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Research Article

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Evaluation of Sugarcane Genotypes for the Susceptibility against Whitefly, *Aleurolobus barodensis* (Maskell) in Sindh, Pakistan

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Abstract

Whiteflies, which are polyphagous and feed on the sap of sugarcane leaves, may result in a reduction in output. The goal of this study was to identify the comparative resistance/susceptibility of the fifteen sugarcane genotypes in 2014–15 and 2015–16. The whitefly infestation was originally discovered in June, began to pick up speed in August, and peaked its maximum population in October. After that, the population gradually declined from November to December. The highest (1.80 per cm^2 $leaf^{-1}$) population of whitefly (nymph & pupae) was recorded on YT-53, followed by 1.56 per cm^2 $leaf^{-1}$ in S-2007-AUS-384, which showed moderate susceptibility. The genotypes Hoth-127, NARC-1, and CP-TJ-349 exhibited less susceptible responses with an average range of 1.01-1.50 per cm^2 $leaf^{-1}$ whiteflies. The other genotypes, i.e., CP-TJ-349, Hoth-326, Th-910, S-2005-CSSG-33, S-2007-AUS-384, Hoth-2109, LAM-76/TJ-803, Th-1201, S-2009-CPSG-06, S-1996-NSG-197, NARC-2, and Th-1210 showed resistance response with an average range of 0.01-1.00 per cm^2 $leaf^{-1}$. The maximum Host Plant Susceptibility Indices (HPSIs) during 2015 (16% and 15%), 2016 (13% and 14%), and cumulative (16% and 14%) were recorded in YT-53 and S-2007-AUS-384 genotypes, respectively, based on the cumulative result of HPSIs, which kept into a moderately susceptible category, Similarly, the genotypes Hoth-127, NARC-1, and CP-TJ-349 showed intermediate HPSIs 12, 11, and 9%, found to be less susceptible. While the genotypes, i.e., Hoth-326, Th-910, S-2005-CSSG-33, LAM-76/TJ-803, Hoth-2109, Th-1201, S-1996-NSG-197, S-2009-CPSG-06, NARC-2, and Th-1210 were discovered to be resistant, with minimum HPSIs in the range of 1-8%.

Keywords: *Aleyrodidae, nymph, puparia, genotypes, population, susceptibility*

Introduction

Sugarcane (*Saccharum officinarum* L.) is a very important food crop and is known as the cash crop of the world (Yao, 2017 and Khan *et al.*, 2019). In Pakistan, sugarcane is growing in a vast area, and it is the 2nd largest industry, its production is 3.7% and 0.8% of agriculture's value addition and GDP during 2021-22, (GoP Economic Survey, 2022). According to estimates by Taspinar *et al*. (2019), 25% of sugar produced globally, from sugar beets and 75% comes from sugarcane. Sugarcane is a long-duration crop, planted across a large area, and is under threat from many insect pests including the sugarcane borer, whitefly, wooly aphid, termites, leafhoppers, and bugs (Prasad *et al.*, 2018). The whitefly is a polyphagous insect belonging to the family Aleyrodidae, identified by its smoky wings with pale yellowish color (Khan *et al.*, 1983), and the most destructive sucking pest of sugarcane crops, which caused a decline in their yield production (Agarwal, (1969); Iqbal *et al.* (2012); and Sheikh, (1968). It was known that 288 insect pests could attack sugarcane, and about 76 are other pests. From those almost 24 insect pests cause considerable losses to sugarcane production and quality (Sanskriti *et al.*, 2022). Three Sugarcane whiteflies species, *A. barodensis*, *N. bergii*, and *N. andropogonis* are vital pests that damage early maturing susceptible varieties (Koohzad-Mohammadi *et al.*, 2021), which cause up to 50% yield losses (SCRI, 2016). In Pakistan, 19 genera with 70 species of whiteflies have been recorded, which significantly damage different crops (Tayyib, 2013). The whitefly nymphs secrete honeydew from the underside of sugarcane leaves, causing sooty mold and hindrance in photosynthesis (Askarianzadeh, 2011). Sugarcane production was affected to the highest degree by different pests, from those rats, termites, borers, leafhoppers, and whiteflies were found main pests (Khan *et al.*, 2022). Spraying insecticides in sugarcane fields is problematic due to the whitefly population's fast growth and the crops' extreme density. Nowadays, the new resistant sugarcane varieties can be developed consistently as a power against insect pests. Agarwal (1969) stated that some morphological characters sugarcane plants are associated with the successful resistance of borers, whitefly, perilla, black bugs, and mites. However, biotic pressures also affect the monoculture cropping system. Numerous insect pests and viruses attack the sugarcane crop, causing significant losses to the crop (Mohammadi, 2017). Malekmohammadi *et al.* (2012) reported that the ecological dynamics of the whitefly population control through variable factors, including a cultivated variety that typically possesses resistant power against insect pests. Sugarcane whitefly now a day's become a major pest, due to climatic conditions and the growth of susceptible varieties. This emphasizes bio-security in pest control and the establishment of preventative measures and to reduce and risk. The requirement for time to perform a research study to screen out different sugarcane genotypes against whiteflies is therefore quite pressing.

Materials and Methods

For the initial year of sugarcane genotype screening: For the initial year of sugarcane genotypes screening the varietal material obtains from National Uniform Varietal Trial, PARC-NSTHRI, Thatta, 2014, and planted. The varieties included in the study were S-1996-NSG-197, S-2005-CSSG-33, and S-2009-CPSG-06 from Shakarganj Sugar Research Institute (SSRI) Jhang, LAM-76/TJ-803, and CP-TJ-349 from Sugarcane Section, ARI, Tandojam, S-2007-AUS-384 from Sugarcane Research Institute, AARI, Faisalabad, NARC-1, and NARC-2 from Sugarcane Research Program-NARC, Islamabad, Hoth-127, Hoth-2109, Hoth-326, YT-53, Th-910, Th-1201, and Th-1210 from PARC-NSTHRI, Thatta. Research trials were conducted 2014-15 and 2015-16 cropping seasons at PARC-National Sugar and Tropical Horticulture Research Institute, Thatta, and laid out according to Randomized Complete Block Design. It has a total plot area of $510m^2$, three replicates, and five rows for each genotype. Fifteen sugarcane genotypes were screened to assess the varietal response against the sugarcane whitefly, *Aleurolobus barodensis*. The observations were collected from the middle leaf (per $4cm^2$ upper, middle, and lower portions) of 10 randomly selected plants, from June to December at fortnight intervals. Sugarcane genotypes were classified into four categories; resistant with 00-1.00, less susceptible with 1.01-1.50, moderately susceptible with 1.51-2.00, and susceptible above 2.01 (nymph & pupae) per cm^2 $leaf^{-1}$. Data results were analyzed statistically by following analysis of variance (ANOVA) through M-Statistics 8.1. To find out the mean differences, the DMR was applied at P=0.05. For the confirmation of the results, the same fifteen genotypes were planted in the second-year screening trial following the same protocols.

Host Plant Susceptibility Indices (HPSI): The objectives of HPSI are to find out the susceptibility level of sugarcane genotypes against whiteflies, based per cm^2 $leaf^{-1}$ population in the first year (2015), second year (2016) individually, and on a cumulative basis.

$$HPSI\ (\%) = \frac{B-A}{B} \times 100$$

Where: A= Pest Population (nymph & pupae) on a single genotype, and

B = Pest Population (nymph & pupae) on all selected genotypes of the sugarcane on a total basis

Results and Discussion

First-year Screening Trial

Varietal Differences: The findings in Table 1 revealed significant variations across genotypes and dates. The population of whitefly during 2015 presented in Figure-1 revealed that the genotype YT-53 showed a moderately susceptible trend with a mean population of 1.66 (nymph & pupae) per cm^2 $leaf^{-1}$. Similarly, the genotypes S-2007-AUS-384, Hoth-127, and NARC-1 were less susceptible, with a population of 1.32, 1.24, and 1.23 per cm^2 $leaf^{-1}$. However, the genotypes CP-TJ-349, Hoth-326, Th-910, S-2005-CSSG-33, Hoth-2109, LAM-76/TJ-803, Th-1201, S-2009-CPSG-06, S-1996-NSG-197, NARC-2, and Th-1210 resistive, with a mean population, as observed 0.93, 0.78, 0.74, 0.67, 0.41, 0.38, 0.30, 0.24, 0.16, 0.12 and 0.09 per cm^2 $leaf^{-1}$, respectively. The result of the study is in validation with Masood (2011), who stated that from 20 sugarcane varieties, no one was observed free from whitefly attack, comparatively SPSG-26, COJ-84, and HSF-242 were susceptible range (15.48-11.36 per leaf), CP-72/2086, NIA-98, and CO-132 were intermediate (10.67-10.91 per leaf) and CPF-243, CPF-237, and CPM-13 (6.39-9.21 per leaf) were found resistant. Rasool *et al.*, 2015 reported that the highest infestation has been observed in sugarcane genotype CSSG-239, followed by HSF-240 & US-240, and the lowest attack was observed in US-272 and CSSG-212 sugarcane genotypes. While none of the genotypes spread onslaught whitefly attack. Furthermore, Viswanathan (2021) demonstrated that the genotypes GT11, GT37, NCO310, POJ2878, and F134 were found highly susceptible; while CP84-1198, GT05-3846, ROC27, and YT94-128 remained highly resistant.

Table.1. Evaluation of the whitefly population through analysis of variance during first-year, 2015

Source of Variance	D.F.	Sum of Square	Mean Square	F. Value	P
Block	2	0.415	0.207		
Date	13	232.202	17.861	173.87	**0.000
Genotypes	14	147.212	10.515	102.36	**0.000
Date*Genotypes	182	117.308	0.644	6.27	**0.000
Error	418	42.940	0.1027		

CV 46.85%
**Significant at $p \leq 0.01$

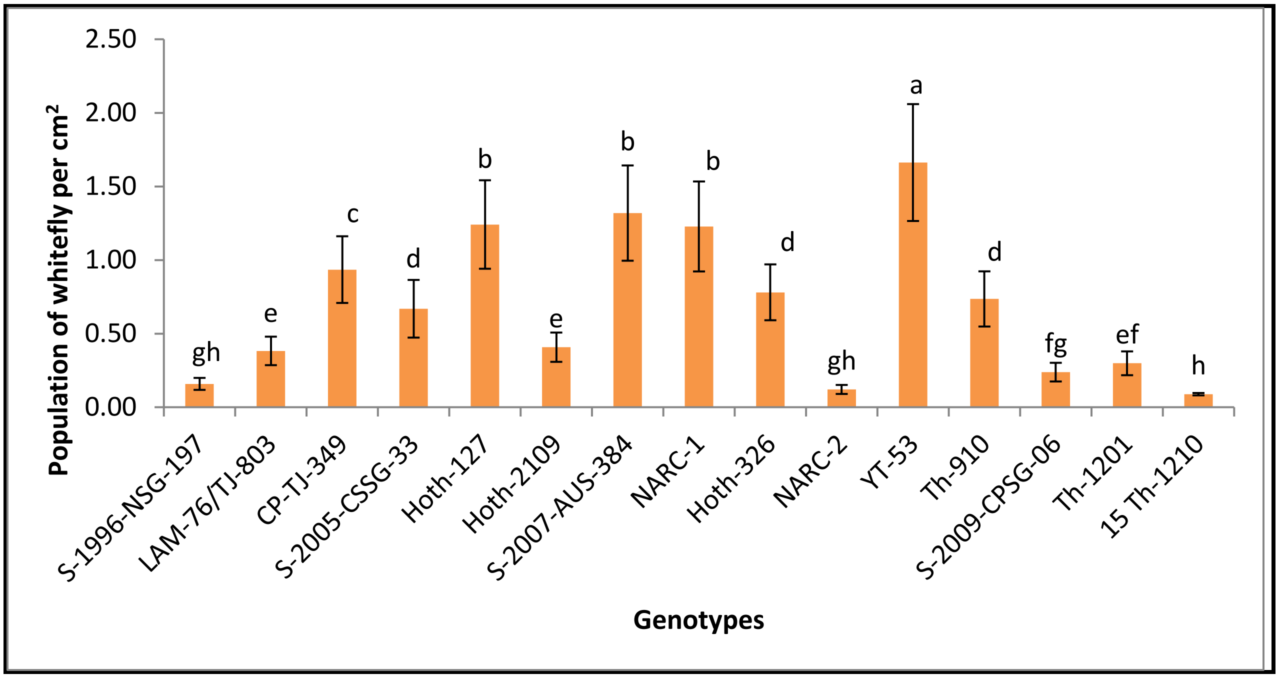

Fig.1. Population of whitefly (nymphs & pupae) per cm^2 $leaf^{-1}$ on different genotypes during 2015

Period of Abundance: The comparisons of means across different dates during 2015 given in Figure 2 demonstrate that the whitefly population began to rise in June, quickly increasing from August 15 (1.01 per cm^2 $leaf^{-1}$), and reached its maximum level (1.72 per cm^2 $leaf^{-1}$) in October. The data further showed the pest population values started declining slowly from December 15 (0.08 per cm^2 $leaf^{-1}$). According to Masood *et al.* (2011), whiteflies are undoubtedly an great affected by humidity in September when their population reaches a considerable highe . Whitefly may generally cause more severe damage to sugarcane in October.

A later decline in the standard temperature the patient population is deceased till November. However, Nikpay (2017) reported that as the relative humidity increases the population of whitefly is enhanced till the 21st of October, while the population is reduced as the temperature declines. In contrast, Saeedi (2020) reported that the pupal population of whitefly reached its peak (156 pupae per leaf) on 27th October.

Second Year Screening Trial

Varietal Differences: The same fifteen genotypes were again screened in 2016 under similar ecological conditions. The results shown in Table 2 that significant variation was observed among the genotypes and dates of observation and interactions between genotypes and dates at p (<0.05). The population values of whitefly were found higher in 2016 as compared to 2015 (Figure 3). The genotypes YT-53 and S-2007-AUS-384 showed moderately susceptible to a mean average of 1.95 and 1.81 (nymphs & pupae) per cm^2 $leaf^{-1}$. Identically, the genotypes Hoth-127, NARC-1, CP-TJ-349, and Hoth-326 indicated less susceptible responses with a mean average of 1.48, 1.29, 1.24, and 1.01 per cm^2 $leaf^{-1}$, respectively. However, the genotypes Hoth-326, Th-910, S-2005-CSSG-33, Hoth-2109, LAM-76/TJ-803, Th-1201, S-2009-CPSG-06, S-1996-NSG-197, NARC-2, and Th-1210 were showed resistance against whitefly with a mean average <1.00 per cm^2 $leaf^{-1.}$ These findings are partially compared with Rasool *et al.* (2015), who stated that from nine sugarcane genotypes, the highest whitefly population observe in CSSG-239 (6.11 per cm^2 $leaf^{-1}$), followed by HSF-240 (5.34 per cm^2 $leaf^{-1)}$ and US-54 (4.59 per cm2 leaf-1). While a minimum score of 1.30 and 1.44 per cm^2 $leaf^{-1}$ was recorded in US-272 and CSSG-212, respectively. However, Nikpay (2016) reported that across 7 sugarcane varieties, the CP69-1062 was found most susceptible variety with 47.3% stalk and 32.8% leaf damage. Also, Mansoor *et al.* (2016) screened fifteen sugarcane genotypes from which, eight genotypes i.e., S2006- US-469, S2006-US-272, S2005-US-54, S2008-AUS-130, S2006-US-658, S2008-AUS-190, S2008-AUS-107, S2009-SA-169 were ranked resistant. Whereas the genotypes S2008-M-34, S2008-AUS-133, S2003-US-127, S2003- US-704, S2008-Fd-19, S2008-AUS-87 were categorized as a moderately susceptible and S2003-US-618 was remain as susceptible

Period of Abundance: A comparison of the whitefly population amongst various dates during 2016 is present in Figure-4, shown that the population of whitefly was started in June. Figure 4 shows f a comparison of of means the whitefly population on several dates during 2016, demonstrating that the whitefly population began in June. However, the population of whiteflies rapidly increased from August 15 (1.18 per cm^2 $leaf^{-1}$) and reached its peak level (2.27 per cm^2 $leaf^{-1}$) on October 15. The statistics also revealed that starting on November 1, the whitefly instead bug population progressively decreased. (1.07 per cm^2 $leaf^{-1}$) and reached 0.11 at the lowest level up to December 15

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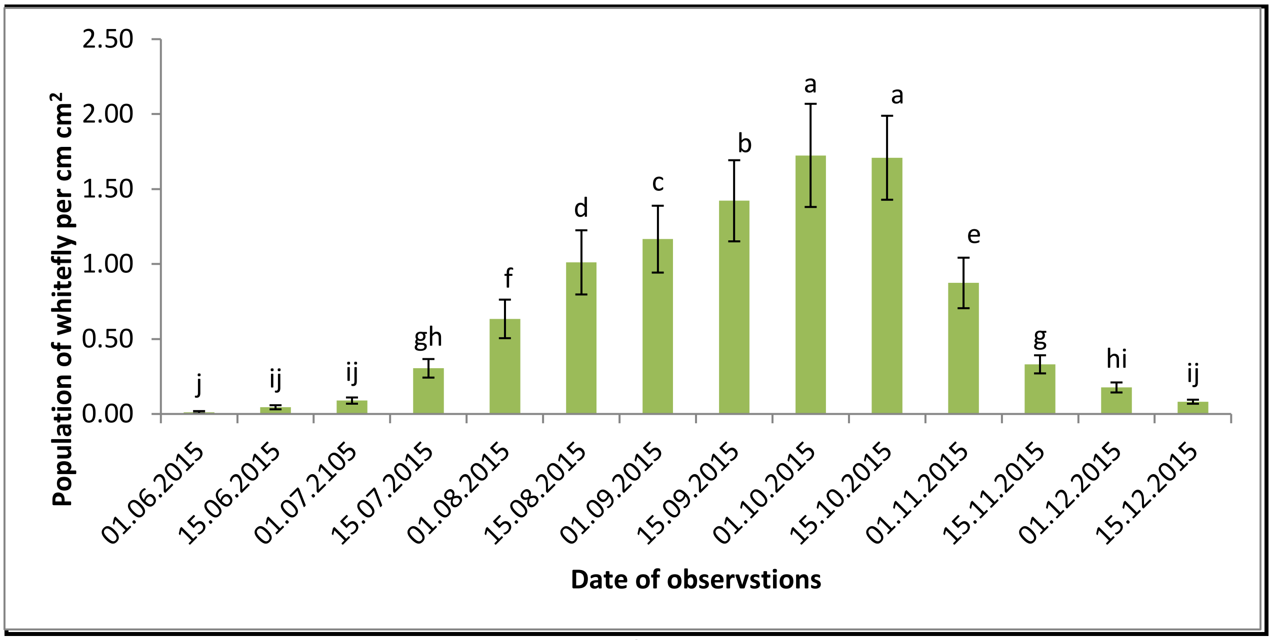

Fig.2. Population of whitefly (nymphs & pupae) per cm^2 $leaf^{-1}$ at different dates during 2015

Table.2. Evaluation of the whitefly population through analysis of variance during the second year, 2016

Source of Variance	D.F	Sum of Square	Mean Square	F. Value	P
Block	2	0.649	0.324		
Date	13	359.351	27.642	242.79	**0.000
Genotypes	14	214.820	15.344	134.77	**0.000
Date*Genotypes	182	167.660	0.921	8.09	**0.000
Error	418	47.590	0.1139		

CV 39.87%
**= Significant at $p \leq 0.01$

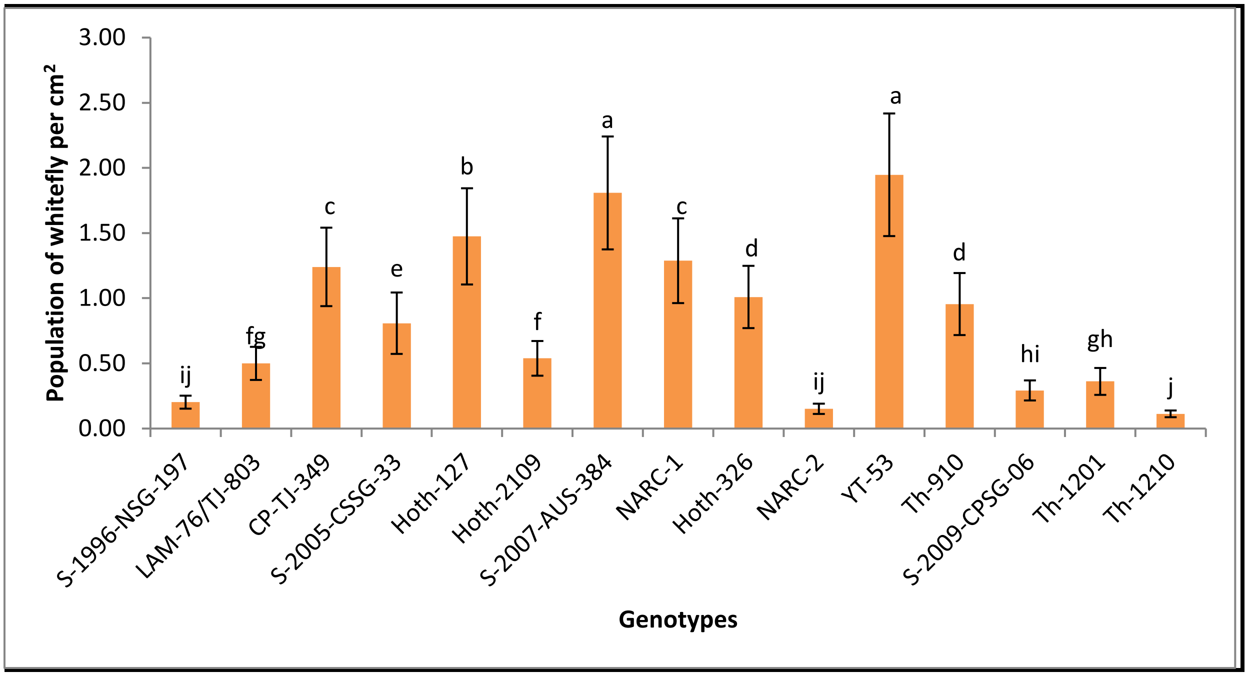

Fig.3. Population of whitefly (nymphs & pupae) per cm^2 leaf^{-1} on different genotypes during 2016

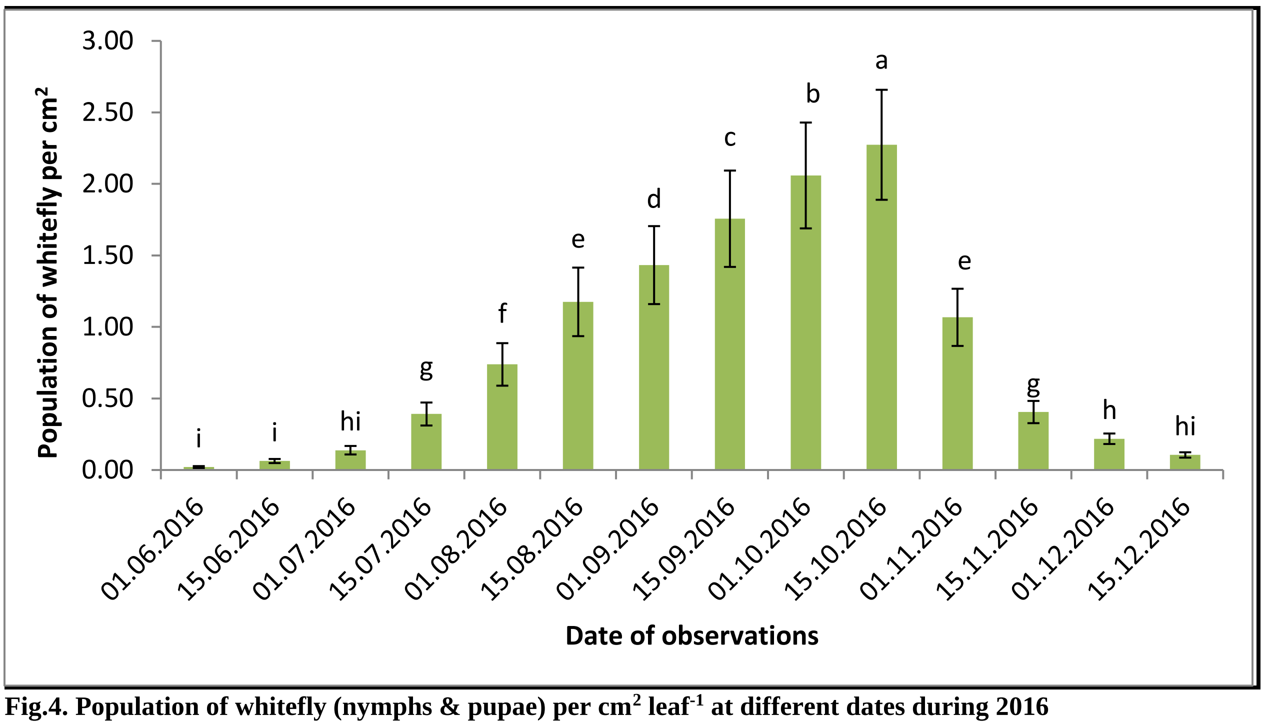

Fig.4. Population of whitefly (nymphs & pupae) per cm^2 leaf^{-1} at different dates during 2016

Average of two-year data of whitefly on screening Trials (2014-15 and 2015-16)

Varietal Differences: The population of whiteflies on a two-year average basis (2015 and 2016) of varietal screening trials resulted in a significant difference ($P \leq 0.01$) among various dates and their interactions is given in Figure-5 and the ANOVA in Table 3. The results observed that a maximum population of 1.80 per cm^2 leaf^{-1} of whitefly was observed in YT-53 followed by S-2007-AUS-384 (1.56), as a result Hoth-127, NARC-1, and CP-TJ-349 which had average whitefly population of 1.36, 1.26, and 1.09 per cm^2 leaf^{-1}, respectively, and less susceptible response followed. The other genotypes Hoth-326, Th-910, S-2005-CSSG-33, Hoth-2109, LAM-76/TJ-803, Th-1201, S-2009-CPSG-06, S-1996-NSG-197, NARC-2, and Th-1210 with 0.89, 0.85, 0.74, 0.47, 0.44, 0.33, 0.27, 0.18, 0.14, and 0.10 per cm^2 $leaf^{-1}$ population of whitefly exposed a resistant response. Rasool *et al.* (2015) observed the highest population of sugarcane whitefly on CSSG-239 (6.11 per cm^2 $leaf^{-1}$) followed by HSF-240 (5.34 nymph per cm2), and US-54 (4.59 per cm^2 $leaf^{-1}$). The genotypes US-272 and CSSG-212 had a minimum infestation of 1.30 and 1.44 per cm^2 $leaf^{-1}$, respectively. Furthermore, Thumar and Kapadia (1994) screened 50 varieties of sugarcane against *A. barodensis;* they did not discover any immune variety but found resistance, i.e., CO-8147 and Co-R-41. No variety was free from the whitefly attack. Mann and Singh (2003) investigated 32 sugarcane genotypes from which 9 genotypes were highly susceptible, 3 (Co 1148, Sel 917/98, and CoP 84212) were least susceptible, and 2 (CoS 96258 and Sel 126/92) were the most susceptible. While the slight attack of whitefly was recorded on the remaining genotypes.

Table.3. Evaluation of two-year (2015 and 2016) average data of whitefly population through analysis of variance

Source of Variance	D.F.	Sum of Square	Mean Square	F. Value	P
Block	2	1.02	0.508		
Date	13	583.91	44.916	460.92	**0.000
Genotypes	14	356.97	25.498	261.65	**0.000
Year	1	8.28	8.284	85.02	**0.000
Date*Genotypes	182	276.15	1.517	15.57	**0.000
Date*Year	13	7.64	0.587	6.03	**0.000
Genotypes*Year	14	5.06	0.361	3.71	**0.000
Error	1020	99.40	0.097		

CV 40.79%
**= Significant at $p \leq 0.01$

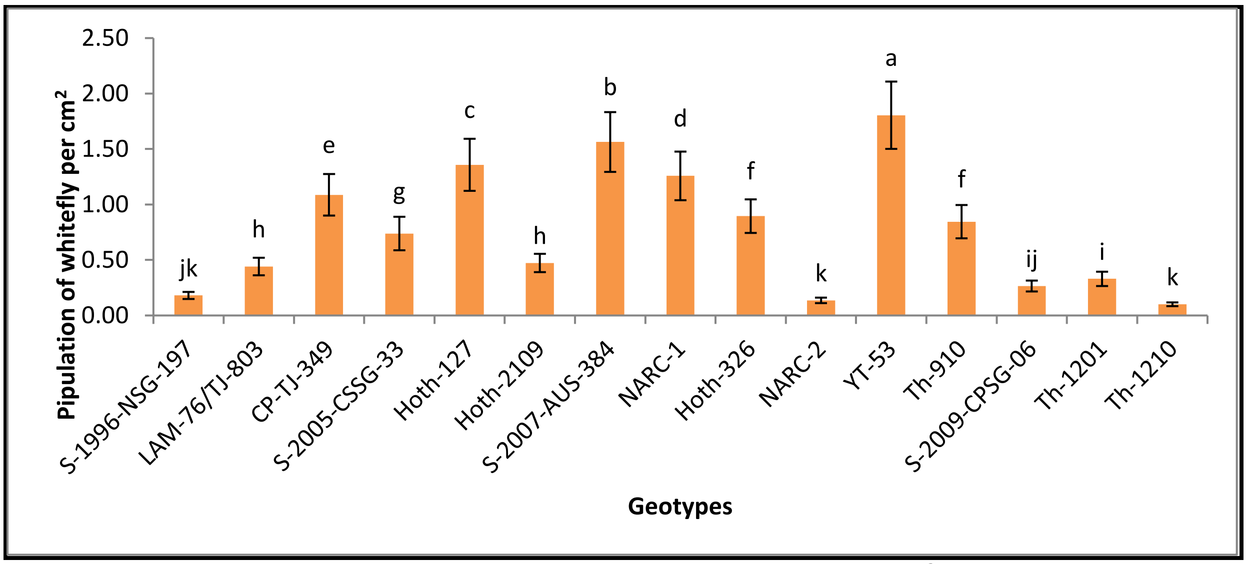

Fig.5. Two-year (2015 and 2016) average population of whitefly (nymphs & pupae) per cm^2 $leaf^{-1}$ on different genotypes

Period of Abundance: The results showed (Figure-6) that the period of infestation was relatively different during both years. The cumulative base result of the whitefly population among various dates of observation showed a maximum population of 2.27 per cm^2 $leaf^{-1}$ in the 2^{nd} week of October 2016, followed by 1.72 per cm^2 $leaf^{-1}$ during the 1st week of October 2015. The present findings conform to those of Thumar and Kapadia (1995), who reported that the pest population reached a peak in the 1st week of October. Another statement of a positive correlation between humidity and the whitefly population was confirmed by Nikpi (2017) stated that the population whitefly increased with humidity up to October.

The sugarcane whitefly activity started from July peaks in the population generally observed in September and October (Sheikh, 1968). Askarianzadeh (2011) reported that the attack of whitefly *N. andropogonis* commences in late August when sugarcane varieties store sucrose in their stalks. The results indicate that the whitefly population decreased suddenly from November to December in both experimental years. Moreover, August to October is the most favorable month for whitefly. Present findings confirm with (Masood *et al.*, 2011), who reported temperature and humidity effects on the whitefly population in Pakistan. However, both factors increase in early September, higher in late October, and later decrease in November. The genotypes Hoth-326, Th-910, S-2005-CSSG-33, Hoth-2109, LAM-76/TJ-803, Th-1201, S-2009-CPSG-06, S-1996-NSG-197, NARC-2, and Th-1210 showed resistant responses against whitefly. Rasool *et al.* (2015) screened nine sugarcane genotypes against sugarcane whitefly, who recorded CSSG-239 with a high infestation, followed by HSF-240 and US-240, and US-272 and CSSG-212 with minimum infestation. None of the sugarcane genotypes was free from whitefly infestation. Present results showing some resistance factors against whitefly agree with Goebel, and Sallam (2011) indicating that integrated pest management practices, i.e., varietal resistance and environmentally eco-friendly control methods, minimize whitefly damage.

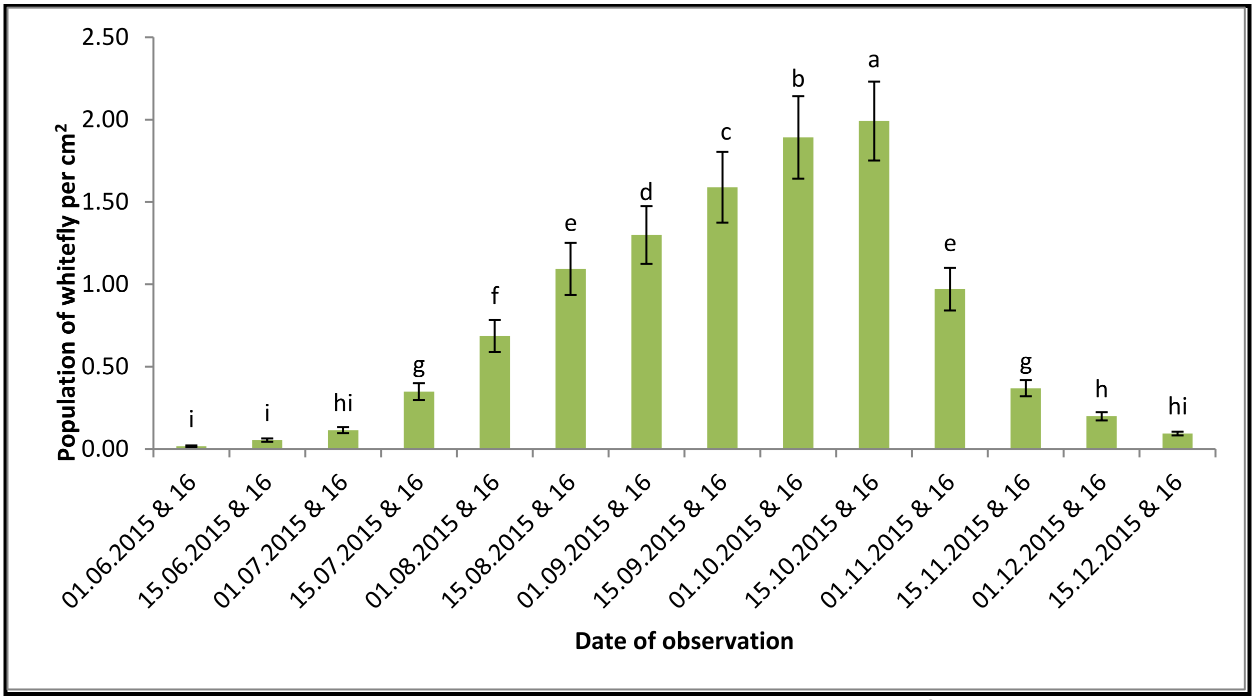

Fig.6. Two-year (2015 and 2016) average population of whitefly (nymphs & pupae) per cm^2 leaf^{-1} at different dates

Host Plant Susceptibility Indices (HPSIs): The HPSIs were calculated based on whitefly (nymphs & pupae) per cm^2 leaf^{-1} individually and on average of two-year 2015 and 2016 results. A detailed discussion of the HPSIs is as below.

HPSIs During 2015: The results of the whitefly population per cm^2 leaf^{-1} for selected varieties during 2015 are given in Figure 7. The result shows that YT-53 revealed a maximum HPSI of 16%, followed by S-2007-AUS-384 (13%), Hoth-127 (12%), NARC-1 (12%), CP-TJ-349 (9%), Hoth-326 (8%), S-2005-CSSG-33 (7%), Th-910 (7%), LAM-76/TJ-803 (4%), Hoth-2109 (4%), Th-1210 (3%), S-1996-NSG-197 (2%), S-2009-CPSG-06 (2%), NARC-2 (1%) and Th-1210 (1%).

HPSIs DURING 2016: The results of the whitefly population per cm^2 leaf^{-1} for selected varieties during 2016 are presented in Figure 8. The result shows that YT-53 revealed maximum HPSI, i.e., 15%, followed by S-2007-AUS-384 (14%), Hoth-127 (12%), CP-TJ-349 (10%), NARC-1 (10%), Hoth-326 (8%), Th-910 (8%), S-2005-CSSG-33 (6%), LAM-76/TJ-803 (4%), Hoth-2109 (4%), Th-1201 (3%), S-1996-NSG-197 (2%), S-2009-CPSG-06 (2%), NARC-2 (1%) and Th-1210 (1%).

HPSIs on an average basis of two years of data: Based on two years of data (Figure-9), the maximum HPSIs was recorded at 16% for YT-53, followed by S-2007-AUS-384 (14%), and kept in the moderately susceptible category. In contrast, the minimum (HPSI) was observed to be from 8-1% for Hoth-326, Th-910, S-2005-CSSG-33, LAM-76/TJ-803, Hoth-2109, Th-1201, S-1996-NSG-197, S-2009-CPSG-06, NARC-2, and Th-1210, respectively on the cumulative based was found to be comparatively resistant genotype.

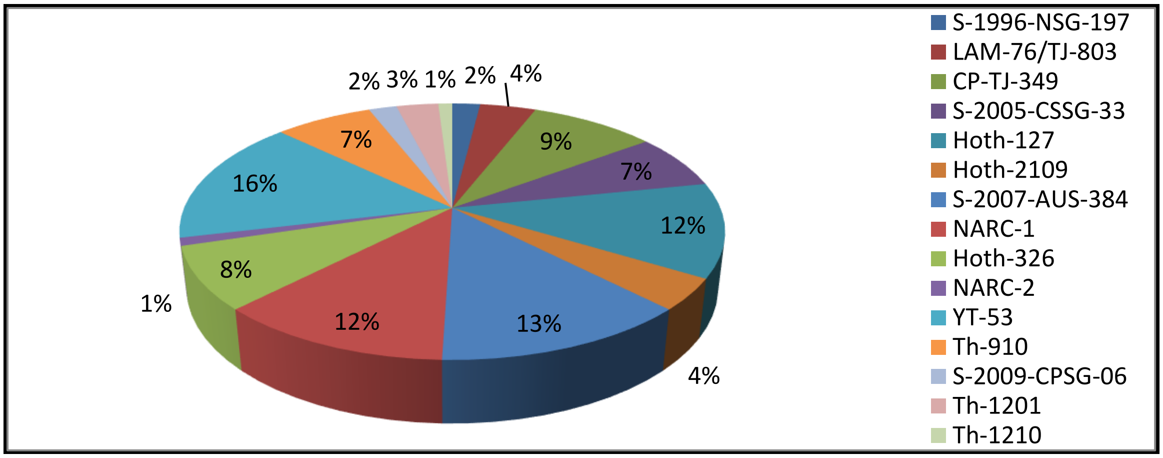

Fig.7. Host plant susceptibility indices of genotypes against whitefly population during 2015

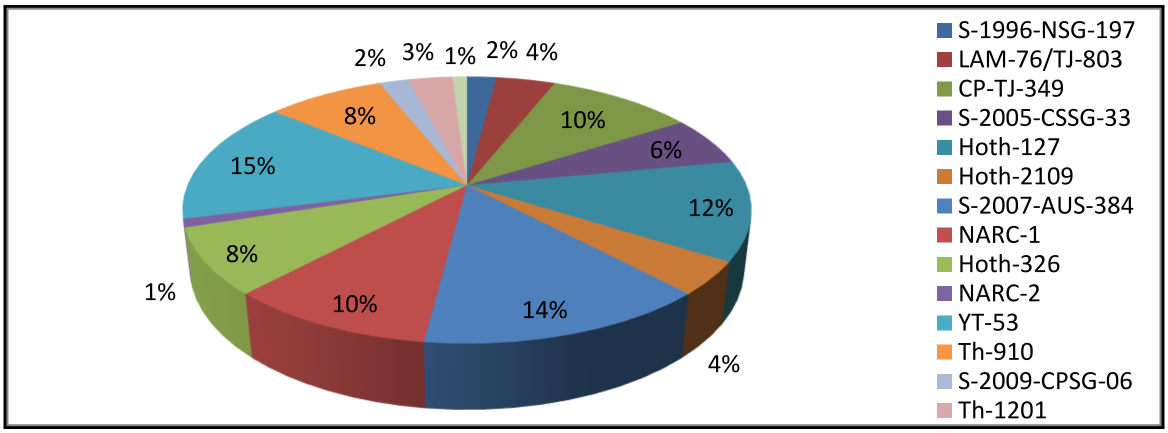

Fig.8. Host plant susceptibility indices of genotypes against whitefly population during 2016

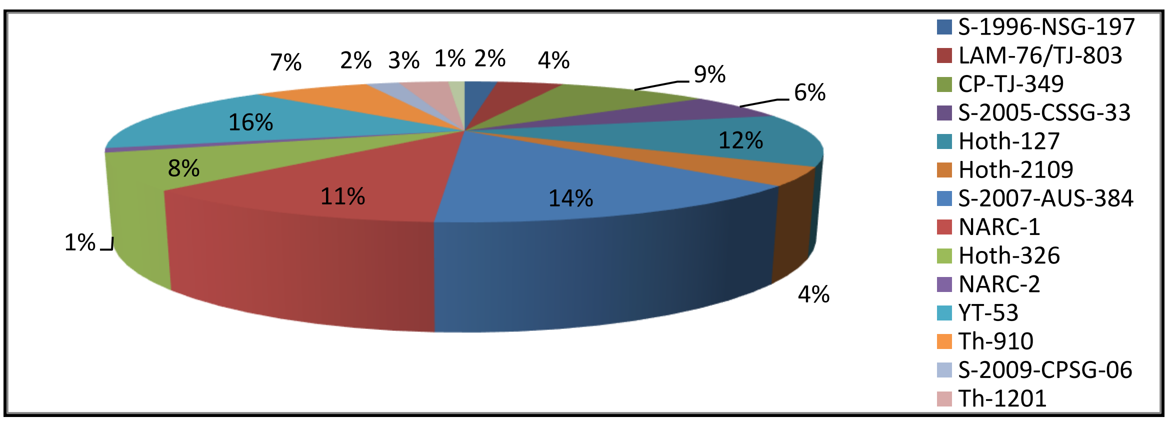

Fig.9. Two-year (2015 and 2016) average host plant susceptibility indices of genotypes against whitefly population

Conclusion and Recommendations

The study indicated that genotypes Hoth-326, Th-910, S-2005-CSSG-33, Hoth-2109, LAM-76/TJ-803, Th-1201, S-2009-CPSG-06, S-1996-NSG-197, NARC-2, and Th-1210 were relatively resistant, whereas YT-53 is moderately vulnerable against whitefly infestation. However, August, September, and October are the best month for growing the whitefly population

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