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Incidence of Major Pests of Pongamia (*Milletia pinnata* L.) as Influenced by Weather Parameters

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Abstract

The incidence of major pests of pongamia in relation to weather parameters was observed during 2016-17 at Zonal Agricultural Research Station, UAS, GKVK, Bangalore. The important pests recorded on pongamia were blotch miner (*Acrocercops anthrauris* Fabricius), spiralling whitefly *Aleurodiccus disperses* (Russel), flower gall producing *Aspondylia pongamiae* Mani and the eriophyid mite, *Aceria pongamiae* Channabasavanna causing leaf galls. Correlation between *A. pongamiae* with weather variables of the preceeding fortnight revealed that, it had highly significant and positive correlation with maximum temperature and minimum temperature ($r= 0.563$, $r= 0.868$, $p<0.01$), respectively. Leaf gall number was significantly and positively correlated with minimum temperature ($r = 0.583$, $p<0.01$), rainfall ($r= 0.478$, $p<0.05$) and wind speed ($r = 0.463$, $p<0.05$). Regarding correlation with corresponding fortnight weather data, *A. pongamiae* incidence was significantly and positively correlated with maximum temperature ($r = 0.465$, $p<0.01$) and minimum temperature ($r= 0.842$, $p<0.05$) leaf gall number due to *A. pongamiae* was significantly and positively correlated with minimum temperature ($r = 0.597$, $p<0.01$), and rainfall ($r = 0.541$, $p<0.01$). Blotch miner incidence was significantly and positively correlated with maximum temperature ($r = 0.421$, $p<0.01$) and minimum temperature ($r = 0.767$, $p<0.01$) of the preceding week. Spiralling whitefly incidence was significantly positively correlated with maximum temperature ($r = 0.652$, $p<0.01$) and minimum temperature *i.e.*, ($r=0.541$, $p<0.01$). Flower galls caused by *A. pongamiae* showed significant and positive correlation with afternoon relative humidity ($r = 0.733$, $p<0.01$) and minimum temperature ($r= 0.311$, $p<0.05$). Regarding correlation with the corresponding week weather parameters, blotch miner showed significant and positive correlation with minimum temperature ($r=0.725$, $p<0.01$), maximum temperature ($r = 0.310$, $p<0.05$), afternoon RH ($r= 0.341$, $p<0.05$) and wind speed ($r= 0.325$, $p<0.05$). Spiralling whitefly, incidence showed significantly positive correlation with maximum and minimum temperature *i.e.*, ($r = 0.518$, $p<0.01$ and $r=0.522$, $p<0.01$), whereas, flower galls were significantly and positively correlated with afternoon relative humidity ($r = 0.688$, $p<0.01$), minimum temperature ($r= 0.342$, $p<0.05$) while it was significantly and negatively correlated with maximum temperature ($r = -0.303$, $p<0.05$) and total rainfall ($r = - 0.594$, $p<0.01$)

Keywords: Pongamia, *Aceria pongamiae*, leaf galls, flower galls, weather parameters

Pongamia (*Milletia pinnata* L.), belongs to family Fabaceae, is a medium-sized evergreen or briefly deciduous, glabrous shrub or tree normally growing to a height of 15-25 m high with straight or crooked trunk of 50-80 cm diameter and broad crown of spreading or drooping branches (Sangwan *et al*., 2010). It is a medium sized glabrous tree, mainly distributed in tidal forests of India. Recent recognition of the importance of the seeds of this plant as a raw material for bio-fuel production extends its economic utility for industrial applications also.

Non-edible oil contains several unsaponifiable and toxic components, which make them unsuitable for human consumption. Karanja (*Pongamia pinnata*) is an underutilized plant which is grown in many parts of India. Sometimes the oil is contaminated with high free fatty acids (FFAs) depending upon the moisture content in the seed during collection as well as oil extraction (Naik *et al*., 2008). The eriophyid mite *A. pongamiae* Channabasavanna and flower galls caused due to *A. pongamiae* Mani are the major pests. *A. pongamiae* feeds on the leaves which lead to the formation of elongate finger like pouches of varying dimensions on both surfaces of the leaves. Individual galls fuse to form complex and irregularly shaped massive structures covering the entire laminar area including the midrib, vein and veinlets. This results

in severe distortion of the leaves and drastically affects the photosynthetic activity of the plant, leading to reduction of biomass and adversely affects the growth of *P. pinnata*. The pest showed higher percentage of damage and number of galls during May leading to a significant reduction in leaf area (Nasareen and Ramani, 2014).

Some important natural enemies observed on *P. Pinnata are Green lacewing, Chrysoperla* sp. Mantids, Spiders, Predatory red stink bug, *Euthyrhynchus floridanus* Linnaeus and Lady bird beetle (Sahu *et al*., 2016).

Growth attributes *viz*., length, collar girth and biomass in treated (non-infested) seedlings are significantly higher than the untreated (infested) seedlings of *P. pinnata,* ($p<0.001$) (Sahadev *et al*., 2009). However, flower galls caused by *A. pongamiae* are also important due to its negative impact on seed set (Sundararaj *et al*., 2005). The present investigation focuses on the population dynamics of major pests of Pongamia in relation to the climatic factors, the findings of which are discussed in the light of earlier reports on similar type of investigations.

Material and Methods

Incidence of eriophyid mite, *Aceria pongamiae* and Leaf gall

For the purpose of recording the incidence of eriophyid mite, *A. pongamiae* and leaf gall causes on Pongamia, fifteen galled leaf samples were collected randomly from Pongamia and observations were carried out for one year, at fortnightly intervals. The leaf samples were kept in polyethelene bags and tied loosely with rubber bands for subsequent transportation to the laboratory for further observation under microscope. Data was recorded on the number of galls developed on both abaxial and adaxial surface of the leaves. Data on temperature, relative humidity, and rainfall of the study site were obtained from AICRP (Agro-meteorology), GKVK, Bangalore. The incidence of *A. pongamiae* and the number of leaf galls was subjected to correlation and multiple linear regression analysis with the weather parameters of the corresponding fortnight and also with that of the preceeding fortnight.

Incidence of blotch miner, spiralling whitefly and flower galls caused by *Aspondylia pongamiae*

The data pertaining to the incidence of insect pests of blotch miner, spiralling whitefly and flower galls on Pongamia were recorded at weekly interval for a period of one year. Fifteen trees were labelled and observed for the incidence of these three pests at weekly intervals. The observation on the pest population was recorded from five upper, five middle and five lower leaves, in each of the fifteen plants from each replication. The same set of labelled plants were used for continuously recording observations during the study period. Incidence of blotch miner, spiralling whitefly and flower galls was subjected to correlation and multiple linear regression analysis with weather parameters of both preceeding and corresponding week.

Weather parameters are mentioned in regression tables as *:*

R_1 = Maximum temperature (^{0}C)

R_2 = Minimum temperature (^{0}C)

R_3 = Relative humidity in the morning (%)

R_4 = Relative humidity in the afternoon (%)

R_5 = Wind speed (km/day)

R_6 = Bright sunshine (hrs)

R_7 = Total rainfall (mm)

Results and Discussion

The results pertaining to the incidence of major pests of Pongamia (*Milletia pinnata* L.) are discussed here under.

Incidence of *Aceria pongamiae* and leaf galls in relation to weather parameters

Maximum mite (*Aceria pongamiae*) population was observed in II fortnight of May (197.96), followed by first fortnight of May (173.03). No mite population was observed in the entire month of February and first fortnight of January (Table Ia and Ib).

Maximum number of leaf galls due to *A. pongamiae* infestation was observed during I fortnight of June (68.7), followed by II fortnight of June (63.64). No leaf gall infestation was observed during II fortnight of January and first fortnight of February (Table Ia and Ib).

TABLE I a

Incidence of Aceria pongamiae *and leaf galls caused by* A. pongamiae *in relation to weather parameters of the preceeding fortnight (2016-17)*

Fort night of eachMonth	Std.Met. week	Date of Observation	No of *A.Pongamiae /gall*	Leaf galls (No/leaf)	Temp (^{0}C)		RH (%)		Wind speed (Km/day)	Sunshine (Hrs)	Total Rainfall(mm)
					Max.	Min.	Morning	A/N			
I FN. Oct	40	3-10-2016	152.97	6.68	28.89	19.05	93.15	50.86	6.20	5.40	16.40
II FN. Oct	42	17-10-2016	121.30	10.41	29.42	18.76	84.93	48.07	4.45	7.05	30.20
I FN. Nov	45	7-11-2016	110.36	12.35	29.68	17.76	80.86	46.50	3.70	8.80	0.00
II FN. Nov	47	21-11-2016	80.87	11.08	29.33	17.20	81.43	45.36	6.20	8.40	0.00
IFN. Dec	49	5-12-2016	70.47	5.76	29.69	21.80	82.29	40.22	5.35	8.70	1.70
II FN. Dec	51	19-12-2016	11.21	4.32	26.09	15.36	86.22	49.57	7.45	4.70	58.20
I FN. Jan	2	9-01-2017	4.50	1.32	28.03	13.76	89.07	48.57	5.30	9.15	0.000
II FN. Jan	4	23-01-2017	0.00	0.00	27.30	13.64	88.5	41.43	5.15	8.80	0.00
I FN. Feb	6	6-02-2017	0.00	0.00	27.03	14.76	89.36	39.00	9.10	7.60	0.00
II FN. Feb	8	20-02-2017	0.00	3.66	28.59	14.66	84.22	36.29	5.65	10.40	0.00
I FN. Mar	11	13-03-2017	24.50	6.07	30.69	15.20	84.29	34.79	8.05	9.95	1.40
II FN. Mar	13	27-03-2017	26.40	8.10	32.13	17.55	82.64	35.22	6.05	9.15	0.00
I FN. Apr	15	9-04-2017	161.26	9.87	32.83	20.22	81.00	41.00	6.70	8.95	1.60
II FN. Apr	17	23-04-2017	166.16	13.98	34.80	21.00	82.00	36.50	6.95	8.95	0.00
I FN. May	19	7-05-2017	173.03	23.95	35.15	22.15	83.00	36.00	7.55	8.10	41.00
II FN. May	21	21-05-2017	197.96	38.94	34.05	21.65	83.00	33.50	6.50	8.50	179.20
I FN. Jun	23	4-06-2017	172.83	68.70	33.05	21.05	83.00	41.50	7.35	7.45	29.90
II FN. Jun	25	18-06-2017	169.80	63.64	31.10	19.85	87.50	44.50	9.40	7.35	40.60
I FN. Jul	27	2-07-2017	101.43	41.23	28.80	20.40	89.00	55.00	10.55	4.55	13.40
II FN. Jul	29	16-07-2017	91.43	31.75	28.20	19.75	88.50	55.00	11.15	4.95	16.00
I FN. Aug	31	01-08-2017	114.03	32.85	28.50	19.75	91.50	59.00	9.70	3.95	77.40
II FN. Aug	34	16-08-2017	159.83	20.67	28.70	19.65	86.50	54.50	11.60	6.05	97.00
I FN. Sep	36	05-09-2017	157.86	14.93	28.05	19.90	91.00	56.00	5.85	3.35	130.00
II FN. Sep	38	19-09-2017	150.43	12.08	27.50	19.70	91.00	61.50	7.25	3.35	48.60

NB: FN: Fortnight

TABLE I b

Incidence of Aceria pongamiae *and leaf galls caused by* A. pongamiae *in relation to weather parameters of the corresponding fortnight (2016-17)*

Fort night of eachMonth	Std.Met. week	Date of Observation	No of *A.Pongamiae /gall*	Leaf galls(No/leaf)	Temp (^{0}C)		RH (%)		Wind speed (Km/day)	Sunshine (Hrs)	Total Rainfall(mm)
					Max.	Min.	Morning	A/N			
I FN. Oct	40	3-10-2016	152.97	6.68	29.05	18.79	92.00	48.93	5.55	6.60	30.20
II FN. Oct	42	17-10-2016	121.30	10.41	29.70	17.05	77.29	45.72	3.55	9.00	0.00
I FN. Nov	45	7-11-2016	110.36	12.35	29.45	17.04	81.86	46.07	4.70	8.80	0.00
II FN. Nov	47	21-11-2016	80.87	11.08	29.67	16.90	83.07	42.07	4.35	7.95	1.70
IFN. Dec	49	5-12-2016	70.47	5.76	28.43	14.80	82.57	62.86	7.20	6.70	58.20
II FN. Dec	51	19-12-2016	11.21	4.32	26.47	14.51	88.65	48.57	5.85	6.65	0.000
I FN. Jan	2	9-01-2017	4.50	1.32	27.64	12.89	88.29	40.15	6.35	9.95	0.00
II FN. Jan	4	23-01-2017	0.00	0.00	27.00	14.60	92.14	40.65	5.15	8.80	0.00
I FN. Feb	6	6-02-2017	0.00	0.00	27.29	15.43	85.57	38.57	6.80	8.15	0.00
II FN. Feb	8	20-02-2017	0.00	3.66	29.66	14.26	83.36	33.93	7.25	10.15	1.40
I FN. Mar	11	13-03-2017	24.50	6.07	31.95	15.40	81.71	32.43	8.35	9.45	0.00
II FN. Mar	13	27-03-2017	26.40	8.10	32.27	20.00	85.07	41.43	5.90	8.45	1.60
I FN. Apr	15	9-04-2017	161.26	9.87	34.20	20.49	80.22	37.72	6.35	9.35	0.00
II FN. Apr	17	23-04-2017	166.16	13.98	35.15	21.95	82.00	37.00	7.30	8.55	41.00
I FN. May	19	7-05-2017	173.03	23.95	35.00	22.15	84.00	36.00	6.45	8.25	179.20
II FN. May	21	21-05-2017	197.96	38.94	32.65	21.05	81.50	39.50	7.70	7.55	29.90
I FN. Jun	23	4-06-2017	172.83	68.70	32.85	20.35	86.00	38.50	6.20	7.25	40.60
II FN. Jun	25	18-06-2017	169.80	63.64	29.75	20.25	88.00	50.00	8.15	7.50	13.40
I FN. Jul	27	2-07-2017	101.43	41.23	28.10	19.85	90.00	56.50	10.50	3.55	16.00
II FN. Jul	29	16-07-2017	91.43	31.75	28.65	19.85	90.00	55.50	9.95	4.65	77.40
I FN. Aug	31	01-08-2017	114.03	32.85	27.50	19.70	89.00	60.00	11.45	3.85	97.00
II FN. Aug	34	16-08-2017	159.83	20.67	28.50	19.50	89.00	53.50	11.30	5.35	130.00
I FN. Sep	36	05-09-2017	157.86	14.93	28.25	20.10	90.50	59.50	7.60	3.60	48.60
II FN. Sep	38	19-09-2017	150.43	12.08	27.35	19.75	92.50	58.50	46.80	8.80	257.00

NB: FN: Fortnight

From the results, it can be conclude that the number of gall to be highest during May. Population studies carried out on *A. pongamiae* enabled to record seasonal fluctuations in the mite density within the leaf galls. The initiation of infestation was recorded in February, reaching to peak population in May. The decline in mite population since June would be reflecting the negative impact of rainfall received by the site. There is no mite population and galls recorded on Pongamia in January and February because of shedding of leaves. Even though the mites enjoy a highly secluded habitat available within the leaf galls, rainfall exerts an adverse effect by penetrating through the holes in to the interior of the gall cavity (Aratchige *et al*., 2012)

The results have been found to be in conformity with the findings of (Aratchige *et al.*, 2012) who reported a significant and negative impact of rainfall on the population density of *Neoseiulus baraki*. Low number of mites recorded inside the dried galls during October and November could be possibly explained on the grounds of their escape in search of suitable sites like the under surfaces of the bark or to hibernate or tide over the unfavourable conditions through the phenomenon of deuterogyny. The plants shed the leaves in January. The trend observed on the population fluctuation of *A. pongamiae* has been found to be in accordance with the findings of (Nasareen and Ramani, 2014) who reported maximum population density of *A. litchi* during April-May and minimum during November-December. Another study also recorded similar trends in population of *Aculus euphorbiae* feeding on *euphorbia* spp. recording a lower population in winter.

Correlation between incidence of *Aceria pongamiae* and leaf galls with weather parameters of preceeding fortnight

The correlation between eriophyid mite population with weather parameters of preceeding fortnight was found to be highly significant and positively correlated with maximum temperature ($r= 0.563$, $p<0.01$) and minimum temperature ($r= 0.868$, $p<0.01$), while it was non- significant and positive with wind speed ($r = 0.166$) and total rainfall ($r = 0.242$). However, mite incidence was negatively correlated with morning RH ($r = -0.070$), afternoon RH ($r = -0.036$) and sunshine hours ($r = -0.315$) (Table II).

The correlation between number of leaf galls caused by mite with weather parameters of preceeding fortnight was found to be significantly positively correlated with minimum temperature ($r = 0.583$, $p<0.01$), total rainfall ($r = 0.478$, $p<0.05$) and wind speed ($r = 0.463$, $p<0.05$). However, gall incidence was found to have non-significant positive correlation with maximum temperature ($r = 0.390$) and it was non-significantly negatively correlated with morning RH ($r = -0.008$), afternoon RH ($r = -0.299$) and sunshine hrs ($r = -0.242$) (Table II).

Correlation between incidence of *Aceria pongamiae* and leaf galls with weather parameters of corresponding fortnight

The correlation analysis between eriophyid mite population with weather parameters of corresponding fortnight was found to be significantly and positively correlated with maximum temperature ($r = 0.465$, $p<0.01$) and minimum temperature *i.e.* ($r = 0.842$, $p<0.05$) and mite population showed non-significant positive correlation with afternoon RH ($r = 0.221$),

TABLE II

Correlation between incidence of Aceria pongamiae a*nd leaf galls with weather parameters of the preceeding fortnight*

Mite / leafgall	Temp (^{0}C)		RH (%)		Wind speed (Km/day)	Bright Sunshine (Hrs)	Total Rainfall (mm)
	Max.	Min.	Morning	A/N			
Aceria pongamiae	0. 563 **	0. 868 **	- 0. 070	- 0. 036	0. 166	-0. 315	0. 242
Leaf galls	0. 390	0. 583 **	- 0. 008	- 0. 299	0. 463 *	-0. 242	0. 478 *

TABLE III

Correlation between incidence of Aceria pongamiae *and leaf galls with weather parameters of the corresponding fortnight*

Mite / leafgall	Temp (^{0}C)		RH (%)		Wind speed (Km/day)	Bright Sunshine (Hrs)	Total Rainfall (mm)
	Max.	Min.	Morning	A/N			
Aceria pongamiae	0.465 **	0.842 *	-0. 061	0. 221	0. 199	-0. 360	0.382
Leaf galls	0. 239	0. 597 **	0. 109	0. 166	0. 374	-0. 341	0. 541 **

wind speed (r = 0.199) and total rainfall (r = 0.382). Negative correlation was recorded between morning RH (r = -0.061) and sunshine hrs (r = -0.360) with mite incidence. However, but this relationship was found to be non-significant (Table III).

The correlation between incidence of leaf galls with weather parameters of corresponding fortnight was found to be significant and positively correlated with minimum temperature (r = 0.597, $p<0.01$), and total rainfall (r = 0.541, $p<0.01$), while it showed non-significant positive correlation with maximum temperature (r = 0.239), morning RH (r = 0.109), afternoon RH (r = 0.166) and wind speed (r = 0.374). However, leaf gall number was negatively correlated with sunshine hours (r = -0.341) and this relationship was non-significant (Table III).

Multiple linear regression between incidence of *Aceria pongamiae* and leaf galls with weather parameters of preceeding fortnight

Multiple linear regression analysis revealed that the weather parameters of preceeding fortnight influenced *A. pongamiae* and leaf gall formation to an extent of 81.9 and 69.3 per cent, respectively. Aratchige *et al.* (2012) and Nasareen *et al.* (2014) also reported a similar impact of weather parameters on leaf galls and eriophyid mites (Table IV).

Multiple linear regression between incidence of *Aceria pongamiae* and leaf galls with weather parameters of corresponding fortnight

Multiple linear regression analysis revealed that the weather parameters of corresponding fortnight influenced *A. pongamiae* and leaf gall formation to an extent of 80.7and 69.1 percent, respectively (Table V).

TABLE IV

Multiple linear regression between incidence of Aceria pongamiae *and leaf galls with weather parameters of the preceeding fortnight*

Mite / leafgall	Regression equation	R^2
Aceria pongamiae	$Y=-594.313+11.174R_1$ $+14.789R_2-1.674R_3+$ $0.157R_4-2.866R_5$ $-6.943R_6+0.503R_7$	81.90
Leaf gall	$Y=34.617+1.625R_1$ $+2.057R_2+ 0.665R_3$ $+0.459R_4+3.484R_5-$ $0.181R_6 - 0. 158R_7$	69.30

TABLE V

Multiple linear regression between incidence of Aceria pongamiae *and leaf galls with weather parameters of the corresponding fortnight*

Mite / leafgall	Regression equation	R^2
Aceria pongamiae	$Y=—293.683-4.609R_1$ $+ 25.382R_2-2.920R_3$ $+3.627R_4+0.880R_5$ $+18.90R_6 - 0. 911 R_7$	80.70
Leaf gall	$Y=-42.610-5.563R_1$ $+7.727R_2-0.961R_3$ $+ 0.746R_4+5.443R_5$ $+12.097R_6 - 0.645R_7$	69.10

Aratchige *et al.* (2012) and Nasareen *et al.* (2014) also reported about weather parameters influencing leaf galls and eriophyid mites to an extent of 78.3 and 50.28 per cent, respectively, which is similar to the present findings (Table V).

Incidence of blotch miner, spiralling whitefly and flower galls caused by *Aspondylia pongamiae* in relation to weather parameters

Maximum blotch miner population was observed in I week of June (49.8), followed by II week of June (31.12). Maximum spiralling whitefly population (*i.e.*, egg spiral number) was observed in I week of May (14.91), followed by IV week of April (14.63). Maximum number of flower galls due to *Aspondylia pongamiae* was observed during III week of June (9.16) followed by IV week of October (9.06) (Table VIa & VIb). From this we can conclude that temperatures may be favourable for the egg spirals of *Aleurodiccus* whitefly.

Intensive study on the incidence of whitefly family *Aleyrodidae* was undertaken at monthly intervals and the weather condition was recorded (Chikkaswamy *et al*., 2014). The incidence of whitefly was maximum in May and June months, which is due to suitable temperatures for whitefly population.

In Pongamia, the plants shed the leaves in January, and new flesh will start in the middle of February. Pongamia trees come into flower from late February to March and flowers until the middle of April in Karnataka. Flowering and fruiting range from the last week of March to last week of June in some areas, so there is almost no flower gall formation in January to April months (Sundararaj *et al*., 2005).

The mean maximum population of blotch miner was observed in the Jabalpur provenance recording 8.41 blotches / leaf and minimum in the Zaheerabad provenance which was recorded as 3.33 blotch / leaf during August to April. Hence, it can be concluded that Jabalpur provenance was more susceptible and Zaheerabad provenance was less susceptible to the attack of leaf blotch miner (Sahu *et al*., 2016).

Correlation between incidence of blotch miner, spiralling whitefly and flower galls with weather parameters of preceeding week

The correlation analysis between number of leaf blotches with weather parameters of preceding week (Table VII) was found to be highly significant and positively correlated with minimum temperature ($r = 0.421$, $p<0.01$), maximum temperature ($r = 0.767$, $p<0.01$) and wind speed ($r = 0.345$, $p<0.05$). However, leaf blotches had a non-significant and positive correlation with afternoon RH ($r = 0.24$) and total rainfall ($r = 0.195$). Negative correlation existed between blotch number and sunshine hrs. ($r = - 0.243$) and morning RH ($r = -0.077$), but this relationship was non-significant.

The correlation between spiralling whitefly with weather parameters of preceeding week (Table VII) was found to be highly significant and positively correlated with maximum temperature ($r = 0.652$, $p<0.01$) and minimum temperature *i.e.*, ($r =0.541$, $p<0.01$). Non significant and positive correlation existed with rainfall ($r=0.175$) and sunshine hrs ($r=0.081$). Number of egg spirals were significantly negatively correlated with morning relative humidity ($r=-0.287$, $p<0.05$), but non-significant and negative correlation was observed with afternoon relative humidity ($r= - 0.214$) and wind speed ($r = - 0.068$).

The observations on the correlation between flower galls with weather parameters of preceeding week (Table VII) was found to be highly significant and positively correlated with afternoon relative humidity *i.e.* ($r = 0.733$, $p<0.01$). Flower gall incidence showed positive and significant correlation with minimum temperature *i.e.* ($r = 0.311$, $p<0.05$) and morning RH ($r = 0.31$, $p<0.05$). But wind speed ($r = 0.198$) and total rainfall ($r = 0.249$) showed non-significant and positive correlation. However, maximum temperature ($r = - 0.347$, $p<0.05$) and sunshine hrs. ($r = -0.603$, $p<0.01$) were significantly and negatively correlated with flower gall incidence.

Correlation matrix between incidence of blotch miner, spiralling whitefly and flower galls with weather parameters of corresponding week

The correlation between leaf blotches with weather parameters of corresponding week (Table VIII) was found to be significant and positive with minimum temperature ($r= 0.725$, $p<0.01$), maximum temperature ($r = 0.310$, $p<0.05$), afternoon relative humidity ($r= 0.341$, $p<0.05$) and wind speed ($r= 0.325$, $p<0.05$). However it was significantly and negatively correlated with sunshine hrs ($r= -0.325$, $p<0.05$) and it was non-significant and negatively correlated with morning relative humidity ($r= -0.037$).

TABLE VIa

Incidence of blotch miner, spiralling whitefly and flower galls caused by Aspondylia pongamiae *in relation to weather parameters of the preceeding week (2016-17)*

Fort night of eachMonth	Std.Met. week	Date of Observation	No of *A.Pongamiae /gall*	Leaf galls(No/leaf)	Temp (^{0}C)		RH (%)		Wind speed (Km/day)	Sunshine (Hrs)	Total Rainfall(mm)
					Max.	Min.	Morning	A/N			
3-10-2016	40	19.80	5.13	5.80	27.86	19.20	94.29	54.43	6.80	2.50	16.40
10 -10-2016	41	19.96	5.63	7.20	29.91	18.91	92.00	47.29	5.60	8.30	0.00
17 -10-2016	42	20.13	6.01	9.05	29.09	18.66	92.00	50.57	5.50	4.90	30.20
24-10-2016	43	20.49	6.43	9.06	29.74	16.69	77.86	45.57	3.40	9.20	0.00
31 -10-2016	44	20.49	6.43	9.06	29.66	17.40	76.71	45.86	3.70	8.80	0.00
7-11-2016	45	20.66	6.12	5.30	29.69	18.11	85.00	47.14	3.70	8.80	0.00
14 -11-2016	46	20.58	6.18	4.56	29.20	15.97	78.71	45.00	4.70	9.60	0.00
21-11-2016	47	24.60	6.39	4.01	29.46	18.43	84.14	45.71	7.70	7.20	0.00
28-11-2016	48	21.53	5.12	3.12	29.89	29.60	82.00	38.43	6.70	8.70	0.00
5-12-2016	49	13.02	5.42	2.99	29.49	14.00	82.57	42.00	4.00	8.70	1.70
12-12-2016	50	8.33	8.00	1.53	27.37	15.60	82.57	43.14	7.70	4.70	0.00
19 -12-2016	51	3.15	8.36	1.34	24.80	15.11	89.86	56.00	7.20	4.70	58.20
26 -12-2016	52	2.13	8.17	0.50	28.14	13.91	87.43	41.14	5.50	8.60	0.00
2-01-2017	1	2.01	8.91	0.00	27.91	13.6	90.71	39.29	5.10	9.70	0.00
9-01-2017	2	0.00	9.63	0.00	27.37	12.17	85.86	41.00	5.20	9.40	0.00
16-01-2017	3	0.00	0.00	0.00	27.23	15.11	91.14	41.86	5.10	8.20	0.00
23-01-2017	4	0.00	0.00	0.00	26.77	14.09	93.14	39.43	8.50	9.40	0.00
30-01-2017	5	0.00	0.00	0.00	27.29	15.43	85.57	38.57	9.70	5.80	0.00
6-02-2017	6	0.00	0.00	0.00	27.29	15.43	85.57	38.57	4.80	10.50	0.00
13-02-2017	7	0.12	0.00	0.00	29.89	13.89	82.86	34.00	6.50	10.30	0.00
20-02-2017	8	4.43	0.00	0.00	29.43	14.63	83.86	33.86	10.20	10.00	0.00
27-02-2017	9	8.14	4.20	0.00	31.97	15.77	84.71	35.71	5.90	9.90	1.40
06-03-2017	10	14.56	6.01	0.00	31.97	15.03	78.71	29.14	5.90	9.90	0.00

TABLE VIa (contd.)

Fort night of eachMonth	Std.Met. week	Date of Observation	No of *A.Pongamiae* /gall	Leaf galls(No/leaf)	Temp (^{0}C)		RH (%)		Wind speed (Km/day)	Sunshine (Hrs)	Total Rainfall(mm)
					Max.	Min.	Morning	A/N			
13-03-2017	11	16.78	6.13	0.00	32.29	20.06	86.57	41.29	6.20	8.40	1.40
20-03-2017	12	19.43	7.21	0.00	32.26	19.94	83.57	41.57	6.50	8.50	0.00
27-03-2017	13	20.60	8.99	0.00	33.40	20.49	78.43	40.43	6.90	9.40	0.00
2-04-2017	14	19.87	9.16	0.00	35.00	20.50	82.00	35.00	7.70	9.30	0.00
9-04-2017	15	21.23	13.13	0.00	34.60	21.50	82.00	38.00	6.20	8.60	1.60
16-04-2017	16	23.17	14.47	0.00	35.70	22.40	82.00	36.00	6.70	8.50	0.00
23-04-2017	17	24.24	14.51	2.11	34.60	21.90	84.00	36.00	8.40	7.70	0.00
30-04-2017	18	25.24	14.63	2.36	35.40	22.40	84.00	36.00	7.00	8.80	0.00
7-05-2017	19	27.36	14.91	3.17	32.70	20.90	82.00	31.00	6.00	8.20	25.80
14-05-2017	20	28.53	13.01	3.17	32.60	21.20	81.00	48.00	6.40	6.90	15.20
21-05-2017	21	29.88	13.12	3.63	33.50	20.90	85.00	35.00	8.30	8.00	45.60
28-05-2017	22	30.33	12.11	3.91	32.20	19.80	87.00	42.00	8.00	6.50	133.60
4-06-2017	23	49.80	10.68	4.21	30.00	19.90	88.00	47.00	10.80	8.20	8.30
11-06-2017	24	31.12	9.31	9.01	29.50	20.60	88.00	53.00	10.20	6.80	21.60
18-06-2017	25	29.40	8.16	9.16	28.10	20.20	90.00	57.00	10.90	2.30	8.00
25-06-2017	26	27.31	5.32	6.13	28.10	19.50	90.00	56.00	9.00	4.80	32.60
2-07-2017	27	26.64	5.41	7.21	28.30	20.00	87.00	54.00	13.30	5.10	3.20
9-07-2017	28	25.01	5.29	8.99	29.00	19.70	93.00	57.00	9.60	4.20	10.20
16-07-2017	29	23.72	3.11	6.01	28.00	19.80	90.00	61.00	9.80	3.70	13.40
23-07-2017	30	21.83	3.04	6.43	27.50	19.60	88.00	59.00	12.80	4.00	2.60
01-08-2017	31	19.66	4.17	6.12	29.90	19.70	85.00	50.00	10.40	8.10	2.40
08-08-2017	32	17.60	4.21	6.18	27.10	19.30	93.00	57.00	4.80	2.60	4.60
15-08-2017	33	16.50	6.13	6.39	29.00	20.50	89.00	55.00	6.90	4.10	70.40
22-08-2017	34	15.23	6.41	5.63	27.50	19.70	92.00	64.00	6.30	3.10	34.20
29-08-2017	35	15.23	6.41	5.41	27.50	19.70	90.00	59.00	8.20	3.60	62.80
05-09-2017	36	17.32	6.15	5.33	27.20	19.80	95.00	58.00	9.40	3.00	30.80
12-09-2017	37	18.01	5.11	5.24	28.30	19.50	89.00	56.00	4.20	5.30	99.20
19-09-2017	38	18.77	5.17	5.24	28.80	19.30	89.00	57.00	6.40	5.20	24.20
26-09-2017	39	19.05	5.41	5.01	28.10	18.80	92.00	65.00	9.70	3.60	24.40

TABLE VIb

Incidence of blotch miner, spiralling whitefly and flower galls caused by Aspondylia pongamiae *in relation to weather parameters of the corresponding week (2016-17)*

Fort night of eachMonth	Std.Met. week	Date of Observation	No of *A.Pongamiae /gall*	Leaf galls(No/leaf)	Temp (^{0}C)		RH (%)		Wind speed (Km/day)	Sunshine (Hrs)	Total Rainfall(mm)
					Max.	Min.	Morning	A/N			
3-10-2016	40	19.80	5.13	5.80	29.91	18.91	92.00	47.29	5.60	8.30	0.00
10 -10-2016	41	19.96	5.63	7.20	29.09	18.66	92.00	50.57	5.50	4.90	30.20
17 -10-2016	42	20.13	6.01	9.05	29.74	16.69	77.86	45.57	3.40	9.20	0.00
24-10-2016	43	20.49	6.43	9.06	29.66	17.40	76.71	45.86	3.70	8.80	0.00
31 -10-2016	44	20.49	6.43	9.06	29.69	18.11	85.00	47.14	4.00	8.00	0.00
7-11-2016	45	20.66	6.12	5.30	29.20	15.97	78.71	45.00	4.70	9.60	0.00
14 -11-2016	46	20.58	6.18	4.56	29.46	18.43	84.14	45.71	7.70	7.20	0.00
21-11-2016	47	24.60	6.39	4.01	29.89	15.37	82.00	38.43	6.70	8.70	0.00
28-11-2016	48	21.53	5.12	3.12	29.49	14.00	82.57	82.57	4.00	8.70	1.70
5-12-2016	49	13.02	5.42	2.99	27.37	15.60	82.57	43.14	7.70	4.70	0.00
12-12-2016	50	8.33	8.00	1.53	24.80	15.11	89.86	56.00	7.20	4.70	58.20
19 -12-2016	51	3.15	8.36	1.34	28.14	13.91	87.43	41.14	5.50	8.60	0.00
26 -12-2016	52	2.13	8.17	0.50	27.91	13.60	90.71	39.29	5.10	9.70	0.00
2-01-2017	1	2.01	8.91	0.00	27.37	12.17	85.86	41.00	5.20	9.40	0.00
9-01-2017	2	0.00	9.63	0.00	27.23	15.11	91.14	41.86	5.10	8.20	0.00
16-01-2017	3	0.00	0.00	0.00	26.77	14.09	93.14	39.43	8.50	9.40	0.00
23-01-2017	4	0.00	0.00	0.00	27.29	15.43	85.57	38.57	9.70	5.80	0.00
30-01-2017	5	0.00	0.00	0.00	27.29	15.43	85.57	38.57	4.80	10.50	0.00
6-02-2017	6	0.00	0.00	0.00	29.89	13.89	82.86	34.00	6.50	10.30	0.00
13-02-2017	7	0.12	0.00	0.00	29.43	14.63	83.86	33.86	10.20	10.00	0.00
20-02-2017	8	4.43	0.00	0.00	31.94	15.77	84.71	35.71	5.90	9.90	1.40
27-02-2017	9	8.14	4.20	0.00	31.97	15.03	78.71	29.14	5.90	9.00	0.00
6-03-2017	10	14.56	6.01	0.00	32.29	20.06	86.57	41.29	6.20	8.40	1.40
13-03-2017	11	16.78	6.13	0.00	32.26	19.94	83.57	41.57	6.50	8.50	0.00
20-03-2017	12	19.43	7.21	0.00	33.40	20.49	78.43	40.43	6.90	9.40	0.00

TABLE VIb (contd.)

Fort night of eachMonth	Std.Met. week	Date of Observation	No of *A.Pongamiae /gall*	Leaf galls(No/leaf)	Temp (^{0}C)		RH (%)		Wind speed (Km/day)	Sunshine (Hrs)	Total Rainfall(mm)
					Max.	Min.	Morning	A/N			
27-03-2017	13	20.6	8.99	0.00	35.00	20.50	82.00	35.00	7.70	9.30	0.00
2-04-2017	14	19.87	9.16	0.00	34.00	21.50	82.00	38.00	6.20	8.60	1.60
9-04-2017	15	21.23	13.13	0.00	35.70	22.40	82.00	36.00	6.70	8.50	0.00
16-04-2017	16	23.17	14.47	0.00	34.60	21.90	84.00	36.00	8.40	7.70	0.00
23-04-2017	17	24.24	14.51	2.11	35.40	22.40	84.00	36.00	7.00	8.80	0.00
30-04-2017	18	25.24	14.63	2.36	32.70	20.90	82.00	31.00	6.00	8.20	25.80
7-05-2017	19	27.36	14.91	3.17	32.60	21.20	81.00	48.00	6.40	6.90	15.20
14-05-2017	20	28.53	13.01	3.17	33.50	20.90	85.00	35.00	8.30	8.00	45.60
21-05-2017	21	29.88	13.12	3.63	32.20	19.80	87.00	42.00	8.00	6.50	133.60
28-05-2017	22	30.33	12.11	3.91	30.00	19.90	88.00	47.00	10.80	8.20	8.30
4-06-2017	23	49.8	10.68	4.21	29.50	20.60	88.00	53.00	10.20	6.80	21.60
11-06-2017	24	31.12	9.31	9.01	28.10	20.20	90.00	57.00	10.90	2.30	8.00
18-06-2017	25	29.4	8.16	9.16	28.10	19.50	90.00	56.00	9.00	4.80	32.60
25-06-2017	26	27.31	5.32	6.13	28.30	20.00	87.00	54.00	13.30	5.10	3.20
2-07-2017	27	26.64	5.41	7.21	29.00	19.70	93.00	57.00	9.60	4.20	10.20
9-07-2017	28	25.01	5.29	8.99	28.00	19.80	90.00	61.00	9.80	3.70	13.40
16-07-2017	29	23.72	3.11	6.01	27.50	19.60	88.00	59.00	12.80	4.00	2.60
23-07-2017	30	21.83	3.04	6.43	29.90	19.70	85.00	50.00	10.40	8.10	2.40
01-08-2017	31	19.66	4.17	6.12	27.10	19.30	93.00	57.00	4.80	2.60	4.60
08-08-2017	32	17.60	4.21	6.18	29.00	20.50	89.00	55.00	6.90	4.10	70.40
15-08-2017	33	16.50	6.13	6.39	27.50	19.70	92.00	64.00	6.30	3.10	34.20
22-08-2017	34	15.23	6.41	5.63	27.50	19.70	90.00	59.00	8.20	3.60	62.80
29-08-2017	35	15.23	6.41	5.41	27.20	19.80	95.00	58.00	9.40	3.00	30.80
05-09-2017	36	17.32	6.15	5.33	28.30	19.50	89.00	56.00	4.20	5.30	99.20
12-09-2017	37	18.01	5.11	5.24	28.80	19.30	89.00	57.00	6.40	5.20	24.20
19-09-2017	38	18.77	5.17	5.24	28.10	18.80	92.00	65.00	9.70	3.60	24.40
26-09-2017	39	19.05	5.41	5.01	27.30	19.10	90.00	60.00	4.30	4.00	108.60

TABLE VII

Correlation matrix between incidence of blotch miner, spiralling whitefly and flower galls with weather parameters of preceeding week

Pest/Damage	Temp (^{0}C)		RH (%)		Wind speed (Km/day)	Bright Sunshine (Hrs)	Total Rainfall (mm)
	Max.	Min.	Morning	A/N			
Blotches/ leaf	0.421 **	0.767 **	-0.077	0.24	0.345 *	-0.243	0.195
Egg spirals/leaf	0.652 **	0.541 **	-0.287 *	-0.214	-0.068	0.081	0.175
Flower galls	-0.347 *	0.311 *	0.310 *	0.733 **	0.198	-0.603 **	0.249

TABLE VIII

Correlation matrix between incidence of blotch miner, spiralling whitefly and flower galls with weather parameters of corresponding week

Pest/Damage	Temp (^{0}C)		RH (%)		Wind speed (Km/day)	Bright Sunshine (Hrs)	Total Rainfall (mm)
	Max.	Min.	Morning	A/N			
Blotches/ leaf	0.310 *	0.725 **	-0.037	0.341 *	0.325 *	-0.325 *	0.211
Egg spirals/leaf	0.518 **	0.522 **	-0.146	-0.124	-0.029	0.019	0.177
Flower galls	-0.303 *	0.342 *	0.246	0.688 **	0.226	0.212	-0.594 **

The correlation between flower galls with weather parameters of corresponding week (Table VIII) was found to be significantly and positively correlated with afternoon relative humidity *i.e.* (r= 0.688, p<0.01) and minimum temperature (r= 0.342, p<0.05). Flower gall incidence was non-significantly and positively correlated with wind speed (r = 0.226), sunshine hours (r= 0.212) and morning relative humidity (r= 0.246). Negative and significant correlation existed between maximum temperature (r= - 0.303, p<0.05), rainfall (r= - 0.594, p<0.01) and flower gall incidence.

Chikkaswamy *et al*. (2016) reported that maximum temperature had a significant and negative relationship with the incidence of white fly whereas, there was no significant and negative relationship between their incidence and rainfall and relative humility. However, the results of the present study are not in conformity with findings of Chikkaswamy *et al*. (2016), which could be due to differences in geographical location and variations in the environmental conditions and crop situation. Moreover, the place was earlier reported with gemini viruses of whitefly.

Multiple linear regression between incidence of blotch miner, spiralling whitefly and flower galls with weather parameters of preceeding week

Multiple linear regression revealed that the weather parameters of preceeding week influenced blotch miner, spiralling whitefly and flower gall incidence to an extent of 66.20, 53.90 and 54.30 percent, respectively (Table IX).

TABLE IX

Multiple linear regression between incidence of blotch miner, spiralling whitefly and flower galls with weather parameters of preceeding week

Pest	Regression equation	R^2
Blotches/ leaf	$Y= -30.544+0.366R_1 + 2.513 R_2 - 0.470 R_3 + 0.409R_4+0.028R_5 +0.835R_6 +0.939R_7$	66.20
Spirals/leaf	$Y= -10.497+0.948 R_1 + 0.190 R_2-0.088R_3 -0.051R_4 +0.022 R_5 -0.180 R_6 -0.486R_7$	53.90
Flowergalls	$Y= 9.634- 0.618 R_1 + 0 .775 R_2 -0.159R_3 + 0.200R_4+ 0.002R_5 -0.013R_6 +0.409R_7$	54.30

Multiple linear regression between incidence of blotch miner, spiralling whitefly and flower galls with weather parameters of corresponding week

Multiple linear regression revealed that the weather parameters of corresponding week influenced blotch miner, spiralling whitefly and flower gall incidence to an extent of 61.70, 40.00 and 61.70 percent, respectively (Table X).

TABLE X

Multiple linear regression between incidence of blotch miner, spiralling whitefly and flower galls with weather parameters of corresponding week

Pest	Regression equation	R^2
Blotches/ leaf	$Y= -12.863+ 0.671R_1 +1.843R_2-0.679R_3 +0.552 R_4 +0.842 R_5 +0.497R_6+0.028 R_7)$	61.70
Spirals/leaf	$Y= -9.586+0.465R_1 +0.521 R_2+0.012R_3 -0.106R_4-0.184 R_5 -0.288 R_6+0.018R_7)$	40.00
Flower galls	$Y= 23.609-0.549 R_1 + 0.429 R_2-0.271R_3 +0.234R_4-0.001 R_5 -0.010 R_6 +0.132 R_7$	61.70

Therefore, the present study established the relationship between the weather variables and incidence of major pests of Pongamia. This will facilitate the development of feasible management strategies for Pongamia pests in the near future.

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