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Population Dynamics of Mealybug, *Phenacoccus solenopsis* and its Natural Enemies in *Bt* Cotton

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ABSTRACT: Cotton is susceptible to a wide variety of insect pests, among which Mealybug, *Phenacoccus solenopsis* is the most prominent insect pest. A field study was carried out during *Kharif* 2023 and 2024 at the Experimental Farm, S.K.N. College of Agriculture, Jobner (Rajasthan) to assess the seasonal incidence of the *P. solenopsis* on *Bt* cotton and its relationship with prevailing weather parameters. The pest infestation began in the third week of August (34th SMW) with an initial population of 0.60 and 0.92 mealybugs per 10 cm apical shoot in 2023 and 2024, respectively, and continued until the end of the crop season. The peak incidence was recorded in the last week of October (44th SMW), reaching 82.12 and 76.28 mealybugs per 10 cm shoot in 2023 and 2024, respectively. Correlation analysis revealed a significant negative association between mealybug population and relative humidity (r = -0.58 in both years), and a significant positive correlation with sunshine hours (r = 0.49) in 2024. Other weather parameters such as maximum and minimum temperatures and rainfall showed non-significant correlations. These findings indicate that low humidity and prolonged sunshine hours favour the multiplication and population buildup of *P. solenopsis* in the semi-arid climatic conditions of Rajasthan.

Keywords: *Phenacoccus solenopsis*, *Bt* cotton, population dynamics, weather parameters, correlation, Rajasthan.

INTRODUCTION

The word, "Cotton" is derived from Arabic word "Qutun". It is (*Gossypium* spp.) commonly referred as "King of Fibre", belongs to family Malvaceae and most of the world's apparel is made of cotton. It is the most widespread and profitable non-food crop in the world. It plays an important role in the world's economic, political, and social affairs. Hence it is popularly known as "White Gold" and "Friendly Fibre". China is the leading producer of cotton in the world. It is estimated that 26.25% of the world cotton production produced in China, followed by India (20.67%), Brazil (14.05%) and the USA (11.92%). India is the largest cultivating country in the world with 11.8 million hectares, and produces 25.00 million bales with productivity of 461 kg per hectare. The area under cotton in the current year in the country decreased by 10.46% and cotton production decreased by 7.98% compared to last year. North zone states comprise Punjab, Haryana, and Rajasthan estimated to occupy 10.89% of the total cotton area in the country and to produce 11.04% cotton Significant area reduction in country estimated at 10.47% compared to last year, notably, in North zone it was 31.07% reduction. The cotton production in the country reduced by 7.98%, significantly, in North zone it is estimated at 30.57% reduction (Anonymous, 2024-25). Rajasthan's production area covers approximately 6.62 lakh hectares. The state achieves production of 20.42 lakh bales, each weighing 170 kg, with a productivity rate of 524 kg of lint per hectare. Rajasthan secured the third position in productivity, just behind Odisha (Anonymous, 2024-25). *Bt* cotton (*Gossypium hirsutum*) is a genetically modified variety developed by incorporating genes from the soil bacterium *Bacillus thuringiensis* (Berliner), which produce Cry proteins effective against major lepidopteran pests, particularly bollworms (Krishna and Qaim 2012). However, the widespread adoption of *Bt* cotton has been accompanied by a shift in the pest complex, with a notable rise in sap-sucking insect pests (Pal *et al.*, 2014). Of late, *Bt* cotton has attracted wide range of other insect pests, especially sucking pests. Currently,

due to their high biotic potential, sap sucking pests have become a major constraint in cultivation of Bt cotton (Kaur *et al.*, 2024). Aphid (*Aphis gossypii*, Glover), leafhopper (*Amrasca biguttula bigutulla*, Ishida), Thrips (*Thrips tabaci*, Lindeman), whitefly (*Bemisia tabaci*, Gennadius), mealybug (*Phenacoccus solenopsis*, Tinsley), red cotton bug (*Dysdercus cingulatus*, Fabricius) and dusky cotton bug (*Oxycarenus laetus*, Kirby) are common sucking pests of cotton. They damage the crop throughout its growing period, from seedling emergence to harvest with significant decline in yield by sucking sap from plants and making them weaker (Boda and Ilyas 2017). Among these, the mealybug *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) has emerged as a serious threat to Bt cotton cultivation. It infests the crop throughout the growing season, weakening plants by sucking sap, stunting growth, and often leading to yield losses. The pest's activity is known to be closely linked with environmental conditions such as temperature, humidity, and rainfall (Sharma and Sharan 2016). The invasive nature, rapid spread, significant economic impact, and biological advantages of *Phenacoccus solenopsis* have attracted considerable attention from researchers. Initial studies have primarily focused on species identification, natural enemies, outbreak causes, life cycle, and management strategies. The invasive nature, rapid spread, significant economic impact, and biological advantages of *Phenacoccus solenopsis* have attracted considerable attention from researchers. Initial studies have primarily focused on species identification, natural enemies, outbreak causes, life cycle, and management strategies (Tanwar *et al*., 2007; Nagrare *et al*., 2009). However, despite its regular occurrence in recent years, there remains a lack of comprehensive, long-term data on the seasonal population dynamics of *P. solenopsis* and the role of its natural enemies, particularly under the distinct agro-climatic conditions of semi-arid Rajasthan. Therefore, the present investigation was undertaken to address these knowledge gaps and provide a comprehensive understanding of the *P. solenopsis*–cotton ecosystem, with emphasis on its seasonal incidence and interaction with biotic and weather parameters.

MATERIALS AND METHODS

Present investigations on "Population Dynamics of Mealybug, *Phenacoccus solenopsis* and its natural enemies in *Bt* cotton" was carried out at Department of Entomology Instructional Farm, S.K.N. College of Agriculture, Sri Karan Narendra Agricultural University, Jobner during *Kharif* season 2023 and 2024. It was laid in randomized block design with three replications. For recording the mealybug incidence *Bt* cotton cultivar RCH314 BGII was sown at 24th June *Kharif* 2023 and 04th May 2024 *Kharif* 2024 with 90 cm × 60 cm spacing. All the recommended agronomical practices except plant protection were followed for raising the crop. The variety was grown in separate plot measuring 3.6 m × 2.4 m^2. In each plot five plants were selected and tagged to record the population of the mealybugs. The populations of mealybug were recorded at standard week interval during morning hours, starting after germination till the maturity of the crop. Whole plots were kept free from insecticidal application throughout the crop season. For recording observation on the population of mealybugs, 5 plants were selected randomly in each plot and tagged. The number of mealybugs were counted on 3 twigs (each of 10 cm long) selected randomly on each tagged plant. The population of coccinellids, green lacewings and spiders were recorded from randomly selected plants. The population was recorded from whole plant at randomly selected and tagged five plants per plot at weekly intervals. From this, the average populations of natural enemies per plant were worked out.

RESULTS AND DISCUSSION

The incidence of mealybug on *Bt* cotton commenced in the third week of August (34th SMW) during both the years and remained active up to the third week of December during *Kharif* 2023 and 2024, respectively. The population showed a gradual rise with the progress of the cropping season and reached its peak density in the last week of October (44th SMW) with 82.12 and 76.28 mealybug per 10 cm apical shoot during *Kharif*, 2023 and 2024 respectively. The present findings are also supported by Singh and Kumar (2012); Desai *et al.* (2022) who reported that the mealybug incidence initiated during 34th SMW and peak population in the month of October. The results obtained in the present investigation are also in close agreement with the earlier reports of Boda and Ilyas (2017) they recorded the mealybug infestation on *Bt* cotton during 33rd SMW with peak population (12.40 mealybugs/3 shoots) and the infestation continued up to 50th SMW. Hanchinal *et al*. (2010) reported the mealybug infestation appearance in September and gradually increased as crop growth advanced. Babu and Meghwal (2014) observed that the peak incidence of mealybug (42.40 mealybugs/ 2.5 cm shoot length) in 49 to 51st SMW. In contrast to reports of Dhawan *et al.* (2009); Singh and Kumar (2012); Shah *et al.* (2015); Zahi and Farag (2017); Badgujar *et al*. (2018); Harde *et al.* (2018) the present finding differed which might be due to different location, germination time and climatic condition. The correlation matrix indicated that the incidence of mealybug, *P. Solenopsis* on *Bt* cotton crop showed negative significant correlation with relative humidity (r=-0.58 and -0.58), non-significant correlation with maximum temperature (r = 0.21 and r=0.44), minimum temperature (r=-0.10 and r= 0.02) and rainfall (r=-0.15 and r=-0.41) during both *Kharif* 2023 and 2024, whereas, a significant correlation with sunshine hours (r= 0.49) during *Kharif*, 2024 and non-significant correlation (r=0.25) was observed during *Kharif*, 2023. These results are in close agreement with Hanchinal *et al*. (2010); Muchhadiya *et al.* (2014) who reported that the mealybug population had positive but non-significant correlation with temperature and total rainfall while the positively significant correlation with relative humidity. In contrast Babu and Meghwal (2014) reported that the maximum and minimum temperatures had a significant positive correlation with the mealybug population.

Population dynamics of major natural enemies on *Bt*. Cotton crop

Coccinellids. The data revealed that the incidence of coccinellids, one of the prominent natural enemies, commenced in the third week of August (34st SMW) during both the years *i.e*. *Kharif* 2023 and 2024 (0.96 and 0.92 coccinellids per five plants during *Kharif* 2023 and 2024, respectively) continued thereafter for a long period and reached to its peak in the second week of October (41thSMW) with 4.80 and 4.92 coccinellids per five plants during *Kharif*, 2023 and 2024, respectively. After reaching the peak, the population of coccinellids started to decline and reached to low level in the last week of December during both the years. The correlation studies (Table 3 & 4) revealed that the incidence of coccinellid population showed significant positive correlation with *P. solenopsis* (r=0.51 and r=0.51) during *Kharif*, 2023 and 2024, respectively. The population of coccinellid showed positive significant correlation of r=0.59 and r=0.82 with maximum temperature and negative non-significant correlation of r=-0.09 and r=-0.18 with rainfall during *Kharif* 2023 and 2024. A significant correlation with sunshine hours (r=0.49), non-significant correlation with rainfall (r=-0.09) and minimum temperature (r=0.27) during *Kharif* 2023. The population of coccinellids had positive significant correlation with minimum temperature (r=0.54), non-significant correlation with sunshine hours (r=0.33) and relative humidity (r=-0.24) during *Kharif* 2024.

Spiders. The appearance of spiders, one of the generalist predators in the cotton ecosystem, was first noticed in the third week of August (34th SMW) during both the years, *i.e.*, *Kharif* 2023 and 2024 (0.32 and 0.36 spiders per five plants during *Kharif* 2023 and 2024, respectively). The population gradually increased with prey availability and reached its peak in the second week of October (42nd SMW) with 2.56 spiders per five plants during *Kharif* 2023 and in third week of October (41st SMW) with 2.48 spiders per five plants during *Kharif* 2024. After reaching the peak, the population of spiders started to decline and reached a low level in the last week of December during both the years. The correlation studies revealed that the spider population had showed significant positive correlation with *P. solenopsis* (r=0.71 and r=0.62) during *Kharif*, 2023 and 2024, respectively. The spider population had a significant positive correlation with maximum temperatures (r= 0.53 and r=0.66 per five plants), non-significant correlation with minimum temperature (r=0.16 and r=0.32), relative humidity (r= -0.36 and r= -0.39), rainfall (r= -0.39 and r= -0.30) and sunshine hours (r=0.38 and (r=0.43) during *Kharif* 2023 and 2024, respectively.

***Chrysoperla* spp. (Green Lacewing).** The occurrence of *Chrysoperla* sp., a key predator of soft-bodied insect pests, in the crop was started in the third week of August (34th SMW) during both the years, *i.e.*, *Kharif* 2023 and 2024 (0.18 and 0.28 *Chrysoperla* per five plants during *Kharif* 2023 and 2024, respectively). The population gradually increased with prey availability and reached its peak in the third week of October (42nd SMW) with 2.60 and 4.80 *Chrysoperla* per five plants during *Kharif* 2023 and 2024, respectively. After reaching the peak, the population of *Chrysoperla* started to decline and reached a low level in the last week of December during both the years. The correlation studies (Table 3 & 4) revealed that the population of *Chrysoperla* sp. exhibited a significant positive correlation with *P. solenopsis* (r=0.83 and r=0.70) during *Kharif*, 2023 and 2024, respectively. The population of *Chrysoperla* sp. showed a significant positive correlation with maximum temperature (r = 0.56 and r = 0.54) and negative significant correlation with relative humidity (r = -0.49 and r = -0.56) during *Kharif* 2023 and 2024, respectively. A non-significant correlation with minimum temperature (r = 0.08 and r = 0.11), sunshine hours (r = 0.39 and r = 0.41) and rainfall (r = -0.08 and r = -0.33) during *Kharif* 2023 and 2024, respectively.

Table 1: Seasonal incidence of mealybug of *Bt* cotton and their natural enemies in relation to meteorological parameters in *Kharif*, 2023.

SMW	Abiotic Factors					Mealybug per 10 cm apical shoot	Natural Enemies Population (mean no. / 5 plants)		
	Max. Tem. (°C)	Mini. Tem. (°C)	RH	RF	SSH		Coccinellids	Spiders	*Chrysoperla* sp.
34	33.8	22.8	62	0	2.6	0.6	0.96	0.32	0.2
35	35.5	21.3	50	0	7.3	2.24	0.88	0.4	0.36
36	37	21.5	56	0.8	8.7	5.52	0.8	0.44	0.56
37	36	22.7	63	7	6.1	8.36	0.76	0.76	0.84
38	32.4	22.8	72	49.8	4.8	12.24	0.92	0.68	0.92
39	35.6	19.8	55	2.4	7.8	15.52	1.8	0.64	0.84
40	36.3	15.5	45	0	8.7	25.84	1.76	0.72	1.56
41	35.5	16.4	47	0	8.9	38.32	4.8	1.48	2.44
42	33	15.1	51	0	7.6	48.12	2.88	2.56	3.64
43	33	13	47	0	8.9	68.56	2.4	1.52	2.6
44	33.7	13.3	47	0	7.5	82.12	1.48	1.44	2.32
45	33	13.1	49	0	5.7	72.12	1.4	1.36	1.84
46	27.6	9.3	47	0	5.7	53.12	1.12	0.36	1.76
47	28.1	8.1	45	0	6.4	21.12	0.68	0.4	0.56
48	24.5	10.7	64	1	1.9	13.84	0.28	0.36	0.64
49	25.3	8.3	61	0	5.3	9.36	0.32	0.32	0.44
50	26.6	5.5	56	0	7.9	3.2	0.28	0.36	0.36
51	25	5.5	51	0	7	2.88	0.36	0.32	0.2
52	25	4.9	60	0	6.4	1.32	0.2	0.28	0.16

SMW= Standard Meteorological Weeks

Table 2: Seasonal incidence of mealybug of *Bt* cotton and their natural enemies in relation to meteorological parameters in *Kharif*, 2024.

SMW	Abiotic Factors					Mealybug per 10 cm apical shoot	Natural Enemies Population (mean no. / 5 plants)		
	Max. Tem. (°C)	Mini. Tem. (°C)	RH	RF	SSH		Coccinellids	Spiders	*Chrysoperla* sp.
34	33.11	22.72	87	34.8	2.5	0.92	0.92	0.36	0.2
35	33.91	24.54	86	45.2	5.01	1.92	1.08	0.44	0.36
36	32.54	24.24	89	93.7	4.08	2.48	1.4	0.48	0.56
37	32.81	24.18	87	18.3	4.35	7.44	1.68	0.6	0.84
38	32.67	23.54	82	19.3	3.24	15.52	1.96	0.68	0.92
39	35.42	24.37	75	0	8.42	18.28	2.32	0.64	0.84
40	36.4	22.52	67	0	8.51	20.56	3.04	1.72	1.56
41	36.94	20.71	51	0	8.41	23.52	4.92	2.48	2.44
42	36.58	17.21	48	0	7.91	28.76	3.64	1.56	3.64
43	35.04	17.45	48	0	7.08	40.08	3.32	1.52	2.6
44	33.24	13.9	47	0	7.88	76.28	2.2	1.36	2.32
45	33.35	13.47	49	0	7.97	42.08	1.8	1.44	1.84
46	32.54	13.51	49	0	7.74	18.36	1.7	0.36	1.76
47	29.08	8.17	43	0	7.65	15.68	0.64	0.4	0.56
48	27.88	8.71	47	0	8.44	12.04	0.48	0.36	0.64
49	27.1	6.7	62	0	8.45	10.08	0.32	0.32	0.44
50	23.72	1.78	53	0	7.78	5.68	0.3	0.36	0.36
51	24.05	3.04	64	0	5.45	2.04	0.28	0.32	0.2
52	20.27	9.52	79	16.5	3.8	0.08	0.12	0.28	0.16

SMW= Standard Meteorological Weeks

Table 3: Correlation coefficient (r) between the population of mealybug and it's natural enemies on *Bt* cotton crop and meteorological parameters during *Kharif*, 2023.

Sr. No.	Particulars	2023			
		Mealybug	Coccinellids	Spiders	*Chrysoperla* sp.
A	Meteorological parameters				
1	Temperature				
	a. Maximum temperature	0.21	0.59*	0.53*	0.56*
	b. Minimum temperature	-0.10	0.27	0.16	0.08*
2	Average relative humidity (%)	-0.58*	-0.46*	-0.36	-0.49*
3	Total rainfall (mm)	-0.15	-0.09	-0.05	-0.08
4	Sunshine hours	0.25	0.49*	0.38	0.39
B	Natural enemies				
	Coccinellids	0.51*	-	-	-
	Spiders	0.71*	-	-	-
	Chrysoperla sp.	0.83*	-	-	-

***Significant at 5%**

Table 4: Correlation coefficient (r) between the population of mealybug and it's natural enemies on *Bt* cotton crop and meteorological parameters during *Kharif*, 2024.

Sr. No.	Particulars	2024			
		Mealybug	Coccinellids	Spiders	*Chrysoperla* sp.
A	Meteorological parameters				
1	Temperature				
	a. Maximum temperature	0.44	0.82*	0.66*	0.54*
	b. Minimum temperature	0.02	0.54*	0.32	0.11
2	Average relative humidity (%)	-0.58*	-0.24	-0.39	-0.56*
3	Total rainfall (mm)	-0.41	-0.18	-0.30	-0.33
4	Sunshine hours	0.49*	0.33	0.43	0.41
B	Natural enemies				
	Coccinellids	0.51*	-	-	-
	Spiders	0.62*	-	-	-
	Chrysoperla sp.	0.70*	-	-	-

***Significant at the 5%**

A view of infested plant parts of *Bt* cotton by Mealybug.

CONCLUSIONS

The present study clearly established the seasonal incidence, population dynamics, and correlation of *Phenacoccus solenopsis* with weather parameters and its natural enemies on Bt cotton during Kharif 2023 and 2024. The mealybug infestation initiated in the third week of August and persisted until December, peaking in late October. A significant negative correlation was observed with relative humidity, while maximum temperature and sunshine hours showed a variable but generally positive influence on population buildup. Among natural enemies, *Coccinellids*, *Spiders*, and *Chrysoperla* spp. played a vital role in regulating mealybug populations, all showing significant positive correlation with pest density, especially *Chrysoperla spp.*, which exhibited the strongest association. These findings underline the importance of favorable weather conditions in pest outbreaks and emphasize the role of natural enemies in suppressing mealybug populations. Hence, the integration of these natural enemies into pest management strategies can offer effective, eco-friendly control of mealybugs, reducing reliance on chemical pesticides and supporting sustainable cotton production.

FUTURE SCOPE

The findings of this study highlight the potential for developing weather-based forecasting models for timely management of *Phenacoccus solenopsis* in *Bt* cotton. The significant influence of relative humidity and sunshine hours on mealybug incidence suggests the need for climate-smart pest management strategies. Future research can focus on expanding area-wide surveillance, integrating pest-weather interactions into decision support systems, and evaluating resistant *Bt* cotton hybrids. Additionally, understanding the impact of climate on natural enemies may enhance the effectiveness of eco-friendly biological control measures.

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Conflict of Interest. None.

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