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Comparative Study of Sap-Feeding Insects in Cotton Agroecosystems of District Khairpur, Sindh, Pakistan

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Abstract:

Cotton (*Gossypium hirsutum*) is a key crop supporting the textile-based economy of Pakistan. However its productivity is frequently threatened by various insect pests. Among these, sap-sucking insects such as, mealy bugs (*Phenacoccus solenopsis*), dusky cotton bug (*Oxycarenus laetus*) and aphid (*Aphis gossypii*) are considered majorconstraints to cotton production. These pests weaken plants by extracting phloem sap, leading to reduced plant vigor and lower boll formation. In addition, the secretion of honeydew encourages the growth of sooty mold, which further deteriorates plant health and crop quality. The present study was conducted in District Khairpur, sindh particularly in Taluka, Gambat and Kotdiji, to evaluate the occurrence and

infestation patterns of these pests in cotton fields. Field surveys and quadrat sampling indicated that mealybugs were more abundant under hot and dry enviornmental conditions, whereas dusky cotton bugs were commenly observed in Bt cotton varieties. Aphid populations showed clear variation in response to rainfall and humidity. Statistical analysis confirmed significant differences in infestation intensity among pest species and enviornmental conditions. Overall the findings highlight the influence of agro- climatic factors on pest dynamics and emphasize the importance of integrated pest management strategies to reduce losses caused by sap-sucking insects in cotton agroecosystems.

Keywords: Cotton agroecosystem, Mealybug, Dusky cotton bug, Aphids, Khairpur, Sindh

Introduction

The Cotton (*Gossypium hirsutum*) is the staple of Pakistan textile industry as it makes up a significant portion of export revenues and it also offers jobs to millions of individuals. Cotton productivity is compromised by various insect pests, although it has got economic value. Some of these are sap mining insects like, mealy bugs (*Phenacoccus solenopsis*), dusky cotton bugs (*Oxycarenus laetus*), and aphids (*Aphis gossypii*), which have become a big limitation on sustainable cotton production. These pests attack sap of plants, lower physiological functioning, decrease the boll development, and indirectly encourage fungal infestation due to honeydew deposition (Abbas et al., 2010; Arif et al., 2009).

These mealy bugs are now specifically infamous in Pakistan as the outbreak of these bugs has been reported in Punjab and Sindh since the beginning of the 2000s. They can also coexist in large numbers because of their polyphagous nature, that is, they survive on different host plants such as weeds, ornamentals, and vegetables, which persist during down seasons (Dhawan et al., 2007; Nawaz and Freed, 2021). An unfavorable environment, like high temperature and low rainfall, let mealy bugs multiply, pesticide misuse usually causes the death of natural enemies, and the outbreaks are further worsened (Hameed et al., 2021; Hussain et al., 2020).

Along with the introduction of Bt cotton, dusky cotton bugs that were traditionally unimportant as minor pests acquired significance. As Bt toxins are specialized to attack chewing pests like bollworms, the sucking pests like dusky cotton bugs are left untouched and occasionally invasive in the Bt fields (Rind et al., 2024; Shafique et al., 2014). They lower the lint value and seed quality in the course of their feeding, and present economic losses to the farmers.

Another significant sap feeding pest is aphids whose numbers vary with rainfall and humidity. Under good conditions, they multiply at high rates, causing an inconsiderable outbreak thus destroying young cotton plants (Ahmed et al., 2018; Yawar et al., 2020). Bio-controlling insects including ladybird beetles, resistant plants, and bio-controlling biochemicals have been promising in minimising aphid attacks (Tariq et al., 2013; Zia et al., 2012; Akram et al., 2011).

Critical in this is the element of environmental drivers. Over fertilization by using nitrogen chemicals raises the succulence of plants which makes cotton more vulnerable to sap feeding insects (Khan et al., 2017). Weed hosts support the population of the mealy bugs (Saleem et

al., 2016), and the use of pesticides to control the population crosses the ecological balance by killing the desirable predators (Ashraf et al., 2024). Climate variability is also known to affect outbreaks of pests, and research has been used to associate drought and rainfall variation to changes in the abundance of certain pests (Malik et al., 2008).

Irrespective of these findings, the majority of research in Pakistan has been done on the individual pest or agro-climatic conditions. There has been a lack of comparative studies of various sap feeding insects at the same agroecosystem especially in District Khairpur, Sindh. Taluka Gambat and Kotdiji are the valuable areas of cotton cultivation having different environmental conditions. This is important to understand pest dynamics in one or the other location in order to design integrated pest management plans that meet the needs of the area. The purpose of the study is thus to draw a comparison of infestation, feeding ecology, and environmental factors of the mealybugs, dusky cotton bugs and aphids in cotton agroecosystems of Khairpur.

Methodology

Study Area

Study was carried out in the District, Khairpur, Sindh, which is a region of great cotton production, of Taluka Gambat and Kotdiji. These regions are a mixture of agro-climatic conditions with Gambat having a relatively dry and hot climate as compared to Kotdiji that has slightly higher humidity conditions owing to its proximity to irrigation channels. Both the talukas represent the larger cotton agroecosystem in Sindh, and both are an ideal place to study comparative pest ecology.

Sampling Period

Two cotton harvest periods 2024 to 2025 were selected to conduct stage surveys. This time was chosen to bring seasonal changes in the pest numbers and environmental factors.

Data Collection

- **Plant Sampling:** Randomized quadrat sampling was used in which the sampling was done to cover 50 plants in each plot.
- **Pest Counts:** A direct count was made of the mealybugs (*Phenacoccus solenopsis*), dusky cotton bugs (*Oxycarenus laetus*) and aphids (*Aphis gossypii*). The severity of infestation was indicated in terms of the number of insects to each plant.
- **Damage Assessment:** Feeding damage was scored on a standardized 0–5 scale, where 0 indicated no damage and 5 indicated severe infestation with visible plant stress.
- **Environmental Data:** Data on temperature, relative humidity, and precipitation was collected in daily records in the local meteorological stations to compare the abundance of the pests with climatic conditions.

Statistical Analysis

Analysis of Variance (ANOVA) was used to evaluate the significant difference in the intensity of infestation among species and locations. Regressions were made to determine correlations of the pest abundance and the environmental variables. The research design was based on a Dhillon et al. (2010) study, which showed the success of the quadrat sampling combined with weather correlation analysis in the pest ecology research.

Results

Table 1. Infestation Intensity of Sap-Feeding Insects (per 50 plants)

Species	Gambat	Kotdiji	Mean Infestation
Mealy Bug	40	36	38.0
Dusky Cotton Bug	28	31	29.5
Aphids	22	20	21.0

Interpretation:
The group of mealybugs registered the most percentage of infestation in both Talukas, with Gambat having a little more of the insects than Kotdiji. The level of dusky cotton bug was average and Kotdieji was slightly more infested. The population of aphids was relatively reduced and Gambat was slightly affected compared to Kotdiji. These findings suggest that mealy bugs are the most remarkable sap feeding insect in Khairpur cotton field, dusky cotton bugs and aphids are found in moderate and low proportions respectively.

Table 2. Environmental Correlation with Pest Abundance

Species	Temperature (°C)	Humidity (%)	Rainfall (mm)	R^2 Value
Mealy Bug	+0.72	–0.45	–0.60	0.68
Dusky Cotton Bug	+0.55	–0.30	–0.20	0.52
Aphids	–0.20	+0.65	+0.70	0.74

Interpretation:
The regression analysis showed that mealybugs had high positive relationship with abundance of high temperature whereas rainfall, and humidity had negative relationship with the abundance of the mealy bug. Dusky cotton bugs were moderately correlated with temperature, and thus showed to survive better in hot conditions but are less susceptible to rain and moisture. The population density of aphids was positively related to the level of rainfall and humidity, which indicated that it favors wet conditions. These R^2 values show that environmental variables are able to explain a large percentage of the change in the abundance of pests, especially aphids ($R^2 = 0.74$) and mealy bugs ($R^2 = 0.68$).

Discussion

In the current research, it was found that there are clear ecological trends among sap-feeding insects in District Khairpur, Taluka, Gambat and Kotdiji. The number of mealy bugs was greatest in hot and dry conditions, which confirms the earlier report that the temperature and drought conditions favored their population (Dhawan et al., 2007; Hameed et al., 2021). They can even survive on alternative hosts like weeds further keeping populations alive in the off season periods as emphasized by Saleem et al. (2016). This implies that the use of weed should form part of the pest control measures.

The infestation of dusky cotton bugs was an issue in Bt cotton fields that are supported by the Rind et al. study (2024 and, 2021). Bt cotton mainly attacks the bollworms, hence sucking pests such as dusky cotton bugs are not affected; hence, in some cases, secondary outbreaks occur. This is long term economical to farmers because their feeding compromises the quality and the lint value of seeds. Studies of comparative feeding damage augury to identify that dusky cotton bugs may induce considerable yield loss whenever the populations are not controlled (Shafique et al., 2014; Javed et al., 2010).

The abundance of aphids responded to rainfall and humidity similar to finding of Arif et al. (2009) and Ahmed et al. (2018). They are especially hard to control because of the high reproductive potential they have under good conditions. The conservation of the natural enemies is important as biological control agents like ladybird beetles (Akram et al., 2011) and parasitoids (Razaq et al., 2015) have demonstrated a positive effect on the reduction of the aphids population. The role of resistant cultivars is that they help in reducing aphid destruction (Tariq et al., 2013; Zia et al., 2012).

The environmental factors were considered drivers of pest outbreaks, e.g. nitrogen fertilization (Khan et al., 2017) and pesticide mis use (Ashraf et al., 2024). The abundance of nitrogen also renders plants more succulent hence exposed to sap sucking insects and the carefree application of pesticides spread ecological imbalance by destroying the helpful predators. Malik et al. (2008) pointed out that climate variability is one of the environment factors that affect the pest infestations in cotton.

In general, the comparative analysis sheds light on species specific adaptation to environmental conditions. The mealy bugs develop well in drought, the dusky cotton bugs develop well in Bt cotton, and the aphids perform well during rainy seasons. This is why there is a necessity to develop integrated pest management strategies that should use cultural practices, resistant varieties and biological control techniques. By interventions being localized to match local agro-climatic conditions in Gambat and Kotdiji, farmers are able to decrease dependence on chemical pesticides and attain sustainable cotton production.

Conclusion

It is concluded that the comparative analysis of sap feeding insects of cotton agroecosystems in District Khairpur, Taluka, Gambat and Kotdiji establish that the pest processes are highly dependent on the local environmental conditions and crop management practices. The highest numbers of mealy bugs (*Phenacoccus solenopsis*) were found in hot and dry environments,

which validates their adaptation to drought and their dependence on other host plants. Those who were found to be more infested in Bt cotton fields were the dusky cotton bugs (*Oxycarenus laetus*) which is a demonstration of unintended usage of Bt adoption on unwanted pests. The populations of Aphid (*Aphis gossypii*) were determined to be affected by the rainfall and humidity in that they require favorable climatic conditions to reproduce at a high rate.

Results highlight the fact that pest infestations are not a uniform occurrence but species specific, which is determined by temperature, precipitation, type of crop and agricultural activities. This is a call to adopt the integrated pest management (IPM) techniques that would involve the combination of the cultural practice of weeding, wise application of fertilizers, and the preservation of natural predators and the use of resistant crops with specific interventions. When the management methods are adjusted to the ecological conditions of Gambat and Kotdiji, farmers have an opportunity to decrease the use of chemical pesticides, decrease the losses in the economy and render the cotton production more sustainable.

Finally, the study leads to better insight in the ecology of the pests in Sindh and a basis in future study which correlates climate variability, pest resistance, and biocontrol as an element of whole-box management approaches.

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