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Epidemiology of *Papaya ringspot virus-P* (PRSV-P) infecting papaya (*Carica papaya* Linn.) and influence of weather parameters on population dynamics of predominant aphid species

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Abstract

Papaya ringspot virus-P (PRSV-P) disease is a most destructive and devastating disease of Papaya (*Carica papaya* Linn.). All the growth stages of papaya are vulnerable to PRSV infection. PRSV is style borne and transmitted by many species of aphid vectors in a non-persistent manner and spreads rapidly in the field. Monitoring of transitory aphids using yellow sticky traps in papaya orchard revealed, trapping of eight major aphid species *viz*., melon or cotton aphid (*Aphis gossypii*), cowpea aphid (*Aphis craccivora*), milkweed aphid (*Aphis nerii*), bamboo aphid (*Astegopteryx bambusae*), green peach aphid (*Myzus persicae*), eupatorium aphid (*Hyperomyzus carduellinus*), cabbage aphid (*Brevicoryne brassicae*) and banana aphid (*Pentalonia nigronervosa*). The number of efficient vectors decides the epidemiology of PRSV incidence. Hence, a very high incidence of PRSV was observed between 14^{th} and 23^{rd} week after transplantation which was coincided with increased aphid population. The aphid population was peak with rainfall of below 8.00mm, maximum temperature of 28-35^{0}C, minimum temperature of 17-23^{0}C, maximum and minimum relative humidity range of 60-90% and 30-50% respectively.

Keywords: PRSV, epidemiology, predominant aphid species, host selection, weather parameters

1. Introduction

Papaya ringspot virus-P (PRSV-P) disease is a most destructive and devastating disease of Papaya (*Carica papaya* Linn.) and has become a major impediment to the growers and also a challenge to researchers across the globe. All the growth stages of papaya are vulnerable to PRSV infection and exhibit symptoms within two to three weeks after infection. The PRSV disease drastically reduced fruit yield, fruit size and quality and in some cases it resulted in total yield loss of production. PRSV is style borne and transmitted by many species of aphid vectors in a non-persistent manner and spreads rapidly in the field. It readily transmitted mechanically through sap and is not transmitted through seeds. The main factors influencing PRSV disease spread involve the amount of initial virus inoculum in papaya and other unknown hosts of PRSV, the status of aphids as transient vectors, variations in their life cycles, behaviour, ability to transmit the virus and effect of environmental factors on aphid population dynamics [1]. Krishna Kumar *et al*. (2010) monitored transitory aphids in papaya orchards to identify the predominant aphid vector species by using yellow water funnel traps in papaya orchards over three years (2003-2006) [2]. They observed that, three species of aphids such as melon or cotton aphid, *Aphis gossypii* (Glover) (64.22%), the green peach aphid, *Myzus persicae* (Sulzer) (9.88%) and cowpea aphid, *Aphis craccivora* (Koch) (9.66%) were dominant in transmitting PRSV.

Epidemiological studies are more relevant for virus disease incidence in order to design the management strategies which affect virus transmission by vectors. The species composition of aphids involved in the field spread of PRSV under South Indian condition is not clear so far. Consequently, a systematic understanding of probing behaviour of aphid and virus-vector relationship studies are needed through several approaches *viz*., monitoring the aphid vector population in relation to weather parameters to know the population dynamics are very much essential for developing ecologically viable management strategies. Furthermore, information on seasonal incidence of the disease, epidemiology and type of vector in the papaya growing areas is scanty. Hence, studies on epidemiology of PRSV were undertaken to know the predominant aphid vector species of PRSV, their influence on epidemiology of virus and the influence of weather parameters on population dynamics of different aphid species.

2. Materials and Methods

2.1. Daily record of weather parameters

Weather parameters *viz*., Temperature (^{0}C) (Normal, Maximum, Minimum), Relative humidity (%) (Normal, Maximum, Minimum), Wind speed (km/h) and Wind direction (24 h) were recorded daily at morning and evening hours using digital thermo/hygrometer of 103-CTH model obtained from HTC instruments and Rainfall (mm) was recorded using rain gauge. The average of 3 days data collected from August-2013 to July-2014 were tabulated. The average data of different weather parameters were correlated with number of aphids trapped which were collected at 3 days interval.

2.2. Monitoring of major aphid vectors and their identification

Field experiment was conducted from August 2013 to July 2014 at Main Research Station (MRS), UAS, Hebbal, Bangalore, to study the aphid species abundance and their influence on PRSV incidence in relation to weather parameters *viz*., temperature, rainfall, relative humidity, direction and wind speed.

Three papaya varieties *viz*., Red Lady, Sunrise Solo, Arka Surya were raised in glasshouse during July 2013. Ten seedlings of each variety were transplanted in the main field during August 2013 and crop was maintained by following all the recommended cultural practices except plant protection. Aphid abundance in the field was assessed by using 32 yellow sticky traps which were installed in all four directions *i.e*., North, South, East and West at different heights *viz*., 2 feet, 4 feet, 6 feet and at 8 feet. Aphids trapped in different directions and at different heights were collected in tubes at 3 days intervals and the different species were identified by taxonomist at National Bureau of Agriculturally Important Insects (NBAII), Bangalore. To record fresh PRSV infection based on symptoms, observations were made once in 7 days on each plant from the time of transplanting. Plants expressing characteristic symptoms were tagged every week.

2.3. Correlation between incidence of aphid vectors, PRSV and weather variables

Data were subjected to Pearson's correlation analysis to determine the extent and nature of association between number of aphids and per cent PRSV infection. Based on trap catch data, predominant aphid species which contributed for the successful transmission and spread of PRSV in field were considered as independent variables and fresh incidence of PRSV as dependent variable. Further, the weather parameters which influence the spread of aphids *viz*., rainfall, temperature (maximum and minimum), relative humidity (maximum and minimum), wind speed and wind direction were selected as independent variables. Data was analysed to identify the weather factors influencing aphid population build-up, which would help to devise timely management strategies and also to find out active period of the vector.

The influence of each weather parameters on aphid population and influence of each species of aphids on the spread of PRSV was analysed by correlation analysis using 'IBM SPSS Statistics version-20' statistical software package. The contribution of weather parameters on abundance of aphid vector population, proportional contribution of different species of aphids on fresh PRSV infection was calculated.

3. Results and Discussion

3.1. Predominant aphid species trapped in papaya orchard

Monitoring of transitory aphids using yellow sticky traps in papaya orchard, during August-2013 to July-2014 revealed, trapping of eight major aphid species *viz*., melon or cotton aphid, *Aphis gossypii* (Glover), cowpea aphid, *Aphis craccivora* (Koch), milkweed aphid, *Aphis nerii* Boyer de Fonscolombe, Bamboo aphid, *Astegopteryx bambusae* Buckton, the green peach aphid, *Myzus persicae* Sulzer, Eupatorium aphid, *Hyperomyzus carduellinus* Borner, cabbage aphid, *Brevicoryne brassicae* Linnaeus and banana aphid, *Pentalonia nigronervosa* Coquerel. Of these, *A. gossypii* was regularly trapped in large number (66.04%) followed by *A. craccivora* (26.80%) and *M. persicae* (2.12%) [3]. Among six aphid species trapped, *A. gossypii* (Glover) (64.22%), *M. persicae* (Sulzer) (9.88%) and *A. craccivora* (Koch) (9.66%) were the major species and have been reported as major vectors of PRSV in India [4, 2]. Conversely, *A. bambusae* (1.02%), *H. carduellinus* (1.15%), and *B. brassicae* (0.55%) are not reported as vectors of PRSV and were not consistently observed in traps. However, other two species *A. nerii* (1.52%) and *P. nigronervosa* (0.82%) are reported as vectors of PRSV [5, 6].

3.2. Host selection by aphids

Aphid species composition trapped in an area is a reflection of adjacent landscape which was characterized by extent of cropped area, diversity of crops, crop duration, cropping season *etc.* [2]. The crop diversity at experimental plot where study was undertaken and surrounding area was characterized by cultivation of oilseeds, cucurbits and legumes. The dominant species, *A. gossypii* is a common pest on these crops. The leguminaceous crops like cowpea and beans are regular hosts of *A. craccivora*. Equally, *M. persicae* is a polyphagous aphid species. Meanwhile, the biotic potential of some aphids such as *A. nerii*, *A. bambusae* and *Hyperomyzus* sp. also limited by the number of non-host crops/weeds such as, milkweed, bamboo and *Eupatorium*, respectively which are grown in surrounding areas. These weeds potentially influences number and species composition of aphids in papaya orchards. As the main crop progressed towards maturity, the aphid population also declined on the main host and moreover a marked increase in the population of alate forms of aphids can be noticed on the matured crop. It then start migrating towards other crops with conducive weather conditions [7].

Like many non-persistent virus transmission, it has been reported that the PRSV transmission occurs by numerous species of aphids which do not colonize papaya. During host selection process, flying aphids will land on any available plants regardless of the species and they are unable to distinguish host plants from non-host plants. If an aphid encounters an unsuitable host it will move on, trying to maximise the chances of finding a suitable host in the shortest possible time [8, 5]. Host selection occurs only after ingestion of plant sap and at the same time virus transmission also occurs from infected source to non-infected plants [9]. The tendency to land on and probe inappropriate plants is a widespread aphid behaviour and an important component of the epidemiology of many aphid-transmitted viruses [10]. Hence, virus transmission occurs even though the aphid does not colonize the plant. Though colonization of any of the major aphid vectors were not found on papaya plants, *A. gossypii*, *A. craccivora* and *M. persicae* that are regularly observed in traps in large numbers are considered as potential vectors for large scale spread of PRSV.

3.3. Incidence of PRSV in relation to predominant aphid species

Since transplanting, PRSV incidence was recorded at weekly intervals based on symptoms. It is inferred that, fresh incidence of PRSV (%) coincided with major aphid vectors caught in yellow sticky traps suggesting the strong link between aphid vector abundance and PRSV incidence (Table 1). During early 4 weeks of transplanting, the infection was not observed. However the infection was gradually increased from 13th week and reached 100 per cent by 23rd week of transplanting as the number of trap catches increased. This is mainly due to the duration of the incubation period of PRSV is generally 3 to 4 weeks in the field [11, 5]. Nonpersistent viruses are transmitted rapidly to a number of plants in a manner related to the number of viruliferous vectors available [9]. The number of efficient vectors involved decides the epidemiology of PRSV incidence. Hence, a very high incidence of PRSV was observed between 14th week and 23rd week coincided with increased aphid population. The infected plants grown in the surrounding landscape may also contributed for the rate of spread of virus within a short period.

3.4. Population dynamics of aphid vectors in relation to weather parameters

Climatic factors exert a great influence on the development, distribution and population dynamics of aphids. Many researchers have also proved that spread of aphid borne non-persistent viruses follows the seasonality of vectors especially the dominant species [12, 13]. The fluctuation in per cent PRSV infection was noticed in synchrony with the abundance of major vectors. Hence, in the present study attempts were made to identify the weather factors which influence population build-up of major aphid vectors.

The seasonal dynamics of aphid population in relation to weather factors revealed that the aphid population remained active throughout the year (Table 2). Initially, a high aphid population was recorded in the month of August (2,737), then the population diminished in succeeding months due to heavy rainfall which was recorded 39.18 mm in the month of September [11]. The rainfall that occurred during this period had a negative effect on population of major aphid vectors *viz*., *A. gossypii, A. craccivora*, *A. nerii*, *M. persicae* and *P. nigronervosa*. Similar observations were also made by Shivanna *et al.* [14], who reported that the precipitation had negative effect on all the sucking pests. Present results were also in confirmation with the observations of Subhash *et al.* [15] who stated that aphid populations were reduced during rainy days of September in Southern Karnataka. Significantly and suddenly stimulated rainfall of 9.2 mm or 1.0-2.0 cm could lead to mortality of *M. persicae* by 45.47-66.43 per cent due to washing off and drowning. The reduction being greater at the higher rainfall than the lower rainfall [7]. Piyaratne *et al*., too reported, heavy rainfall decreases the aphid population with other indirect consequences like virus spreading [16].

A peak population of aphids were observed during November (2333), December (3095) and attained a peak of 15,808 in January, February (6657) and March (4415) *i.e*., throughout the ascending phase of the aphid population right up to its observed peak, the maximum temperature was at downward trend till peak aphid population reached. These findings were in accordance with Narjary *et al*., who found building up of aphid population started when temperature showed downward trend [17]. Simple correlation analysis also revealed that maximum temperature during winter season showed significant positive correlation with population.

The highest population in January was coinciding with days with no rainfall, mean maximum and minimum temperature of 34.97 and 22.32^{0}C, maximum and minimum relative humidity of 59.16% and 33.99% respectively (Table 3). Many workers also noticed maximum population of *A. gossypii* and *M. persicae* from November which reached maximum during December and January [18, 7].

3.5. Correlation between weather parameters and population dynamics of aphids

The correlation coefficient showed negative relation with minimum temperature, *i.e*., aphid population started building up when minimum temperature showed downward trend (Table 4). The best predictors of *B. brassicae* and *M. persicae* are the days with minimum temperature of >15^{0}C and days with air relative humidity greater than 70% [19]. Nisha [20] also stated maximum and minimum temperature had significant negative correlation (r = -0.456 and r = -0.250) with population of aphid. It was concluded that the less or no rainfall and the minimum temperature with high relative humidity during these months had profound positive correlation on population, because aphid dynamics were largely dependent on temperature and relative humidity, however, aphid population was not significantly correlated with rainfall [21].

Later, population showed a declining trend during April (1699) and May (1263). During summer (March, April and May) the maximum temperature range of 42.89-52.80°C showed highly significant negative correlation with population of major aphid vectors *viz*., *A. gossypii* (r = -0.514, -0.395, -0.350), *A. craccivora* (r = -0.441, -0.228, -0.211), *A. nerii* (r = -0.215,
-0.014, -0.218) *M. persicae* (r = -0.487, -0.483, -0.078) and *P. nigronervosa*
(r = -0.079, -0.196, -0.133). The results are in confirmatory with the findings of Patel *et al.,* who stated that maximum temperature had negative influence on population of *A. craccivora* on cowpea [22]. The maximum activity of aphid during January, February and declining trend in April was also observed by others scientists [23].

The rainfall that occurred during August to October had a negative impact on population of major aphid vectors. The highest rainfall in September (39.18 mm) showed highly positive significant correlation with population of aphids (Table 4). Whereas in the month of November except maximum temperature, all weather parameters showed positive correlation with the population. The less or no rainfall during December, January and February and minimum temperature in January had profound positive correlation on aphid population which was highest during these months (Table 2 & 3).

It is clear that among different contributing factors rainfall, temperature and relative humidity had a role in seasonal fluctuation of aphid population. These predictors are useful for the management of aphid species, because they can forewarn the best starting time. Such observations were also made by Manzar *et al*., wherein they state that among the different weather parameters, temperature and relative humidity are the most important factors affecting aphid's multiplication and growth [24]. This is also in accordance with the earlier report of Sarvendra *et al*., who reported that, average temperature between 21-28^{0}C and average relative humidity of 61-75 per cent were highly conducive for the aphid infestation [18].

Table 1: Weekly cumulative number of major vectors of PRSV contributing for increased percent infection in Papaya

Month	Date of observation	Aphid species					No. of Plants infected	Percent infection (%)
		A. gossypii	*A. craccivora*	*M. persicae*	*A. nerii*	*P. nigronervosa*		
Aug-13	1st week	408	212	23	11	0	0	0
	2nd week	830	421	42	27	0	0	0
	3rd week	1194	561	56	39	0	0	0
	4th week	1571	690	66	43	0	0	0
Sep-13	5th week	1860	859	90	51	4	2	4
	6th week	2146	1024	124	62	4	2	4
	7th week	2476	1202	150	74	4	5	10
	8th week	2712	1295	181	79	8	6	12
	9th week	2944	1375	203	87	11	8	16
Oct-13	10th week	3108	1485	208	94	18	9	18
	11th week	3337	1640	217	106	20	9	18
	12th week	3579	1774	226	123	24	11	22
	13th week	3918	1949	234	136	33	12	24
Nov-13	14th week	4225	2090	290	150	40	12	24
	15th week	4677	2295	329	166	44	18	36
	16th week	4985	2420	354	177	47	23	46
	17th week	5341	2523	388	181	50	26	52
Dec-13	18th week	5687	2712	405	194	54	30	60
	19th week	6092	2939	420	208	59	33	66
	20th week	6376	3123	430	219	59	36	72
	21st week	6618	3278	442	231	59	42	84
	22nd week	7244	3580	461	246	63	49	98
Jan-14	23rd week	8782	4129	500	256	64	50	100
No. of traps installed = 32								

Table 2: Number and percent contribution of different species of aphids trapped during August-2013 to July-2014

Species	Aug-2013	Sep-2013	Oct-2013	Nov-2013	Dec-2013	Jan-2014	Feb-2014	Mar-2014	Apr-2014	May-2014	Jun-2014	Jul-2014	Total	Percent contribution
A. gossypii	1742	1202	1120	1447	1733	11418	4968	2767	1218	740	583	1248	30186	66.04
A. craccivora	800	575	635	572	998	3938	1499	1272	255	414	433	859	12250	26.80
A. nerii	46	41	55	44	60	135	90	125	11	17	35	35	694	1.52
A. bambusae	31	37	84	35	129	73	11	18	11	6	12	17	464	1.02
M. persicae	70	133	59	139	60	168	45	50	40	16	90	98	968	2.12
H. carduellinus	36	64	60	58	78	32	12	40	17	23	45	62	527	1.15
B. brassicae	10	24	21	24	25	18	19	29	44	2	8	26	250	0.55
P. nigronervosa	2	9	26	14	12	26	13	114	103	45	2	7	373	0.82
Total	2737	2085	2060	2333	3095	15808	6657	4415	1699	1263	1208	2352	45712	100.00

No. of traps installed = 32

Table 3: Average weather data recorded to study epidemiology of PRSV in Papaya from August-2013 to July 2014

Month	Rain fall (mm)	Temperature (◦C)		Relative Humidity (%)	
		Maximum	Minimum	Maximum	Minimum
Aug-13	5.89	27.50	18.88	93.33	54.70
Sep-13	39.18	27.60	18.89	91.70	57.89
Oct-13	14.80	27.72	19.08	91.79	58.18
Nov-13	7.55	28.01	17.31	90.57	52.42
Dec-13	0.00	36.89	23.17	68.19	31.15
Jan-14	0.00	34.97	22.32	64.81	33.99
Feb-14	0.00	33.87	24.80	64.31	30.93
Mar-14	2.03	42.89	23.45	65.33	21.83
Apr-14	1.28	50.21	26.56	58.04	28.44
May-14	8.92	44.31	25.33	52.82	31.67
Jun-14	14.09	47.90	26.33	64.84	30.00
Jul-14	13.44	36.29	24.16	83.28	48.50

Table 4: Pearson's correlation coefficients between numbers of aphids trapped and weather parameters during August-2013 to July-2014

Species identified	August-2013					September-2013				
	RF (mm)	Temp (◦C)		RH (%)		RF (mm)	Temp (◦C)		RH (%)	
		Max.	Min.	Max.	Min.		Max.	Min.	Max.	Min.
A. gossypii	-0.142	0.346	-0.752*	-0.701*	-0.573	0.709*	-0.680*	-0.212	0.690*	0.409
A. craccivora	-0.441	0.630	0.454	-0.891**	-0.745*	0.894**	-0.469	0.070	0.761*	0.379
A. nerii	0.418	0.106	0.377	-0.549	-0.145	0.802**	0.088	-0.067	0.634*	-0.218
A. bambusae	0.673*	-0.260	0.072	0.108	0.310	0.742*	0.187	0.052	0.395	-0.147
M. persicae	0.044	0.096	-0.370	-0.490	-0.130	0.079	0.440	0.084	-0.162	-0.338
Hyperomyzus spp.	0.298	-0.287	0.207	-0.268	0.128	0.855**	-0.203	-0.079	0.793*	0.008
B. brassicae	0.197	-0.372	0.036	-0.134	0.258	0.254	0.082	-0.112	0.062	-0.059
P. nigronervosa	-0.298	0.509	-0.252	-0.169	-0.382	-0.788*	0.440	0.104	-0.740*	-0.239

Species identified	October-2013					November-2013				
	RF (mm)	Temp (◦C)		RH (%)		RF (mm)	Temp (◦C)		RH (%)	
		Max.	Min.	Max.	Min.		Max.	Min.	Max.	Min.
A. gossypii	0.558	-0.426	0.360	0.086	0.035	-0.2025	-0.076	0.015	0.518	0.311
A. craccivora	0.704*	-0.317	0.043	0.251	0.041	-0.510	-0.179	0.225	0.683	0.689
A. nerii	-0.169	0.030	0.118	-0.284	-0.195	-0.5831	0.014	0.349	0.563	0.684
A. bambusae	0.603	-0.496	0.382	0.539	0.196	-0.200	-0.173	0.337	0.601	0.680
M. persicae	-0.133	-0.117	-0.063	-0.554	-0.148	-0.255	0.003	0.314	0.270	0.735*
Hyperomyzus spp.	0.184	-0.482	0.540	0.123	0.254	-0.411	0.118	0.444	0.232	0.527
B. brassicae	0.532	-0.672*	0.088	0.346	0.390	0.106	0.360	0.703	-0.062	0.300
P. nigronervosa	-0.061	-0.644	0.432	0.542	0.637	-0.500	-0.219	0.085	0.478	0.694

Species identified	December-2013					January-2014				
	RF (mm)	Temp (◦C)		RH (%)		RF (mm)	Temp (◦C)		RH (%)	
		Max.	Min.	Max.	Min.		Max.	Min.	Max.	Min.
A. gossypii	.a	0.195	-0.606	0.073	-0.009	.a	-0.607	0.561	-0.550	0.087
A. craccivora	.a	0.043	-0.398	0.215	0.182	.a	-0.304	0.253	-0.2664	-0.082
A. nerii	.a	0.143	-0.130	0.250	0.227	.a	-0.391	0.259	-0.4038	0.426
A. bambusae	.a	-0.110	0.218	-0.700*	0.527	.a	-0.507	0.134	-0.2207	-0.044
M. persicae	.a	0.335	-0.596	0.371	-0.143	.a	0.086	-0.079	0.204	-0.542
Hyperomyzus spp.	.a	-0.285	-0.075	0.085	0.408	.a	-0.059	-0.051	-0.0191	-0.218
B. brassicae	.a	-0.291	-0.023	-0.231	0.425	.a	-0.698*	0.589	-0.4846	0.218
P. nigronervosa	.a	0.399	0.195	-0.472	0.748*	.a	-0.828**	0.547	-0.677*	0.391

Species identified	February-2014					March-2014				
	RF (mm)	Temp (◦C)		RH (%)		RF (mm)	Temp (◦C)		RH (%)	
		Max.	Min.	Max.	Min.		Max.	Min.	Max.	Min.
A. gossypii	.a	0.444	-0.656	0.245	0.580	0.764*	-0.514	0.284	0.428	0.798*
A. craccivora	.a	0.748	-0.539	0.008	0.247	0.344	-0.441	0.192	0.557	0.862**
A. nerii	.a	0.194	-0.589	-0.086	0.258	-0.508	-0.215	-0.028	0.254	0.231
A. bambusae	.a	0.554	-0.337	0.147	-0.154	0.260	0.514	-0.050	-0.115	-0.265
M. persicae	.a	0.816*	-0.353	0.298	-0.198	0.572	-0.487	0.308	0.395	0.741*
Hyperomyzus spp.	.a	0.592	-0.597	-0.243	0.004	-0.676	-0.264	-0.468	0.224	-0.226
B. brassicae	.a	0.207	-0.360	0.053	-0.333	-0.445	0.298	-0.148	0.223	-0.047
P. nigronervosa	.a	0.515	-0.242	0.115	-0.127	-0.032	-0.079	0.604	-0.636	-0.120

Species identified	Apr-14					May-14				
	RF (mm)	Temp (◦C)		RH (%)		RF (mm)	Temp (◦C)		RH (%)	
		Max.	Min.	Max.	Min.		Max.	Min.	Max.	Min.
A. gossypii	0.167	-0.395	0.613	0.294	-0.139	-0.328	-0.350	0.399	-0.164	0.262
A. craccivora	-0.058	-0.228	0.079	0.605	-0.463	0.394	-0.211	0.560	0.167	0.149
A. nerii	-0.124	-0.014	-0.203	0.471	-0.320	0.461	-0.218	0.357	0.389	-0.024
A. bambusae	0.089	0.197	0.084	-0.032	0.187	0.135	-0.445	0.590	-0.176	0.509
M. persicae	-0.229	-0.483	0.402	0.465	-0.448	0.192	-0.078	0.008	0.633	-0.246
Hyperomyzus spp.	0.555	0.181	0.368	-0.075	0.099	0.242	0.102	0.084	0.464	-0.195
B. brassicae	-0.015	-0.100	0.378	-0.031	0.080	-0.182	0.585	-0.374	0.118	-0.259
P. nigronervosa	0.546	-0.196	-0.181	0.623	-0.183	-0.678*	-0.133	0.039	-0.598	0.412

Species identified	Jun-14					Jul-14				
	RF	Temp (◦C)		RH (%)		RF	Temp (◦C)		RH (%)	
		Max	Min	Max	Min		Max	Min	Max	Min
A. gossypii	0.210	.a	-0.096	-0.009	.a	-0.566	-0.217	-0.365	0.743*	0.163
A. craccivora	0.200	.a	-0.410	0.494	.a	-0.763*	-0.275	-0.432	0.741*	0.218
A. nerii	0.031	.a	-0.066	-0.274	.a	-0.116	0.330	0.182	0.365	-0.378
A. bambusae	0.546	.a	-0.220	0.266	.a	-0.330	-0.351	-0.478	0.704*	0.302
M. persicae	-0.268	.a	-0.417	0.448	.a	-0.800**	-0.730*	-0.746*	0.669*	0.716*
Hyperomyzus spp.	0.113	.a	-0.308	0.397	.a	-0.520	-0.617	-0.637	0.314	0.602
B. brassicae	0.104	.a	-0.535	0.345	.a	-0.808**	-0.497	-0.620	0.742*	0.449
P. nigronervosa	0.395	.a	-0.316	0.368	.a	-0.471	-0.355	-0.454	0.361	0.316

4. Conclusion

In general from the present epidemiological results it was concluded that, the population was at its peak with rainfall of below 8.00mm, maximum temperature of 28-35^{0}C, minimum temperature of 17-23^{0}C, maximum and minimum relative humidity range of 60-90% and 30-50% respectively. Whereas, maximum rainfall range between 5.89-39.18 mm during rainy season, maximum temperature range of 42.89-52.80^{0}C during summer and the relative humidity of less than 52% are not contributing for population build-up.

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