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Seasonal abundance and population dynamics of cotton whitefly (*Bemisia tabaci* L.) under spatio-temporal environment of South Punjab, Pakistan

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Abstract

Cotton whitefly (*Bemisia tabaci* L.) is a serious threat to qualitative and quantitative production of cotton in Pakistan since the cultivation of *Gossypium hirsutum* in 1980s. Cotton is grown in the southern districts of Pakistani Punjab *viz.*, Khanewal, Vehari, Multan, D. G. Khan, Bahawalpur and Rahim Yar Khan. However, recently, the cotton production in Faisalabad, Khanewal and other districts of upper Punjab has been declined due to lower cost benefit ratio because of excessive use of pesticides, hence farmer shifted towards sugarcane and corn. However, farmers in Multan, D. G. Khan, and Rajanpur still cultivate cotton. Data of whitefly population colonization initiation, peak abundance timings and weather relations is not available in these districts. Hence a study was designed to determine the population trends of whitefly on crop for two years at D. G. Khan, Rajanpur and Multan districts during 2019-2020 (two crop seasons). Data was statistically analyzed through ANOVA and means were compared by Tukey Honestly Significance difference test using R. Correlation and regression analysis was done to determine the impact of environmental variables on whitefly abundance. Whitefly population started in last week of June in Multan while in D. G. Khan and Rajanpur it starts in 2nd week of July. The pest populations increased gradually and reached at ETL level in last week of July in D. G. Khan, while in Multan and D. G. Khan reached at highest level in 2nd week of August. In Rajanpur the pest population reached highest level during 2nd week of September. Temperature and relative humidity showed non-significant positive correlation with whitefly. During 2019-2020, maximum temperature and minimum temperature showed negative correlation while relative humidity showed positive correlation with whitefly population. Farmers should start monitoring and management of cotton whitefly from 2nd week of August to reduce pest pressure on cotton crop.

Keywords: *Bemisia tabaci*, Cotton whitefly, Correlation, Population dynamics, Regression, Weather factors

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Introduction

Agriculture is considered backbone in agro-based economy of Pakistan (Statistics, 2023) and contributes 19% to the GDP of the country. About 65% people of Pakistan (about half of the employed labor force) are linked to agriculture and relevant business directly or indirectly (Statistics, 2023). Among the major crops of Pakistan, cotton (*Gossypium hirsutum* L.) contributes 5.2% in agriculture value addition, 10% to national GDP and is an important raw material source for the textile industry (Ali et al., 2012; Zia et al., 2015; GOP, 2017; Zia et al., 2018; Shoukat et al., 2020; Shah et al., 2021; Zia et al., 2022) . Production of cotton crop in Pakistan is decreasing day by day due to numeral factors (Muhammad & Anjum, 2010; Makwana et al., 2018; Arif et al., 2022; Abbas et al., 2022; Khan et al., 2023) including environmental factors (Chaudhry et al., 2021), water related constraints (low availability of canal irrigation water at the time of sowing and critical stages of crop growth) (Mikosch et al., 2020), agronomic factors (expensive fertilizer, reduced knowledge of south Punjab farmers for enhancing cotton production and combating insect pests damage) (Anwar et al., 2009) and socio-economic factors (poor land holding capacity of Pakistani farmers about 2.5 acre per farmer) (Anwar et al., 2009).

Among a variety of reasons of low yield, the magnitude of insect pests, which damage the cotton crop from sowing to maturity, plays an important role (Ali et al., 2019; Ashraf et al., 2018; Khan et al., 2020). The insect pests cause 5-10 percent losses on average but severe attack of insect pests can cause

heavy qualitative and quantitative losses varying from 40-50% (Dhaliwal et al., 2015; Naqvi, 1976). About 150 different kind of insect pest attack and reduce the cotton yield and quality (Atique & Rashid, 1983).

Among these insect pests, the whitefly (*Bemisia tabaci* L.) (Aleyrodidae: Hemiptera) causes massive loss to cotton crop throughout the world including the United States and Pakistan (Duffus & Flock, 1982; Rao et al., 1989). In the United States, during 1981 whitefly caused 100 million dollars' worth of losses to growers and consumers. Not only the qualitative production on of cotton crop was affected in North America but also cantaloupe, melons and squash production was seriously declined (Duffus & Flock, 1982). Due to this pest 100% yield of lettuce & 20-30 percent sugar beet production declined (Duffus & Flock, 1982). In the well developed countries massive projects were initiated to control the pest. Various disaster loan programs were given to farmers to combat the menace. However, in Pakistan, farmers were not supported in that way, although research and development of Pakistan Government developed whitefly resistant varieties (CIM 446, FH 78, & NIAB-78)(Akhtar, Khan, Hussain, Haq, & Khan, 2002) but mutant strains of virus (CLCuV Burewala strain and Khokran strain) developed (Saleem et al., 2016) as result of which the varieties became susceptible (Briddon, 2003) and Pakistan production continued to decline due to these environmental factors favoring pest and CLCV growth, farmer reduced knowledge and access to the new technological advancement and increase in price of the insecticides while reduced earnings per capita of Pakistani farmer.

In Pakistan, cotton whitefly gained as an important pest situation since 1980, due to Cotton leaf curl virus disease and pest prevalence on hybrid cotton. The pest had become serious threat to cotton productivity from 1980 to onward (Ali et al., 1995). This pest secretes the honey dews on leaves and causes the development of sooty mold fungus, which deteriorates plant photosynthesis rate resulting in stunted growth, reduced yield, small boll size and worsen quality of fiber (Naqvi, 1976). The pest vectors 38 plants diseases including Cotton leaf curl virus disease(Hussain et al., 1991).

Cotton leaf curl gemniviruses are single stranded DNA virus in the family Gemniviridae (Fauquet et al., 2008). The betasatellite component of CLCuV genome is associated with pathogenicity while alpha satellite molecule is not associated with disease development and is frequently found in plants. DNA 1 components of virus are originated from nanoviruses belonging to family Nanoviridae. Until now, five strains of cotton leaf curl virus have been identified viz., Cotton leaf curl Alabad strain (Zhou et al., 1998), Cotton leaf curl Khokran virus (Mansoor et al., 2003; Zhou et al., 1998), Cotton leaf curl Multan virus (Briddon et al., 2000; Zhou et al., 1998), Cotton leaf curl Rajasthan virus (Briddon, 2003), Papaya leaf curl virus (Mansoor et al., 2003). The symptoms of disease attack are deep downward cupping of young leaves, enation and swelling of veins, and leaf enations (Briddon et al., 2000).

Climate conditions, for example relative humidity, ambient air temperature and rainfall play a significant role in the occurrence of pests (Taylor et al., 2018; Liliane & Charles, 2020). All insect pests are very dependent on the predominant environmental factors including temperature, relative humidity and precipitation for their growth and development (Metwally et al., 2021). Temperature is one of the most vital ecological factor which effect growth and development of insect (Deutsch et al., 2018). Prior studies have revealed that temperature regulates seasonal and daily cycles, and thus ultimately affects various aspects of insect biology, such as sex ratio, adult life span, survival, fecundity, and fertility (Basit et al., 2021). As a result, temperature greatly affects colonization, distribution, abundance, behavior, life history, and fitness of insects (Karar et al., 2021). Therefore, information on the thermal requirements of intrusive insect pests' development has important implications for control programs, as temperature determines the population growth and size of intrusive pests and their variation under different conditions (Karar et al., 2021).

Keeping in view the above scenario, a reliable pest management strategy should be developed to cope with pests and increasing environmental problems by studying the relationship between population and weather factors which not only affect crop growth (Nawaz et al., 2015; Rehmani et al., 2016) but also play a key role in the development of insect pest population (Arif et al., 2004; Isler & Özgur, 1992). The current study has been carried out to know the overall population situation of whitefly at various locations and to determine when population starts colonization in Multan, D.G.Khan and Rajanpur, when the population reach at peak, when farmer should start pest monitoring and management to avoid losses caused by whiteflies and virus.

Materials and Methods

The current study was carried out at the farmer field in D. G. Khan (30.0489°N, 70.6455°E), Multan (30.1525°N 70.6455°E), and Rajanpur (29.1044°N 70.3301°E) during 2019-2020. The cotton variety MNH-1020 was obtained from Cotton Research Institute Multan for experiment purpose. Fifteen plants were observed for whitefly population. Upper, middle and lower leaves of each selected plant was observed for whitefly population. The experiment was laid out in RCB design with each treatment having three replications. The plot size for each treatment was 350 cm × 650 cm. Whitefly population data was recorded at weekly intervals starting from May, 2019 and 2020. The numbers of insects were counted from upper leaf of the 1st plant, middle leaf of the 2nd plant, lower leaf the 3rd plant and so on with a total of nine plants from each replication. Total 09 observations per replicate and overall 27 observations per location.

Data analysis

The data of the weekly population in each treatment were analyzed by the analysis of variance (ANOVA) and means were compared by Tukey Honstly Significance difference using R. Weather data (temperature, relative humidity, wind speed and rainfall) of concerned dates was obtained from Cotton Research Institute, Multan, Director Agriculture Extension D. G. Khan for D. G. Khan and Rajanpur and correlated with the fluctuating population of whiteflies. The correlation and linear regression analysis were conducted using package 'cor' and 'lm' in R and the graphs were plotted using the scatter plot package in ggplot 2. Multiple comparisons were evaluated using the package "agricolae" in R 3.5.3. Tukey honest significant difference was used to compare the individual means. Letters were used to rank the groups. The results were considered significant if the P values were less than 0.05. The Tukey Test at 5% level of significance was used to establish statistical ranks. Graphs were plotted using ggplot2 software.

Results and Discussion

Population dynamics of whitefly at Multan, D. G. Khan, and Rajanpur during 2019

In Multan, whitefly population started in the last week of June i.e. 2.57/leaf, it increased gradually and reach at ETL level in last week of July with whitefly population 5.90/leaf and population remain up to 1st and 2nd week of August i.e. 6.05 and 8.28 nymphs or adult/leaf (Fig. 1). It showed abrupt increase in population 3rd week of August i.e. 13.0 nymphs or adult/leaf. Whitefly population reached at maximum level in last week of August i.e. 15.0 nymphs or adult/leaf. The whitefly population showed decrease in next 1st and 2nd weeks of September i.e. 9.90 and 9.00 nymphs or adults/leaf. In the 3rd and 4th week it again showed increase in population i.e. 12.43 and 11.37 nymphs or adults/leaf. The highest population of whitefly was recorded in 1st week of October i.e. 16.75 nymphs or adults/leaf then the population showed decline. In D. G. Khan, Whitefly population starts in 2nd week of July i.e. 1.61 nymphs or adult/leaf and it reach at ETL level at 3rd week of July with 7.33 nymphs or adult/leaf (Fig. 1). It increases gradually and reached at maximum level in 2nd week of August i.e. 25.33 nymphs or adult/leaf (Fig. 1). Then it showed decline in population. However, whitefly population ranges from 6.6-22.85 in rest of weeks of studies. Minimum population of whitefly was observed in 1st week of August. In Rajanpur, the whitefly population starts in 2nd week of July i.e. 1.62 nymphs or adult/leaf and it remain below ETL up to 1st week of August (Fig. 1). Population reached at ETL level 2nd week of August i.e. 5.76 nymphs or adult/leaf. Population increased gradually from 2nd week of August to last week of September ranging population 5.76 -10.71 nymphs or adult/leaf. Highest population was recorded in the 1st week of October then population decreased down.

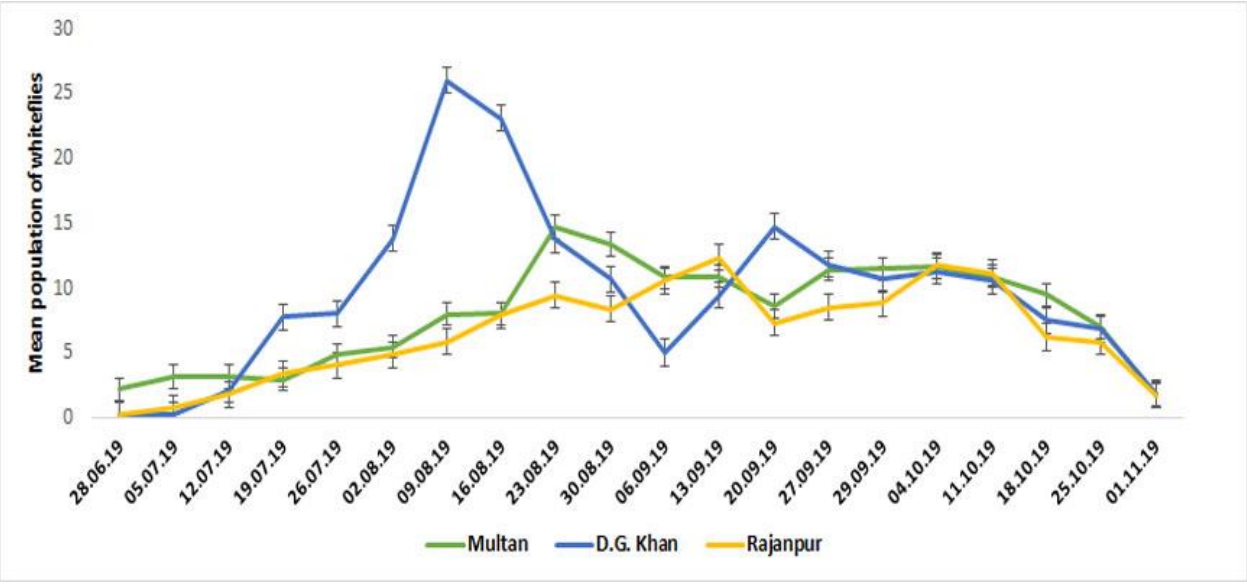

Fig. 1 Population dynamis of cotton whitefly in Multan, D.G.Khan and Rajanpur districts of Southern Punjab Pakistan During 2019-2021

Population dynamics of whitefly at Multan, D. G. Khan and Rajanpur during 2020

In Multan, that the whitefly population started in the last week of June i.e. 2.16/leaf, it increased gradually and reach at ETL level in 1st week of August with whitefly population 5.45/leaf and reach at maximum level in 3rd week of August i.e. 14.66/leaf (Fig. 2). The whitefly population remains at 13.33/leaf during last week of August (Fig. 2). The slight decrease in whitefly population recorded during 3rd week of

September i.e. 8.95/leaf it again showed slight increase during last week of September to last week of October ranging from 7.00 to 11.43/leaf. The population decrease 1st week of November i.e. 1.69/leaf (Fig. 2). In DG Khan, whitefly population starts in 2nd week of July i.e. 2.14 nymphs or adult/leaf and it reach at ETL level at 3rd week of July with 7.75 nymphs or adult/leaf. It increases gradually and reached at maximum level in 2nd week of August i.e. 26.00 nymphs or adult/leaf (Fig. 2). Then it showed decline in population. However, whitefly population ranges from 6.81-23.19 in rest of weeks of studies. Minimum population of whitefly was observed in 1st week of October i.e. 1.85/leaf (Fig. 2). In Rajanpur, the whitefly population starts in 2nd week of July i.e. 1.78 nymphs or adult/leaf and it remain below ETL upto 1st week of August. Population reached at ETL level 2nd week of August i.e. 5.86 nymphs or adult/leaf. Population increased gradually from 2nd week of August to last week of September ranging population 5.86 -10.56 nymphs or adult/leaf (Fig. 2).

Impact of weather factors on population dynamics of whitefly at various locations:

Effect of weather factors on the population dynamics of whitefly was studied during years 2019-2021.It was found that there was a negative correlation between maximum temperature and whitefly population at Multan, D. G. Khan, Rajanpur during 2019 and 2020 (Fig. 2).

Correlation & regression of whitefly population with weather factor in Multan locality:

In 2019, maximum temperature and minimum temperature showed negative correlation while relative humidity showed positive correlation with whitefly population (Fig. 3). The value of correlation coefficient for maximum temperature and minimum temperature and relative humidity in Multan was -0.195, -0.207, and -0.04 respectively. In 2020, again maximum temperature and minimum temperature showed negative response to whitefly population, while relative humidity showed positive correlation with population. The value of correlation coefficient for maximum temperature, minimum temperature and relative humidity in Multan was -0.19, -0.04, 0.05 for year 2020 respectively. During both years, regression equation was Y=15.62 – 0.1993* (Max.T) ($p<0.05$) (Fig. 3). R^2 was 0.0295 and R^2 adjusted value was 0.39%. During both years, the regression equation was Y=10.72-0.093*(Minimum Temperature) ($p>0.457$). The value of $R^2$was 0.01459 and R2 adjusted was -0.01134. During both years the regression equation was Y=9.120 -0.01(RH) ($p>0.05$). R^2 was 0.00037 and R^2 adjusted value was 0.905.

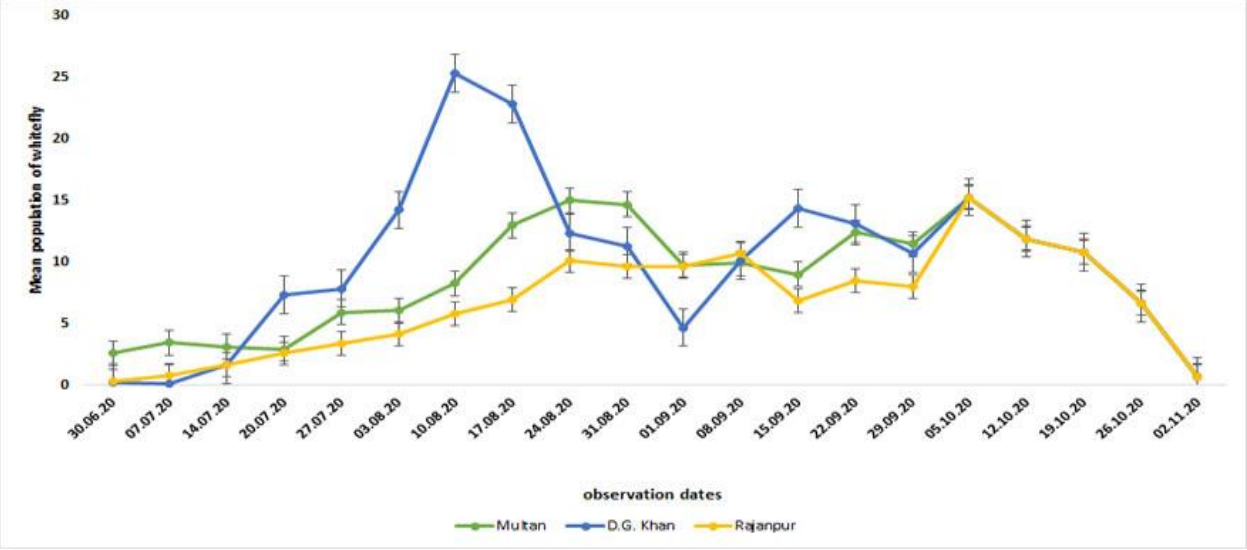

Fig. 2 Population dynamis of cotton whitefly in Multan, D.G.Khan and Rajanpur districts of southern Punjab Pakistan during 2020

Correlation & regression of whitefly population with weather factor in D.G.Khan locality

In 2019 maximum temperature showed negative correlation while minimum temperature and relative humidity showed positive correlation with whitefly population (Fig. 4). The value of correlation coefficient for maximum and minimum temperature and relative humidity in D. G. Khan was -0.13, 0.08, and 0.34 respectively. In 2020 maximum temperature and minimum temperature showed negative response while relative humidity showed positive response towards whitefly population. The value of correlation coefficient for maximum temperature and minimum temperature and relative humidity in D. G. Khan was -0.29, -0.39, and 0.089 respectively.

During both years, regression equation was Y=13.904 – 0.089 (Max.T) ($p>0.05$) (Fig. 4). R^2 was 0.003 and R^2 adjusted

value was -2.3%. During both years, the regression equation was Y=5.1240 + 0.2138*(Min.T) (p>0.05). The value of R^2 was 0.02369 and R^2 adjusted was 2%. During both years the regression equation was Y=-15.98 + 0.479*(RH) (p>0.05). R^2 was 0.138 and R^2 adjusted value was 11.59%.

Correlation & regression of whitefly population with weather factor in Rajanpur locality

In 2019 maximum and minimum temperature showed negative correlation while relative humidity showed positive correlation with whitefly population (Fig. 5). The value of correlation coefficient for maximum temperature, minimum temperature and relative humidity in Rajanpur was -0.13, 0.08, 0.34 respectively. In 2020 maximum and minimum temperature showed negative correlation while relative humidity showed positive correlation. The value of correlation coefficient for maximum temperature, minimum temperature and relative humidity in Rajanpur was -0.33, -0.05, and 0.10 respectively. During both years, regression equation was Y=25.39-0.48 (Max.T) (p>0.05) (Fig. 4). R^2 was 0.0969 and R^2 adjusted value was 7.3%. During both years, the regression equation was Y=13.398 – 0.2552(Min.T) (p>0.05). The value of R^2 was 0.059 and R^2 adjusted was 3.4%. During both years the regression equation was Y=5.05 + 0.03(RH) (p>0.05). R^2 was 0.0099 and R^2 adjusted value was 16.13%. The result indicated that whitefly population initiated colonization during last week of June in Multan District, while the population initiated during development and colonization during the 2nd week of July in Rajan pur and D.G. Khan district. Whitefly population reached at peak earlier in 2nd week of August in D.G.Khan and last week of August in Multan and Rajanpur District. Overall, whiteflies were higher in number on cotton plants in district D. G. Khan compared to Multan and Rajanpur. Correlation was positive with relative humidity and negative with increase in temperature. Overall, we found that whiteflies population initiated colonization during month of June in Multan and 2nd week of July in D. G. Khan, however, our results were not in agreement with Alvi et al. (2021) who documented that whiteflies population initiated in the last week of May in D. G. Khan district. This might be due to stage of crop growth.

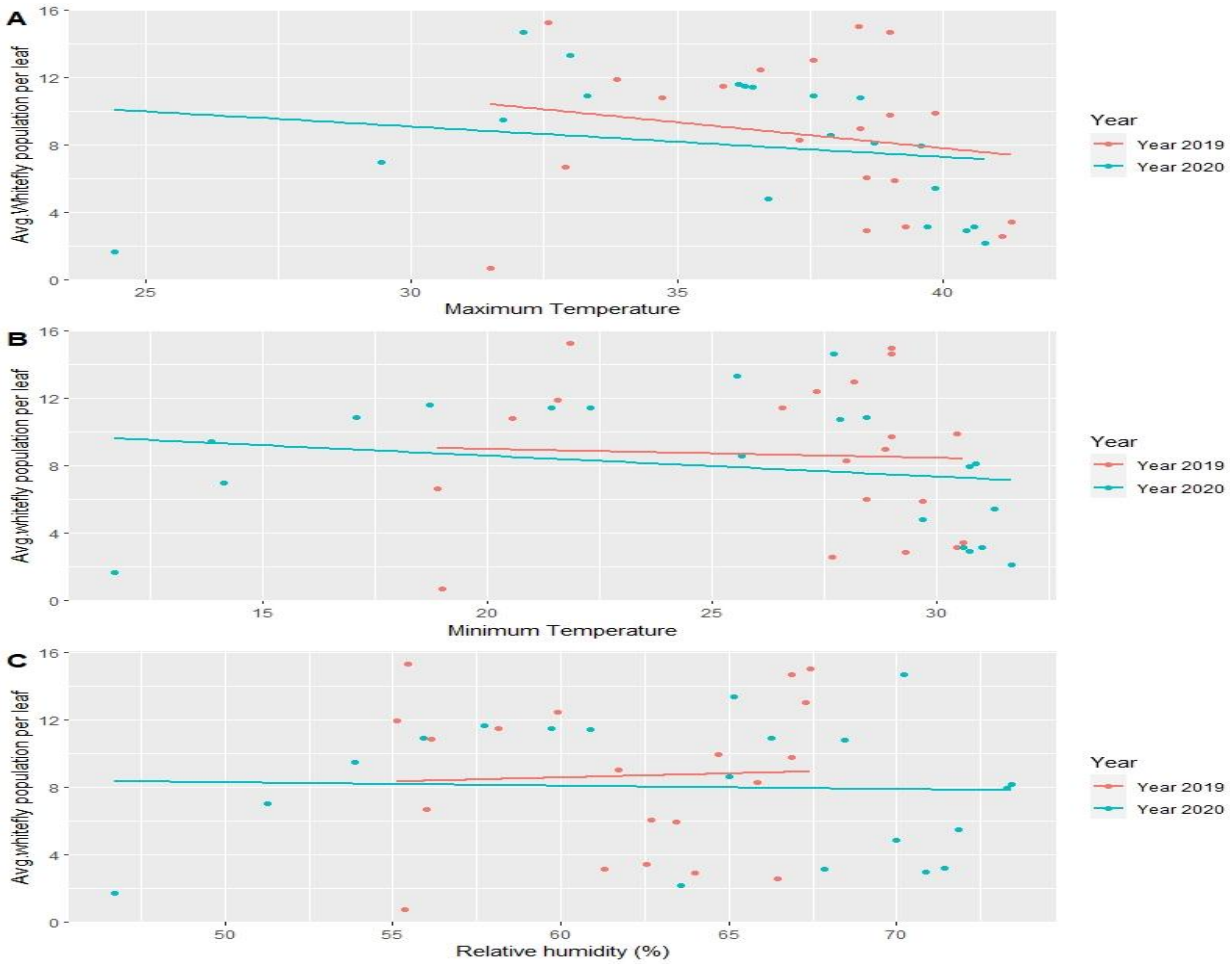

Fig. 3 Regression and correlation analysis between weather factors and the whitefly abundance during 2019-2020 in district Multan

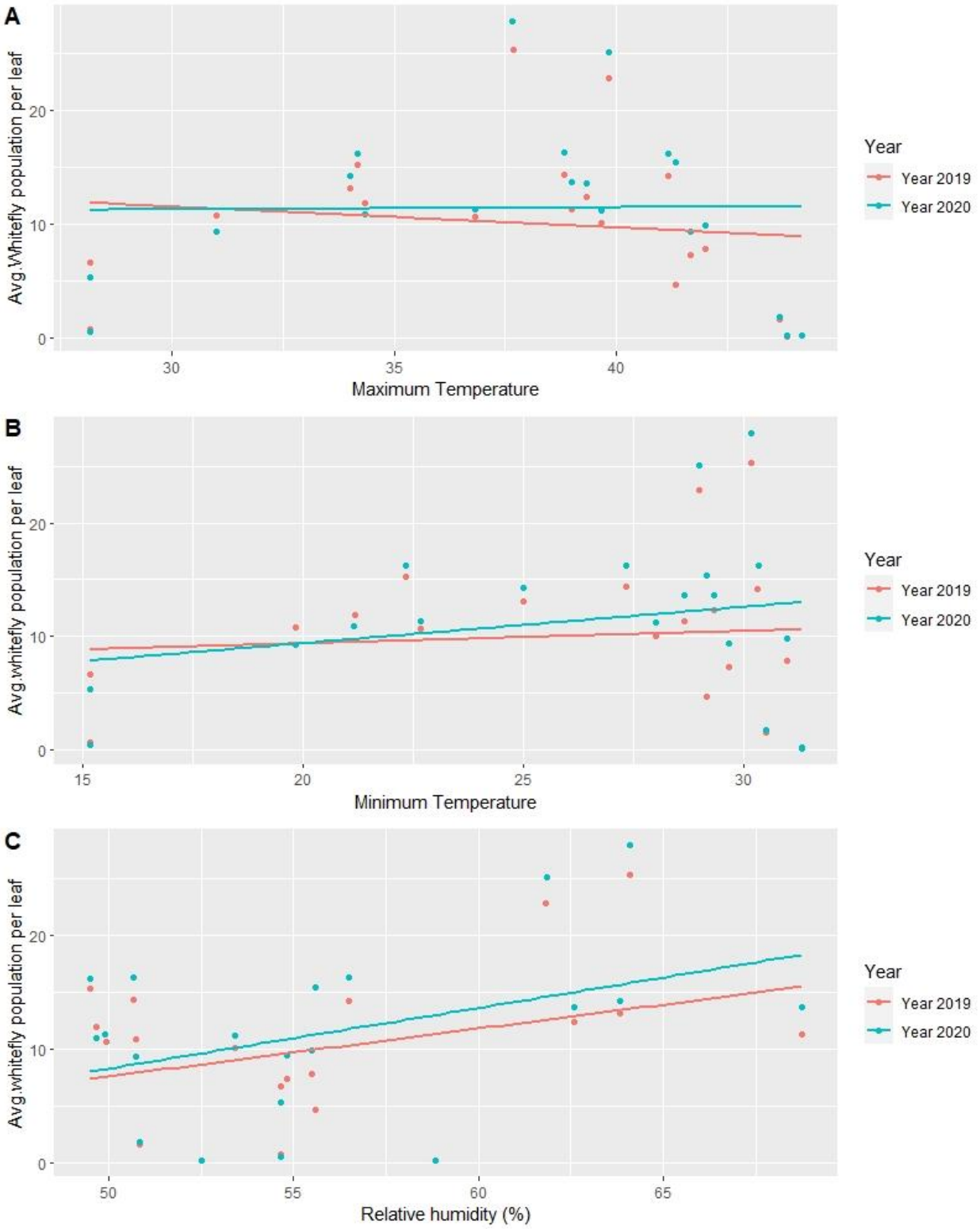

Fig. 4 Regression and correlation analysis between weather factors and the whitefly abundance during 2019-2020 in district D.G.Khan

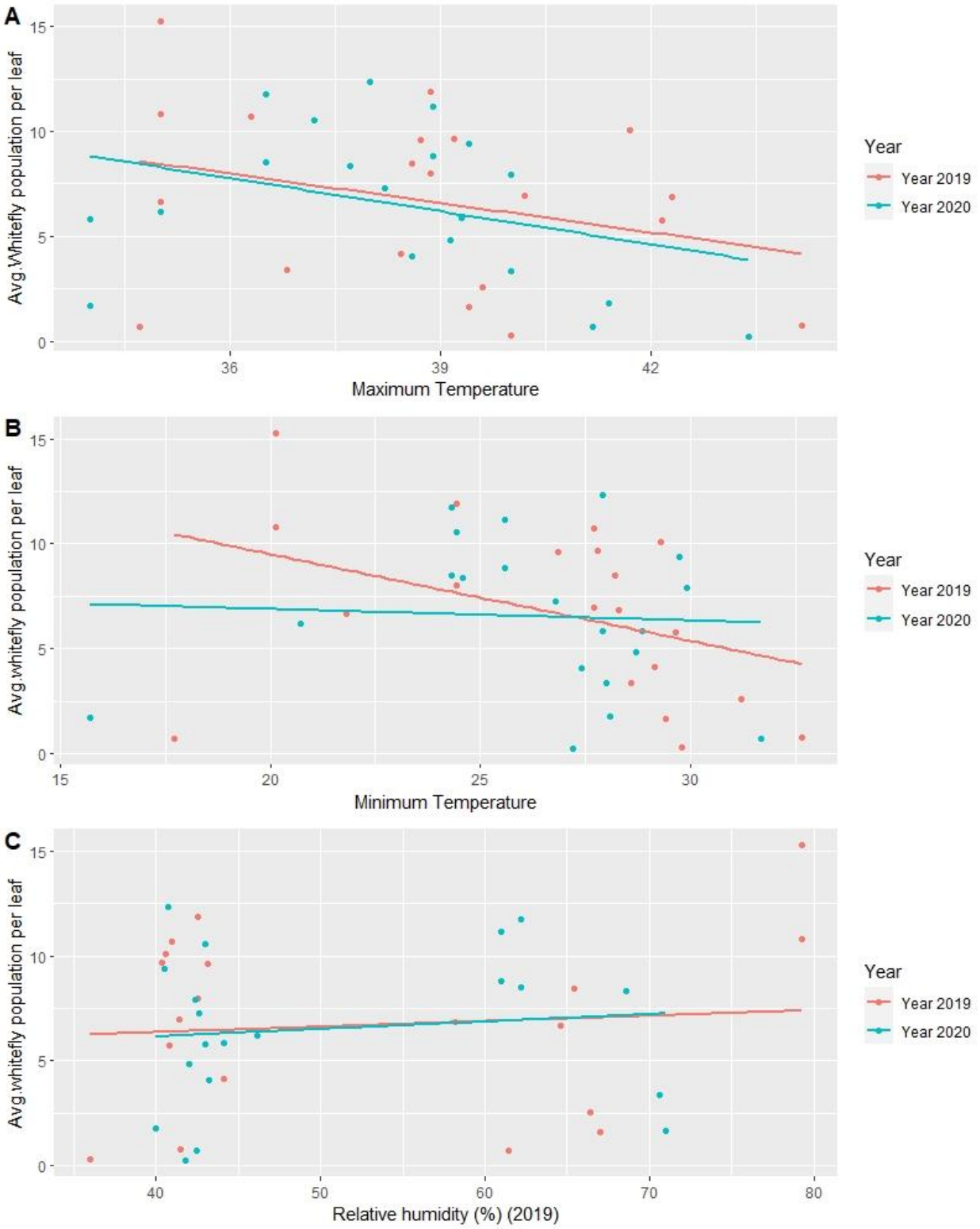

Fig. 5 Regression and correlation analysis between weather factors and the whitefly abundance during 2019-2020 in district Rajanpur

We planted cotton after wheat harvest, hence population initiated colonization at 2nd true leaf stage 15-20 days after planting while Alvi et al. (2021) might have planted the crop earlier. We found that whiteflies population was positively correlated with relative humidity and negatively correlated with increase in temperature. The results of present studies were similar to Janu and Dahiya (2017), who documented that whitefly population was negatively correlated

with maximum temperature and positively correlated with relative humidity. The results of present studies were also in agreement with other authors (Bashir et al., 2022; Kedar, 2014; Muchhadiya et al., 2014; Phulse & Udikeri, 2014; Swati & Krishna, 2017).

We found that whiteflies population was higher in D. G. Khan and lower in Multan and Rajanpur. D. G. Khan is surrounded by Kohesuleman which is flooded with water during moon soon season. Hence the whiteflies increase in number during August and September because of high humidity and lowered temperature. Vegetables are often cultivated in Rajanpur and Multan districts. The vegetables although support initital colonization of pest but biological control agents as well. Hence population might be lower in these regions because of the predators and parasitoid insects colonization on vegetable crops. However, future studies are needed to support our speculation that vegetables cultivations support biological control agents and decrease the whitefly numbers.

Overall, we found that whitefly population started in last week of June (2.57 nymphs or adult/leaf) in Multan while in D. G. Khan and Rajanpur it starts in 2nd week of July (1.61 nymphs or adult/leaf. The whitefly populations increased gradually and reached at ETL level in last week of July in D. G. Khan (7.75/leaf), While in Multan and D. G. Khan whitefly reached at highest level of population 2nd week of August 14.66, 23.19 and 15.90 respectively while population in Rajanpur reached highest level during 2nd week of September i.e. 12.35/leaf. The correlation was positive with relative humidity and negative with temperature increase. Similar results were obtained through regression. We recommend that farmers should start whitefly management from 2nd week of July in Multan, while in D. G. Khan last week of July.

Conclusion and Recommendations

We found that whitefly population initiated colonization in last week of June in Multan and 2nd week of July in Rajanpur and D. G. Khan. Whitefly population was higher in D.G.Khan compared to Rajanpur and Multan. Whitelies reached at peak in 2nd week of August in D.G. Khan, while the population reached at peak in 2nd week of September in Rajanpur and Multan. The farmers in D.G. Khan should start monitoring and management of pest population from 2nd week of July while cotton growers in Multan district should start monitoring and management from last week of June. Whitefly population was higher in D. G. Khan than Rajanpur and Multan location. This might be due to Koh-e-suleman and increased floods during moon soon. Whiteflies had positive association with increase in relative humidity and negative association with increase in temperature. Monitoring and management should be initiated early to control the pest population.

Conflict of interest: The authors declare that there is no conflict of interest among the authors of the manuscript.

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