	66.00
	Avg.		46.75	63.75	42.50	51.00
March	10	Flowering initiation and fruiting	98	87	95	93.33
	11		136	102	88	108.67
	12		195	162	134	163.67
	13		280	217	152	216.33
	Avg.		177.25	142	117.25	145.5
April	14	Peak flowering and fruiting	442	296	182	306.67
	15		568	479	265	437.33
	16		516	619	427	520.67
	17		620	708	737	688.33
	Avg.		536.50	525.50	402.75	488.25
May	18	Peak flowering and late fruiting	830	861	1048	913.00
	19		1183	1074	1041	1099.33
	20		1275	1222	712	1069.67
	21		921	1138	321	793.33
	22		555	803	249	535.67
	Avg.		952.80	1019.60	674.20	882.20
June	23	Late flowering	305	558	106	323.00
	24		168	296	141	201.67
	25		182	212	173	189.00
	26		285	318	142	248.33
	Avg.		235.00	346.00	140.50	240.50
July	27	Fruit development and late flowering	212	232	161	201.67
	28		157	285	121	187.67
	29		194	260	108	187.33
	30		227	209	130	188.67
	Avg.		197.50	246.50	130.00	191.33
August	31	Fruit development	271	168	276	238.33
	32		306	188	222	238.67
	33		281	169	255	235.00
	34		247	178	156	193.67
	35		302	163	130	198.33
	Avg.		281.40	173.20	207.80	220.80

Cont...

September	36	Fruit development	235	143	101	159.67
	37		252	126	84	154.00
	38		207	137	79	141.00
	39		175	113	46	111.33
	Avg.		217.25	129.75	77.50	141.50
October	40	New foliage flush and fruiting initiation	148	102	29	93.00
	41		121	87	27	78.33
	42		92	65	39	65.33
	43		66	52	43	53.67
	Avg.		106.75	76.50	34.50	72.58
November	44	New foliage flush and fruiting initiation	73	44	42	53.00
	45		84	52	51	62.33
	46		56	56	97	69.67
	47		66	39	60	55.00
	Avg.		69.75	47.75	62.50	60.00
December	48	Peak fruiting and new foliage	44	30	52	42.00
	49		32	21	37	30.00
	50		38	19	30	29.00
	51		26	26	57	36.33
	52		22	22	89	44.33
	Avg.		32.40	23.60	53.00	36.33

Table 2. Correlation of fruit fly (*Bactrocera* spp.) with weather factors during 2013-15

Year	Weather parameters						
	Temperature (°C)		Relative Humidity (%)		Bright sunshine hrs.	Rainfall (mm)	Evaporation (mm/day)
	Max.	*Min.*	*Mor.*	Eve.			
2013	0.424**	0.449**	-0.434**	0.106	0.167	-0.078	0.592**
	(0.438)**	(0.535)**	(-0.408)**	(0.160)	(0.064)	(-0.060)	(0.622)**
2014	0.487**	0.421**	-0.365**	0.049	0.088	-0.078	0.654**
	*(0.463)***	*(0.499)***	*(-0.414)***	*(0.110)*	*(-0.025)*	*(-0.059)*	*(0.684)***
2015	0.064	0.361**	-0.165	0.073	0.108	-0.005	0.491**
	(0.106)	(0.424)**	(-0.144)	(0.097)	(0.101)	(-0.068)	(0.550)**
Avg.	0.388**	0.441**	-0.383**	0.083	0.151	-0.065	0.679**
	*(0.392)***	*(0.519)***	*(-0.352)**	(0.138)	(0.056)	(-0.056)	(0.709)**

* Significant at 5% level and ** at 1% level.
# Value in parentheses are current weekly data and values in outside are preceding weekly data.

and current minimum temperature and evaporation only. The preceding and current maximum temperature and morning relative humidity had no role in increasing fruit fly population during 2015 as observed in earlier seasons of 2013 and 2014 may be due to variability in weather situation of 2015 along with low population occurrence. The correlation study revealed that the increasing maximum-minimum temperature and evaporation rate increases the population of adult fruit fly with low morning relative humidity in sapota, which is coincide with the fruiting phase of crop phenology during summer season.

The regression coefficient corresponding to same weather parameters were found significant to fruit fly population (Table 3). During 2013 season, regression coefficient of evening relative humidity, bright sunshine hrs and evaporation both in preceding and current weather situation was found significant with the variability of 72 and 76%, respectively. While in regression equation of 2014, minimum and maximum temperature along with evening relative humidity, bright sunshine hrs and evaporation were showed significant relation against fruit fly catches data and could explain the expression to the extent of 52 and 61 per cent in former and current weather condition, respectively. Exception to above parameters, current maximum temperature and evening relative humidity regression coefficient was non-significant during 2014. The ecological

Table 3. Regression equations of fruit fly (*Bactrocera* spp.) in sapota during 2013-15

Year	Regression equation		R^2
2013	Preceding	$Y = -384.718 - 2.790X_1 - 2.212X_2 - 10.021X_3 + 15.687X_4 + 60.430X_5 + 0.538X_6 + 105.936X_7 + 162.461$	0.72
	Current	$Y = -775.565 + 1.247X_1 - 2.502X_2 - 3.999X_3 + 12.754X_4 + 19.542X_5 + 0.163X_6 + 140.918X_7 + 150.599$	0.76
2014	Preceding	$Y = -327.987 + 8.488X_1 + 5.787X_2 - 6.778X_3 + 3.693X_4 + 18.316X_5 + 0.854X_6 + 94.804X_7 + 224.611$	0.52
	Current	$Y = 396.143 - 15.806X_1 + 21.544X_2 - 6.132X_3 - 2.229X_4 + 10.922X_5 + 0.927X_6 + 109.672X_7 + 203.494$	0.61
2015	Preceding	$Y = -351.714 - 12.657X_1 + 20.348X_2 - 0.078X_3 + 1.340X_4 + 42.036X_5 + 0.661X_6 + 41.717X_7 + 195.304$	0.38
	Current	$Y = -432.845 - 11.087X_1 + 21.894X_2 - 1.074X_3 + 2.756X_4 + 42.602X_5 + 0.194X_6 + 45.917X_7 + 180.935$	0.47
Avg.	Preceding	$Y = 80.242 - 40.418X_1 + 16.499X_2 - 6.320X_3 + 11.776X_4 + 95.840X_5 + 0.794X_6 + 108.103X_7 + 150.002$	0.72
	Current	$Y = 311.639 - 38.184X_1 + 20.858X_2 - 6.556X_3 + 8.099X_4 + 61.622X_5 + 0.357X_6 + 116.003X_7 + 140.893$	0.75

situation during 2015 differed slightly and regression equation of minimum temperature, bright sunshine hrs and evaporation in respect to preceding and current weather condition was found significant with lower variability only up to 38 and 47 per cent, respectively as compared to previous two years circumstances. Besides, there was significant *effect of only current evening relative humidity on fruit fly* catches.

On an average, ecological situation indicated that the preceding and current minimum temperature, evening relative humidity, bright sunshine hrs and evaporation, regression coefficient was observed significant in relation to fruit fly catches in sapota orchard. The R^2 value in fruit fly population catches in average weather condition explained the variability up to 72 and 75 per cent in previous and current weather situation, respectively. There was variation in significance level of coefficient of correlation and regression with respect to maximum temperature and morning relative humidity and this may be due to high temperature and *humidity fluctuations during summer* period in coastal area.

In earlier reports of sapota, maximum and minimum temperature as well as relative humidity played a major and significant role in deciding fruit fly population with 64.3 per cent variability based on three years data (Anonymous, 1998).While in mango orchard of Paria, regression equation of minimum temperature and evening relative humidity had significant effect with 58 per cent variability during 2015-16 (Anonymous, 2016) and only significant relationship in minimum temperature with 74% variability during 2014-15 (Anonymous, 2015). These findings confirm the fact of present research.

The current investigation showed that the current weather situation had more influence on population activity under trapping method as compared preceding condition. In regards to coefficient of correlation and regression results, the minimum temperature, evening relative humidity and evaporation persuades the fruit fly activity in sapota orchard,

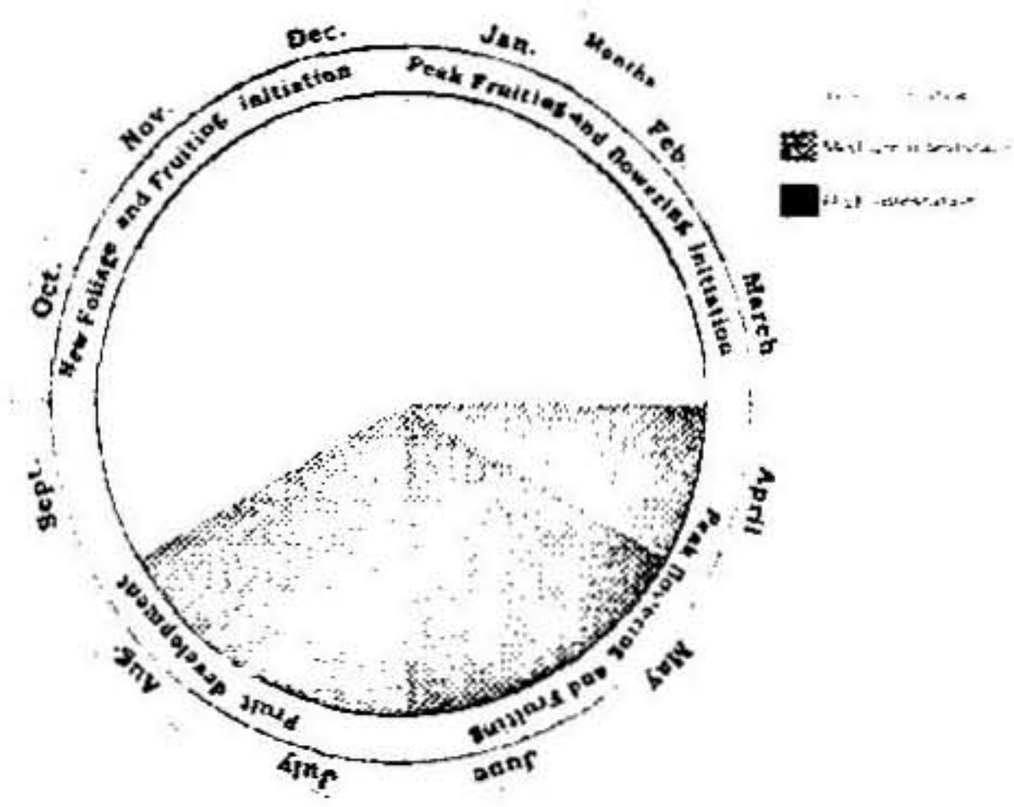

Fig. 1. Pest calendar of fruit fly (*Bactrocera* spp.) population

which mainly coincide with the fruiting stage of mango. The egg laying in early phase of mango succeeds with increased *activity at ripening period of summer season may had* positive discrimination with humidity under mixed sapota-mango orchard situation of South Gujarat condition. Such type of temperature dependent phenological synchrony was observed between host fruit availability and fruit fly trap catch in oriental fruit fly, *B. dorsalis* at Bengaluru (Jayanthi *et al.*, 2014).

Under present investigation trial, *B. dorsalis* was observed as lead species in sapota located in periphery of mango orchard in South Gujarat condition. The population monitoring data indicated that fruit fly adult males were active throughout the year due to its round the year overlapping bearing pattern of sapota. The population reached highest *during April and May with the late fruiting* stage of sapota during summer period, which was influenced gradually due to the succeeding mango fruiting stage under South Gujarat agro-ecological situation. Among weather parameters, temperature along with evaporation and humidity play an important role in fluctuating fruit fly population trend during

different growth period of sapota. These ecological factors have relationship with the fruiting phase of host-plant phenology of sapota as well as mango in nearby periphery, which also showed interaction with pest occurrence indicates the clue for *predictability of fruit fly management* at appropriate timing. Therefore, mass trapping campaign can be initiated from February onwards to bring down the male adult fruit fly population below decisive level and to escape succeeding fruit damage during fruiting phase.

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Received 02 February, 2017; Accepted 24 April, 2017