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POPULATION FLUCTUATION OF *BEMISIA TABACI* (L) AND ITS ASSOCIATED PREDATORS UNDER COMBINED EFFECTS OF SOWING DATE AND VARIETIES

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ABSTRACT

The sowing date is very crucial among agronomic techniques for ensuring productivity and controlling insect pest. In 2018 and 2019, sowings were carried out 15 days intervals, starting on March 1 and ending on June 16. The dates were: March 1, March 16, April 1, May 1, May 16, and June 1. On advanced cultivars of Bt cotton, namely MNH-1026, MNH-1050, and IUB-13, the whitefly, *Bemisia tabaci* (Aleyrodidae: Hemiptera), and beneficial/predatory fauna were researched (control). The statistical analysis was multivariate. The relationship between the predatory fauna and the prey (whiteflies) in the correlogram was favourable. Predators showed a positive association with whitefly (0.592), boll weight (0.681), boll number (0.872), and seed cotton production (0.886) per acre, in that order. It was determined through Principal Components Analysis (PCA) that PC1 had an Eigen value >1 and accounted for 79.3% of the overall variation due to the greatest positive loading vectors. It was determined that because late planting had a short growing period, whiteflies attacked it less frequently. It was determined that short-season crop cultivation and the breeding of resistant germplasm are advantageous in the face of climate change.

Key words: Predatory fauna, sowing date, agronomic practices, short season cotton, Bt cotton

INTRODUCTION

Whitefly, *Bemisia tabaci* (Aleyrodidae: Hemiptera) is the major insect pest of cotton all over the world (Perring, 2008; Ali et al., 2015). It has polyphagous feeding nature and feed on lot of host plants other than cotton. Both nymphs and adults suck cell sap from the lower side of the leaves. It reduces vigor and disturb photosynthesis due to the development of sooty mold fungus on leaves (Oliveira et al., 2001) and transmission of cotton leaf curl virus disease in infested plants (Javaid et al., 2012). The climatic conditions affect oviposition, feeding and development of whitefly and its associated beneficial fauna (Latif and Akhter, 2013). Each insect has an optimum range of climatic factors for its activity and induces maximum damage to the economic crop (Shahid et al., 2012). Under favorable climatic conditions, its multiplication and rate of development is very rapid. Adaptability in different climatic conditions and polyphagous feeding nature is the cause of spread of *B. tabaci* in different geographical regions (Ali and Erenstein, 2017). No doubt minute insect, but it is very difficult to control because of its high multiplication rate. Due to quick knock down effect farmers mainly depend upon chemical control for the control of whitefly. The use of insecticides for its management is also health hazardous (Zaganasa, 2013).

Cultural control is safe in all aspects and plays an important role in the management of whitefly (Summy and King 1992). The most important tactics of cultural control are crop rotation, planting time and plant resistance (Javaid et al., 2012; Philips et al. 2014). Early or late sown of crops have potential to escape and synchronize the activity of arthropod herbivore. Early or delayed sowing has a significant effect on the onset of insect pest attack (Fuchs et al., 1998). There are a lot of examples regarding the use of early sowing to avoid insect pest and to maximize crop productivity. Stages of the crop also counter to be affected by the insect pests. Likewise, in the United States of America population of midge shifts from Johnson grass during spring and early summer which migrates to the sorghum at its flowering stage (Knutson et al., 2018).

Plant resistance involves the use of biophysical and biochemical traits of host plants that develop a mechanism of antixenosis, antibiosis and tolerance resistance (Sana-Ullah et al., 2011). These mechanisms deter the incidence of arthropod herbivores (Shahid et al., 2017). Morphological features of plants such as hair, gossypol gland, leaf area, shape and color of the leaf create defensive mechanism (Shahid et al., 2012). Glandular hair/trichomes excrete exudates called secondary metabolites that repel the insect pests. If the insect pests feed on these metabolites, the functioning of their body is disturbed (Duke et al., 2000). Integration of resistant cultivars with agronomic practices could be useful for the management of insect pest herbivores. Principal Component Analysis (PCA) helps to identify the correlation and dependencies among the features in a data set. Correlation between the different variables in the data set is expressed through a covariance matrix. Given the significance of *B. tabaci*, advanced cotton cultivars were sown on various sowing dates to examine their impact on the cyclical nature of the whitefly population.

MATERIAL AND METHODS

In order to study the combined effect of sowing dates on *B. tabaci*, studies were carried out during 2018 at the farm of Cotton Research Institute (CRI), Multan located at 30.1486° N latitude and 71.4396° E longitude and at altitude of 383 feet. *Bemisia tabaci* population was recorded on advanced genotypes of upland Bt cotton. In order to maintain purity pre-basic seed of each genotype was obtained from the Cotton Research Institute, Multan, de-linted with concentrated sulfuric acid @1kg/10kg seed and ridges were made on soil that was previously green manured with alfalfa legume crop and having organic matter (1.5 %). Dibbling method was used with seed depth of 2.5cm each. For weed management pre-emergence weedicide pendimethalin was sprayed @ 1000ml/acre. Three genotypes viz. MNH-1026, MNH-1050 and IUB-13 were sown on 8 different sowing dates following three replications under Split Plot Design. Sowings were done at 15 days interval i.e., on 1st March, 16th March, 1st April, 16th April, 1May, 16th May, 1st June and 16th June (Table 1). The net plot size was 20′ x 7.5′ with the distance between rows 75 cm and plant to plant 30 cm, respectively. The recommended field practices for irrigation were also conducted. However, no spray of insecticide was done for the control of whitefly. Comparative population of whitefly and beneficial fauna was recorded from all eight sowing dates.

In the next season during 2019 the experiment was conducted to investigate the effects of planting dates on dependent parameters.

Investigating the Effect of Sowing Dates on Agronomic Traits of Cotton

Cotton seed production from all plot size was converted into kg/ha was in order to study the impact of sowing dates on agronomic parameters. Each genotype's average number of bolls per 10 plants was noted, and the average boll weight in grams was determined after the bolls were harvested and weighed. The yield of the plot was used to calculate per-acre yield, which was then modified using the formula provided by Shahid et al., (2014).

$$\text{Yield per acre} = \frac{\text{Plot size}}{43560} \text{ X Yield per plot}$$

Table 1: Details of Treatments (Sowing dates)

Treatment No.	Sowing dates	Classification	Growth period (Days)
1	1st March	D*1:Early	280
2	16th March		264
3	1st April	D*2:Medium	248
4	16th April		232
5	1st May	D*3:Seasonal	216
6	16th May		200
7	1st June	D*4:late	194
8	16th June		178

D= Sowing date*

Determining the Effect of Sowing Dates on Population of Whitefly and Beneficial Fauna

Population of whitefly (adults and nymphs) per leaf was recorded by using leaf turn method during early morning time when activity of pest was slow and counted easily. Twenty leaves form each plot was randomly selected from twenty different plants of each genotype. For observation of whitefly population, we took first leaf from upper one third of the first plant, second leaf from middle of the second plant and third leaf from the lower portion of the third plant (Shahid et al., 2012) and so on. The average population/leaf of whitefly both adult and nymphs for each genotype was calculated by the simple arithmetic mean using the following formula:

$$\bar{\mathbf{X}} = \frac{\text{x1} + \text{x2} + \text{x3} \ldots\ldots \text{xn}}{N}$$

Where $\bar{\mathbf{X}}$= arithmetic Mean, *N*=Total leaves, and X1+x2+x3+…+X14+x20 = Number of whitefly observed on 20 leaves.

Population of beneficial insects was recorded from each cultivars and (sampling unit 5 numbers) was done from 5 plants. Total population of all predators was calculated following arithmetic mean.

Statistical Analysis

Data recorded was subjected to Correlogram for independent (sowing dates) and dependent variable (whitefly, beneficial fauna and agronomic traits) of upland cotton. For comparison effect of the eight different sowing dates on the population buildup of whitefly, beneficial fauna and the agronomic traits of cotton, Tukey's HSD (honest significant difference) test was used. Data was also subjected to principal component analysis using an advanced computer operated statistical package "R Studio Version 3.6.2".

RESULTS

Comparative Whitefly, Beneficial Fauna and Agronomic Traits of Cultivars in Different Sowings

As indicated in (Figure 1) by using Tukey HSD test at P=0.05 among sowing dates six to eight dates had whitefly population per leaf was at par with each other in all observations. Whitefly differed significantly among early, medium and the late sowings. Mean comparison regarding the effect of sowing dates on the population of whitefly revealed that population of whitefly was a minimum on late sowings. Selected varieties had non-significant difference from each other due to similar pattern of whitefly population per leaf. Observations demonstrated significant effect on population of whitefly. Out of six observations, first two observations had lowest population of whitefly per leaf. It started to increase in the subsequent observations i.e., observation three and four so attained its maximum peak population in observation five. Decline in population was recorded afterwards. Interaction among sowing dates and varieties demonstrated that whitefly per leaf in observation one ranged from 2 to 8 per leaf. In second observation average population of whitefly per leaf was gradually increased to 10 in all sowing dates except in sowing date three with 12 whiteflies per leaf. In observation three average population of whitefly on all varieties sown in sowing dates one to six was 10 to 12 per leaf. In fourth observation population of whitefly on all varieties sown on different sowing dates was more than 10 except the 7th and 8th sowing dates. In fifth observation, whitefly ranged from 10-15 per leaf among the selected cultivars of cotton sown on different sowings. It was the peak period for the population buildup of whitefly. For May 16th, whitefly population was again decreased on all selected cultivars sown on all eight sowings. In (Figure 2) effect of sowing dates on the population of beneficial fauna by using Tukey Honesty Significant Difference test at P=0.05 revealed that population of beneficial fauna was almost similar among all sowings among selected cultivars of cotton. During first three observation dates population of beneficial fauna on selected cultivars that ranged from 0.8 to 1.2 per 5 plants but on subsequent observation dates it ranged from 0.5 to 1.0, respectively.

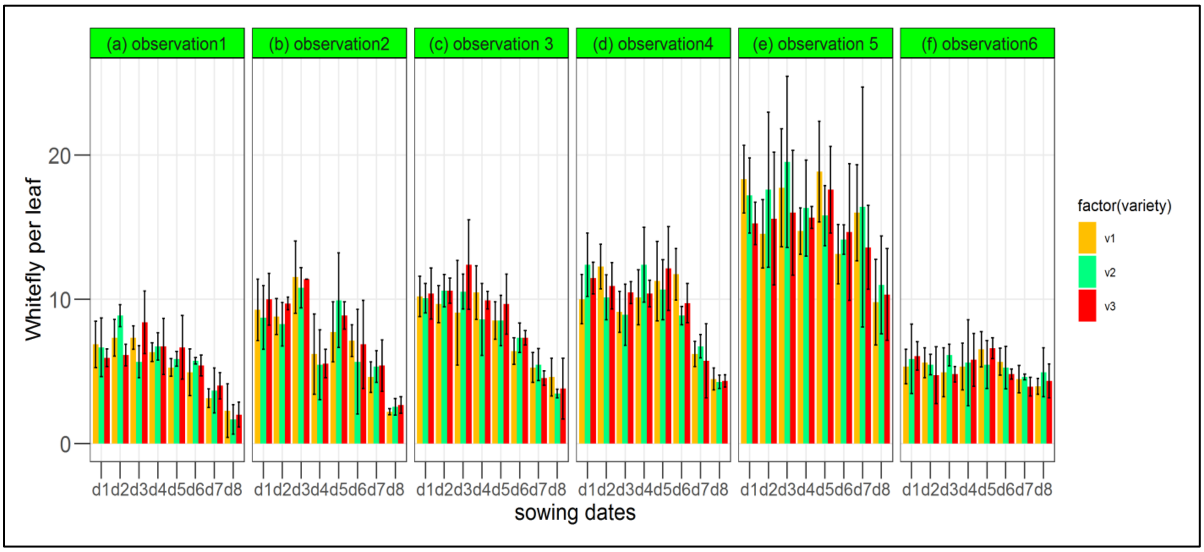


Figure 1: Mean comparison regarding the effect of sowing dates on the population of whitefly of upland cotton by using Tukey Honesty Significant Difference test at P=0.05 during 2018.

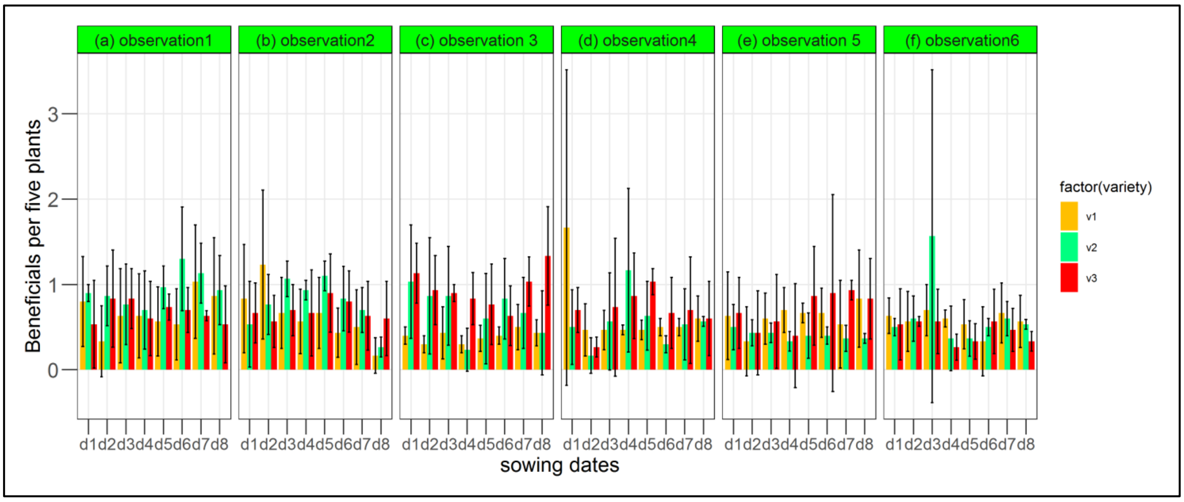


Figure 2: Mean comparison regarding the effect of sowing dates on the predatory fauna of upland cotton by using Tukey Honesty Significant Difference test at P=0.05.

Effect of Sowing Dates, Whitefly, Beneficial Fauna and Yield Related Traits of Cotton

Means and ranges of dependent variables are given in (Figure 3). All traits demonstrated considerable variation among analyzed sowing dates. As shown in correlogram the correlation (r) between whitefly, beneficial fauna on cotton in different sowing dates, there was existed positive correlation between whitefly and beneficial fauna. Agronomic traits showed positive correlation with sowing dates.

Correlation coefficient (r value) depicted that whitefly displayed positive correlation with beneficial insects (0.592). Beneficial insects had positive correlation with number of bolls (0.872), boll weight (0.681) and per acre yield of seed cotton (0.886) respectively. Data points remain scattered very close to the positively sloped line (Figure- 3). For each variable density distribution is shown at the bottom most rows diagonal with distinct colors. On the upper side, the bivariate scatter plots are displayed. Trait wise boxplot are depicting variations among sowing dates with central box representing the middle half data lengthening from upper to lower quartile while the horizontal line is located at median. The central box represents the middle half data lengthening from upper to lower quartile while the horizontal line is located at the median. The end points of vertical projection data points, unless the presence of outliers. A solid dot at the upper and lower side represents the outliers.

Principal Components Analysis (PCA) was used in order to visualize and verify similarity and variability among the varieties and traits. It was carried out for correlation between dependent and independent variables. As shown in Figure 4(A), five principal components from five dependent traits were extracted through PCA. Among all principal components having Eigen value exceeding 1 contributed maximum variations. PC1, PC2, PC3, PC4 and PC5 accounted 79.3, 10.2, 7.05, 2.13 and 1.22 % of the total variation respectively. As shown in Figure 4(B) PC1 contribution of whitefly, number of bolls, yield per acre, beneficial fauna and boll weight donated maximum positive loading vector was 20.5, 20.0, 19.5 and 19.0 that followed by number of bolls, boll weight and per acre of yield of seed cotton respectively. Cumulative variance was 79.3, 89.5, 96.6, 98.8 and 100 of PC1, PC2, PC3, PC4 and PC5 respectively as shown (Table 2). Beneficial fauna was positively correlated with boll weight and cotton yield.

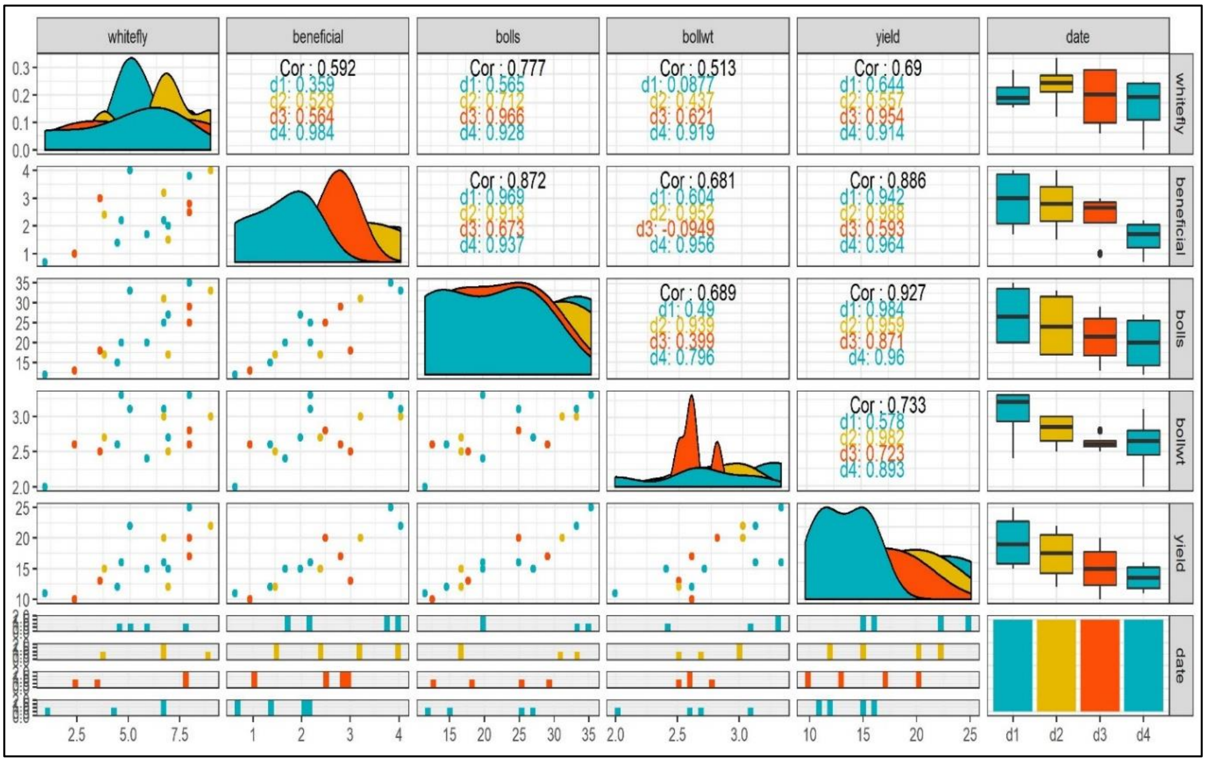


Figure 3: Correlogram for independent (sowing dates) and dependent variable (whitefly, beneficial fauna and agronomic traits) of upland cotton during 2019.

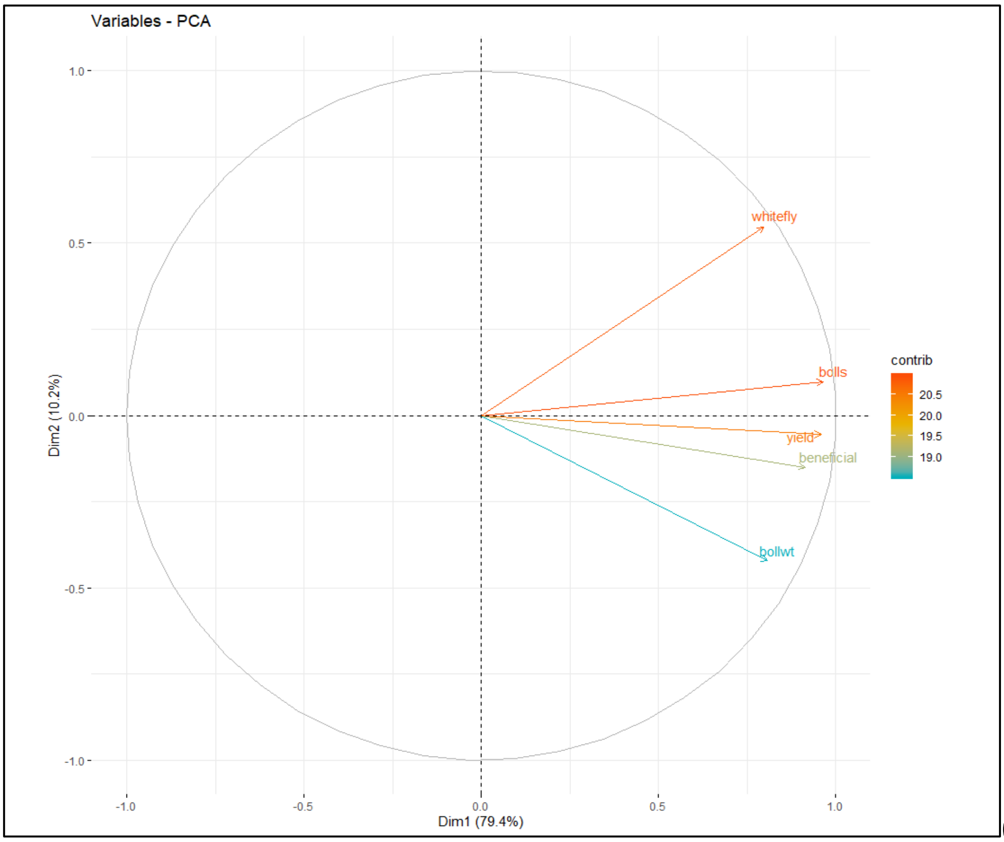
Table 2: Eigen values showing contribution of different PC's from total variance

Variation	PC1	PC2	PC3	PC4	PC5
Eigen value	3.97	0.51	0.35	0.10	0.06
Total variance	79.3	10.2	7.05	2.13	1.22
Cumulative variance %	79.3	89.5	96.6	98.8	100

The Figure (Figure 5A & 5B) regarding scatter diagram of PCA for the studied material depicted a considerable amount of variability among sowing dates.

First and second principal components (PC1 and PC2) was plotted in which three major distinct groups were encountered including two main groups of beneficial fauna and whitefly in selected sowing dates lying apart clearly indicating their diversity from each other (Figure 5 A & 5B). It showed that first and second dates had positive association with whitefly in comparison with other sowing dates.

As shown in Figure 6(A) growing period of early sown cotton i.e., first and second dates 280, 264 days was 86-102 days longer than the late sown crop. Similarly, its effect on whitefly and beneficial insects was significant and positive as shown in Figure 6(A). It indicated that growing period (days) exerted 90.0% association with whitefly and 80.0% with beneficial fauna.



(A)

(B)

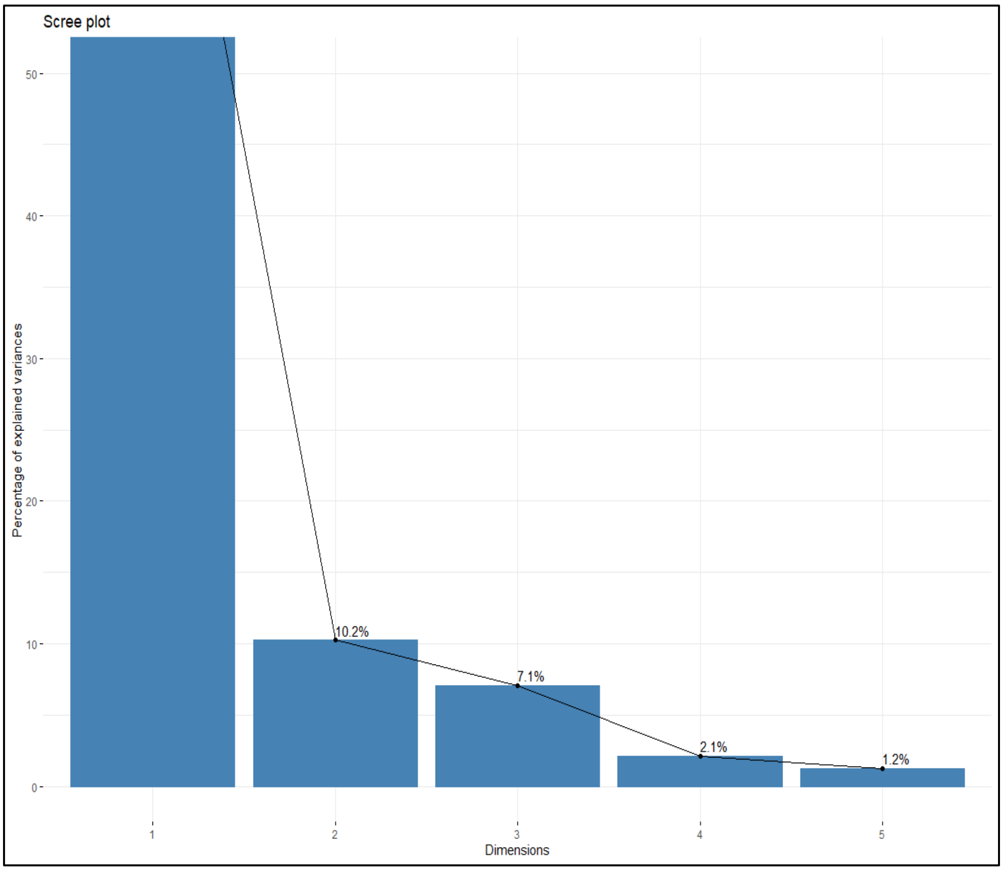
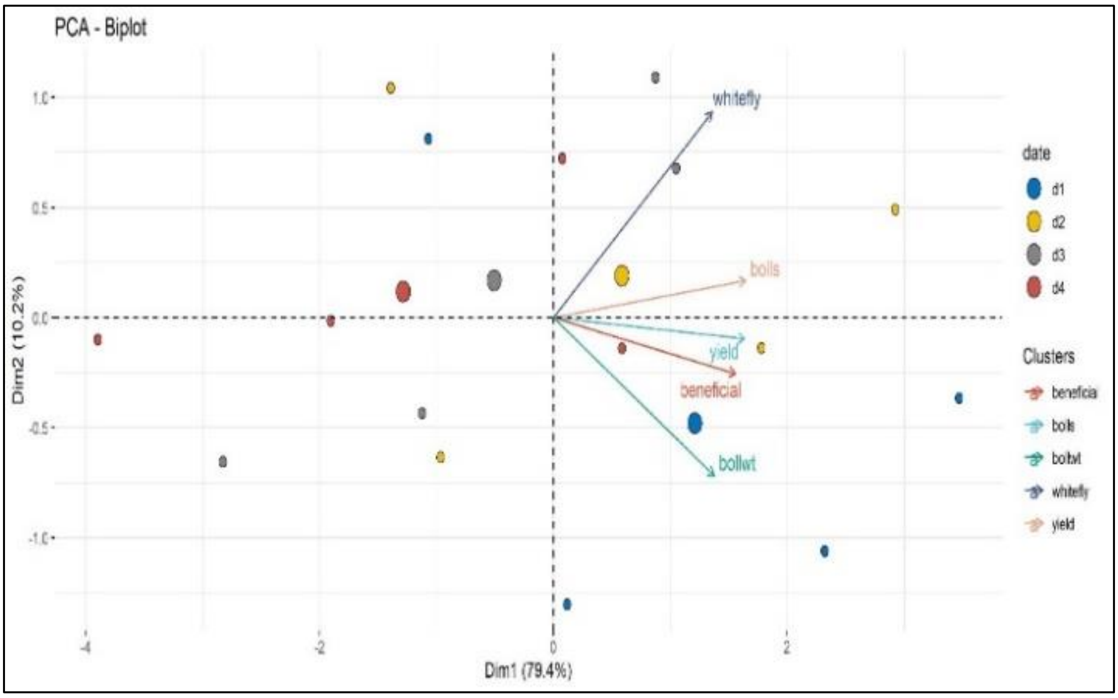


Figure 4 A & 4 B: Mean comparison regarding the effect of sowing dates on the predatory fauna of uplan d cotton by using Tukey Honesty Significant Difference test at P=0.05 during 2019.



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(A)

(B)

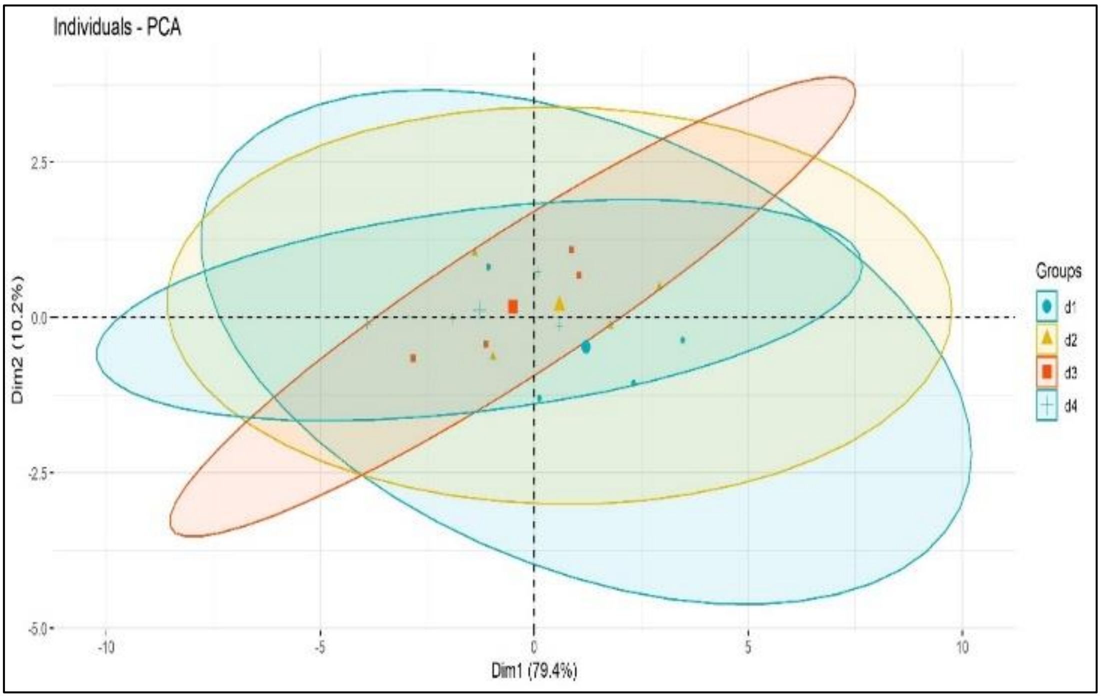
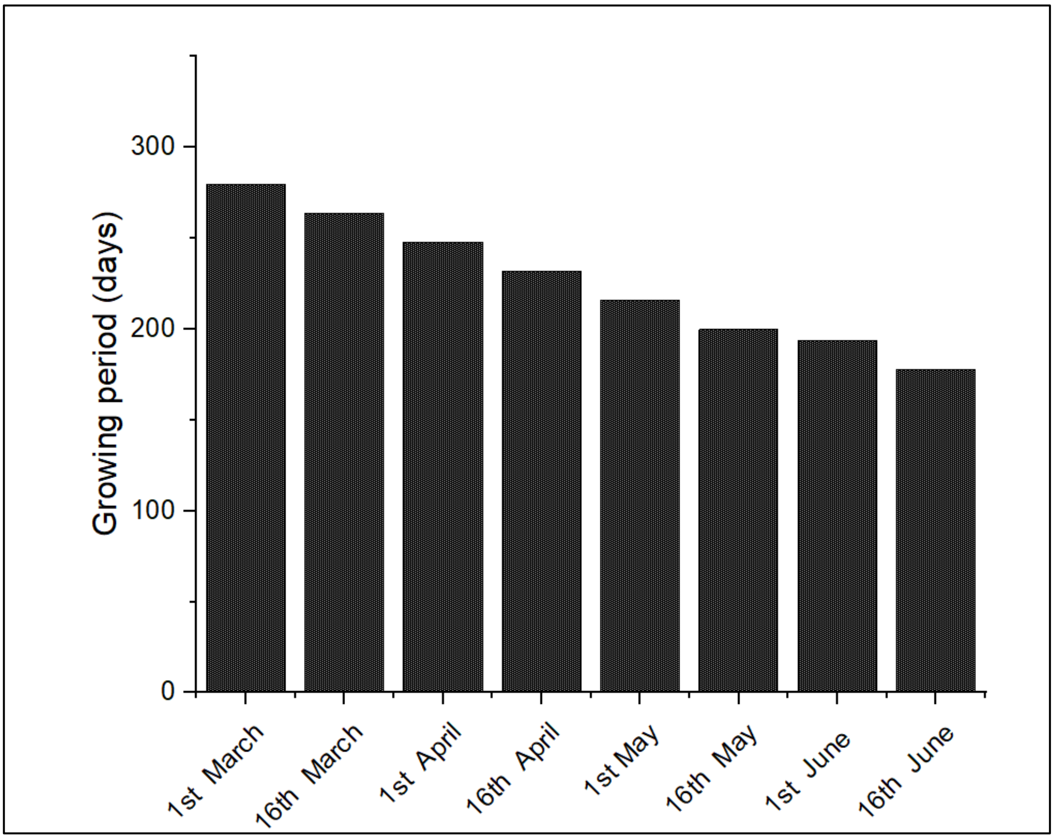


Figure 5A & 5 B: PCA-Biplot and Individual PCA for independent (sowing dates) and dependent variable (whitefly, beneficial fauna and agronomic traits) of upland cotton during 2019.

(A)



(B)

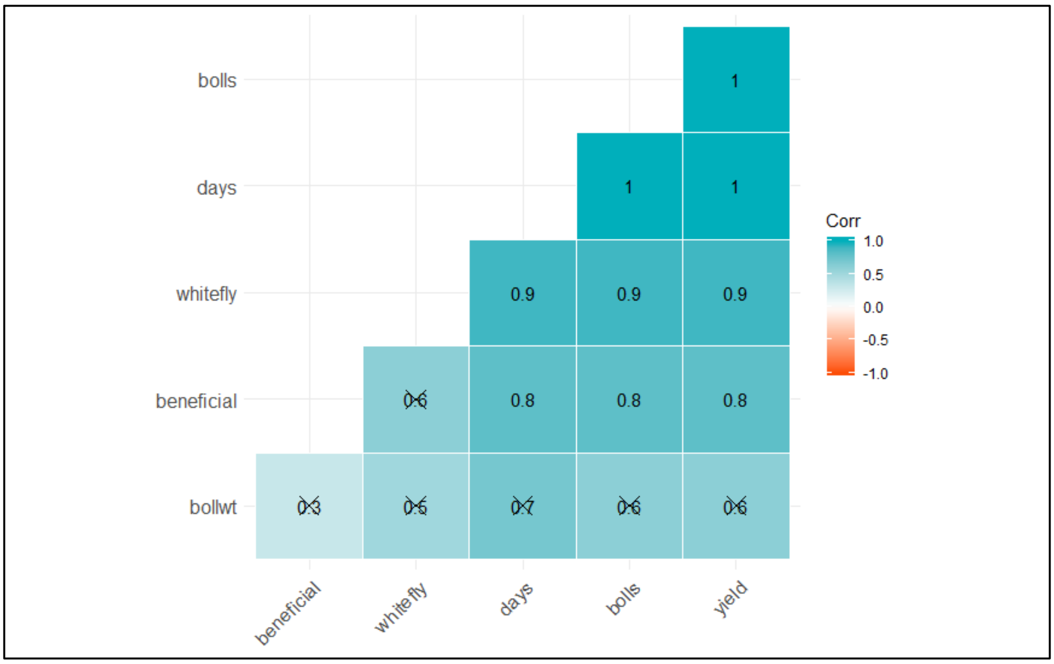


Figure 6A & 6B: Mean comparison regarding the effect of sowing dates on the predatory fauna of upland cotton by using Tukey Honesty Significant Difference test at P=0.05 during 2019.

DISCUSSION

Continuous use of conventional insecticide raised insecticide resistance and pest induced resurgence related issues in Pakistan (Ahmad et al., 2007; Ahmad et al., 2008; Shad et al., 2012) (Cherry et al., 1997) Furthermore, increased use of these chemical insecticides creates environmental and health-related issues. In this regard, there is a need to find an eco-friendly alternative like cultural practices for the management of insect pest. Changing the sowing time of crop can escape the incidence of insect pest.

Food chain of arthropod herbivory depends upon the growth cycle and planting time of crops. Perennial crops provide food supply throughout the activity period of the pest. Furthermore, early sown crops are the source of insect pest flare up due to availability of food supply and substrate for egg laying to the pest. It is also the basic pillars in the production technology of any crop therefore, it was imperative to find out the planting time that could escape the insect pest herbivory on cotton crop. Well suited practice is the provision of favorable environmental condition to the genetic material that collectively ensure the high productivity of the crop.

In the present studies selected cultivars had non-significant effect on the population of whitefly sown on different sowing dates. The results are similar with the finding of (Shahid et al., 2012a) who reported significant effect of abiotic factors on the population dynamics of insect pest. In present study it is demonstrated that whitefly population was minimum on the last sowing dates as compared with the early sowing dates. Similar results were reported by McPherson et al. (2001) that early planted soybeans had higher populations of stink bugs. Similarly sowing dates had significant effect on the population of red and dusky cotton bug. In early sowing dates the population of whitefly was also high than the seasonal and late sowings (Shahid et al., 2014). It might be due to the reason crop becomes available for feeding and breeding of insect pest during the off-season and provision of food facility remain for a longer period of time or shortening of sowing window. The results are similar to the findings of (Showler et al., 2005; Shahid et al., 2014) that insect pest is shifted from the reduced window crop to the long season crop.

Significant difference in whitefly population was recorded on different observation dates. Observations demonstrated significant effect on population of whitefly. Out of six observations, whitefly per leaf during first observation (2 to 8 per leaf) was gradually increased to 10 per leaf in second observation, 12 whitefly per leaf on third and fourth observation. In fifth observation, it ranged from 10-15 per leaf among the selected cultivars of cotton sown on different sowings. Fifth observation on 15th September that was the peak period for the population buildup of whitefly. It might be due to the effect of abiotic factors. The climatic conditions during the fifth observation period might be in optimum range for the activity of whitefly (Sharaf and Batta, 2009). After May 16, whitefly populations on all selected cultivars sown on all eight sowings decreased once more. It might be due to the reason that crop starts its termination stage. Similar results have been reported by Bariola et al., (1976) that pink bollworm diapausing larvae were reduced by (90 %) due to use of chemicals for the termination of cotton.

In present studies results demonstrated that beneficial fauna had positive association with whitefly. It might be due to natural availability of food prey for the beneficial fauna that keep them under check (Shahid et al., 2007; Syed et al., 2015). Results of present study revealed that early sowing has positive impact on the yield related traits of cotton.

These results are similar to the findings of (Shahid et al., 2013). It might be due to difference in crop maturity. According to Huang, 2015 early planted cotton plants received additional benefit of soil moisture, nutrients. From present studies observations demonstrated that first two observations had lowest population of whitefly followed by three and four observations but peak population was in observation five. It might be due to effect of abiotic factors. Results are similar to Huang (2015) who reported that early planted cotton took advantage of more accumulated temperature which allowed last bolls to develop due to extended growing season. It might be due to the succulence level of plants is changed, resultantly preference of insect pest is also changed accordingly. So by altering of planting time is useful for breakage of breeding and feeding link of insect population. The effect of climate change on *B. tabaci* is important for predictions and its management practices. Climate have impact on life parameters of whitefly. Levi et al., (2014) claim that temperatures (25, 28 and 33°C) were utilized to evaluate their influence on life cycle characteristics. Temperature influenced oviposition, nymphal survival, and reproduction rate of whitefly, with net reproductive rates reducing to 36.4% at 33°C. They further explained that overall, 28°C was optimum temperature for whitefly fitness and multiplication between 28 and 33°C. So, climate change directly influenced the life parameters of pest as well as it induces stress on the crop and under plant stress conditions insect pest cause more losses than on healthy plants (Holtzer et al., 1988; Waring et al., 1992). From the results it was found that growing of late planting dates had least population of whitefly. It further indicated that growing period (days) exerted 90.0% effect on whitefly and 80.0% on beneficial fauna. Shortening of sowing window has been recommended for the management of various insect pest of cotton. Already, this practice is very useful for the management of pink bollworm and red cotton bug. No doubt, on late sowing there is major threat of CLCuD (cotton leaf curl disease). However it is requisite to study the effect of sowing dates related factors to minimize the effects of changing climate.

Therefore, we should work on growing of short duration crops to escape the effects of changing climate and avoid its stress on the economic crop. Climate change also had adverse effects on the predatory/parasitism potential of bio-control agents (Hance et al., 2007).

CONCLUSION

One of the basic techniques of cultural management is to alter the timing of sowing. The major crop's vulnerability to insect pest assault must be minimized. The ideal sowing times for cotton (early and late sowing) are believed to be essential for controlling crop arthropod pests and ensuring yield. We could conclude that sowing dates are essential for predatory fauna in cotton and whitefly escape. Because late sowing dates with shorter growth seasons had the lowest risk of whitefly, we should focus on planting short-duration crops in the future.

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AUTHORS CONTRIBUTION

All authors contributed equally to draft and publish this manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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