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Evaluation of Cotton (*Gossypium hirsutum* L.) Varieties/Genotypes for Jassid, *Amrasca biguttula biguttula* (Ishida) Resistance under Rainfed Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Host plant resistance is an important component of integrated pest management strategy for jassid resistance. Evaluation of germplasm to identify the stable source of resistance is a predominant step in any resistance breeding programme. In this study, screening of *Gossypium hirsutum* cotton varieties/genotypes against jassid, *Amrasca biguttula biguttula* (Ishida) was carried out under rainfed conditions during *kharif* seasons of 2016-17, 2018-19 and 2019-20 at Regional Cotton Research Station, Navsari Agricultural University, Maktampur farm, Bharuch, Gujarat. Among thirteen cotton varieties/genotypes screened, none of variety/genotype was categorized as resistant by considering jassid population as well as Jassid Resistance Index. Six cotton varieties/genotypes *viz.,* NH-615, GBHV-201, GBHV-209, GBHV-204, G.N.Cot-26, GBHV-206 and two checks *i.e.* DHY-286 and NDLH-1938 were categorized as moderately resistant based on maximum jassid population ranged from 4.40 to 7.40 jassids/3 leaves. Three cotton varieties/genotypes *viz.*, Suraj, Bunny BG II and Bunny Non *Bt* were categorized as susceptible with population of 12.50 to 13.70 jassids/3 leaves. The cotton variety G.Cot-16 (16.70 jassids/3 leaves) and check DCH-32 (24.60 jassids/3 leaves) were categorized as highly susceptible to jassids. Five cotton varieties/genotypes *viz.,* NH-615, GBHV-201, GBHV-204, GBHV-209, G.N.Cot-26 and two checks *i.e.* DHY-286 and NDLH-1938 were categorized as moderately resistant based on maximum Jassid Resistance Index in range of 1.10 to 2.00. Only the genotype GBHV-206 was found susceptible with 2.20 JRI. Four cotton varieties/genotypes *viz.,* G.Cot-16, Bunny BG II, Suraj, Bunny Non *Bt* and check DCH-32 were categorized as highly susceptible to jassid based on maximum JRI of 3.10 to 4.00. Overall five varieties/genotypes of *G. hirsutum* cotton *viz*., NH-615, GBHV-201, GBHV-209, GBHV-204 and G.N.Cot-26 were found moderately resistant to jassids under rainfed conditions.

Keywords: Cotton varieties/genotypes; Gossypium hirsutum; jassid; Amrasca biguttula biguttula; screening; Jassid Resistance Index (JRI).

1. INTRODUCTION

Cotton is an important cash crop cultivated in diverse agro ecosystems in tropical and subtropical regions of the world for both domestic consumption and export purpose. Cotton is one of the most important commercial crop in India. *Gossypium hirsutum* is the most widely cultivated cotton species in India because of its wide range of adaptation and high yield potential. "The global cotton production was 116.56 million bales (1 bale= 480 lb.) from 31.71 million hectares with a productivity of 800 kg/ha in 2022-23. India ranks second in cotton production (26.30 million bales) after China (30.70 million bales). India ranks first in cotton cultivated area (12.93 million hectares) however, the productivity of cotton crop in India (443 kg/ha) is still far less than world average (800 kg/ha) as well as many other cotton growing countries (highest in China *i.e.* 2122 kg/ha) of the world in 2022-23" [1]. "Gujarat leads in production and productivity among cotton growing states of India. The provisional cotton production of Gujarat was 87.12 lakh bales (1 bale= 170 kg) from an area of 25.49 lakh hectares with a productivity of 581 kg/ha in 2022-23" [2]. "A decline in cotton production has several reasons in which the insect pests played an important role. Cotton is highly vulnerable to bollworm (Pink, Spotted and American bollworm) and sucking pest complex (jassids, whitefly, thrips, aphids, mealybug and mites). The avoidable losses due to major insect-pests (sucking pests + bollworms) were 2.94 q/ha or 28.13 per cent" [3].

"Jassid, *Amrasca biguttula biguttula* (Ishida) (Homoptera: Cicadellidae) is polyphagous pest of many agricultural and non-agricultural plants. It sucks the cell sap from leaves, flowers, fruits and tender stems and affects the growth of crop plants adversely. It also creates sooty mould on crop leaves which affect photosynthesis, growth and yield of the crops. *A. biguttula biguttula* attacked Cotton (*Gossypium hirsutum* L.), Brinjal (*Solanum melongena* L.) and Okra (*Abelmoschus esculentus* L.) throughout the year. It was also found attacking Sunflower *Helianthus annus* L., Cowpea *Vigna unguiculata* L., China Rose (*Hibiscus rosasinensis* L.), Pigeonpea (*Cajanus cajan* Millsp.) and several grasses including durva lawns (*Cynodon dactylon* L.)" [4]. "Leafhoppers employ a lacerate-and-flush-feeding strategy for food intake. Adults and nymphs of leafhopper penetrate their stylets either continuously or intermittently, they secret saliva inside the leaf tissues, this saliva after solidification forms a sheath like structure called

salivary sheath; it protects the stylet from external damage while feeding. Once the stylet enters into the phloem sap, it sucks the sap and causes injury to the tissues, which results in turning of the tissues into yellow, after wards, the leaf starts to curling downward and finally withered and detached" [5].

Cotton jassid *A. biguttula biguttula*, is a major sap sucking insect pest which causes losses in cotton crop. Both nymphs and adults suck the plant sap and apparently introduce salivary toxins that impair photosynthesis in proportion to the amount of feeding. The attacked leaves turn pale and then rust-red. With change in appearance, the leaves also turn downwards, dry up and fall to the ground. "The extent of avoidable losses due to leafhopper and whitefly were 263 kg/ha (11.2%) to 290 kg/ha (16.2%) in three *Bt* cotton hybrids" [6]. In India, *Bt* cotton impacted tremendous change in cotton cultivation. *Bt* cotton has effectively controlled the lepidopteron pests which includes the bollworm complex. An outbreak of jassids or in broad sense sucking pests was mainly due to ignorance towards the IPM measures suggested after the introduction of *Bt* cotton. *Bt* cotton growers reduced or even stopped application of pesticides for bollworm complex which also used to keep in control the sucking pest to some extent, sufficient enough to keep them well below their ETL levels. The management practices used for sucking pest of cotton, chemical control is the most used method among farmers. The indiscriminate use of chemical pesticides for control major pests on cotton led to development of pesticide resistance in pests, disruption of their natural enemies, resurgence of minor pests, pollution of the crop ecosystem, health and economic risks and development of sucking pest resistance. Resistant cotton cultivar is the cheapest and most harmless strategy to managing sucking pest infestations in an integrated pest management programme. It is play an important role in a long-term agricultural system. Screening trial is used to determine plant resistance against insect pest under field condition. Therefore, the present study was conducted to identify resistant sources against jassid under field condition.

2. MATERIALS AND METHODS

The experiment was conducted under rainfed conditions at Regional Cotton Research Station, Navsari Agricultural University, Maktampur, Bharuch, Gujarat during *kharif* 2016-17, 2018-19 and 2019-20. Thirteen varieties/genotypes of *G. hirsutum* cotton were screened against jassid, which were common among three seasons, selected from AICRP as well as State trials. Cotton varieties/genotypes were screened with two jassid resistant checks and one susceptible check. During season 2016-17, the crop was sown on 9th and 13th July, 2016, whereas it was sown on 5th July, 2018 and 6th July, 2019 during 2018-19 and 2019-20, respectively. The experiment was laid out in Randomized Block Design replicated twice. Two rows of each cotton variety/genotype with ten dibbles in each row were sown in an individual treatment. Okra crop was grown with cotton for population buildup of jassid. One infester row of okra was sown in between each two treatment *i.e.* four rows of cotton. The crop was sown under a spacing of 120 x 45 cm with 120 kg/ha nitrogen fertilizer application. The field experiment was conducted with cotton crop grown in gross plot size of 2.40 m x 4.50 m and net plot size of 2.40 m x 3.60 m in each treatment. All recommended agronomic practices were adopted for raising good crop condition. Okra crop was removed after 60-75 days after sufficient population buildup of cotton jassid. Both cotton and okra crop were kept free from insecticidal spray during entire crop period. The data on incidence of jassid in cotton varieties/genotypes including checks for three seasons under open field conditions were used for pooled analysis in evaluating the performance against pest. The treatment details are as under.

Chart 1. Cotton varieties/genotypes

T_1	GBHV-201	T_8	NH-615
T_2	GBHV-204	T_9	DHY-286 (Jassid resistant check)
T_3	GBHV-206	T_{10}	NDLH 1938 (Jassid resistant check)
T_4	GBHV-209	T_{11}	DCH-32 (Jassid susceptible check)
T_5	G.Cot-16	T_{12}	Bunny BG II
T_6	G.N.Cot-26	T_{13}	Bunny Non *Bt*
T_7	Suraj		

2.1 Method of Recording Observations

Observations on population of jassid were recorded during peak infestation of the pest. The number of nymphs and adults of jassid were recorded from five randomly selected plants in each replication of different cotton varieties/genotypes. The numbers of jassids were recorded from three leaves *i.e.* top, middle and bottom of each selected plant. Cotton variety/genotype, which was screened more than one time in a season, the maximum pest infestation was taken into account. The observations of Jassid Injury Grade (JIG) were also recorded.

2.2 Categorization Based on Population of Jassid

The maximum data out of three seasons were taken for categorization. For the purpose, the mean value of individual genotype ($\bar{X}i$) was compared with mean value of all genotypes ($\bar{X}$) and standard deviation (SD) following the scale adopted by Patel et al. [7].

Chart 2. The scale used for categorizing different genotypes

	Category of resistance	Scale of resistance
1	Resistant (R)	$\bar{X}i < (\bar{X} - SD)$
2	Moderately Resistant (MR)	$\bar{X}i > (\bar{X} - SD) < \bar{X}$
3	Susceptible (S)	$\bar{X}i > \bar{X} < (\bar{X} + SD)$
4	Highly Susceptible (HS)	$\bar{X}i > (\bar{X} + SD)$

2.3 Assessment of Cotton Jassid Severity

The observation of Jassid Injury Grade (JIG) was recorded as per following [8].

Grade 0	:	Healthy plants free from leafhopper infestation
Grade I	:	Entire foliage free from crinkling or curling with no yellowing
Grade II	:	Crinkling and curling of few leaves in the lower portion of plant + marginal yellowing of leaves
Grade III	:	Crinkling and curling of leaves almost all over the plant. Plant growth hampered
Grade IV	:	Extreme curling, crinkling, yellowing, bronzing and drying of leaves

2.4 Categorization Based on Jassid Resistance Index

The cotton varieties/genotypes were classified into different categories based on jassid resistance index as proposed by Nageswara Rao [9].

$$\text{Jassid Resistance Index (JRI)} = [(G_1 \times P_1) + (G_2 \times P_2) + (G_3 \times P_3) + (G_4 \times P_4)] / (P_1 + P_2 + P_3 + P_4)$$

Where, P_1, P_2, P_3 and P_4 are the number of plants with G_1, G_2, G_3 and G_4 grades

After indexing, the varieties/genotypes were categorized as under.

Chart 3. Category of resistance

	Jassid Resistance Index (JRI)	Category/ Reaction
1	0.1 – 1.0	Resistant (R)
2	1.1 – 2.0	Moderately Resistant (MR)
3	2.1 – 3.0	Susceptible (S)
4	3.1 – 4.0	Highly Susceptible (HS)

In past, several workers adopted method for recording jassid/leafhopper injury grade and resistance index/injury index. Murugesan and Kavitha [10] rated twenty four cotton entries against *Amrasca devastans* (Distant) by adopting hopper burn assessment of 1-4 grade scale of Indian Central Cotton Committee (ICCC). They classified cotton entries into different categories based on leafhopper resistance index (LHRI) as per Nageswara Rao (1973). After indexing, the entries were categorized as highly resistant (1.0 - 1.5), resistant (1.51 - 2.0), intermediate (2.01 - 2.5), susceptible (2.51 - 3.0) and highly susceptible (3.01 - 4.0) group. Karishma et al. [11] assessed hopper burn injury as per the methodology enumerated by Indian Central Cotton Committee (1960) in 1 to 4 grades and calculated leafhopper injury grade index (LIGI) in four categories *viz.*, resistant (LIGI 0.0 > ≤ 1.0), moderately resistant (LIGI 1.0 > ≤ 2.0), susceptible (LIGI 2.0 > ≤ 3.0) and highly susceptible (LIGI 3.0 > ≤ 4.0) as proposed by Nageswara Rao (1973). Keerthivarman et al. [12] examined jassid injury using the technique of the Indian Central Cotton Committee (ICCC, 1960) in 1 to 4 grades based on infestation symptoms and determined injury index (grade index). They calculated leafhopper resistance index proposed by Nageswara Rao (1973) in four categories *viz.*,

resistant (Grade index 0.0 - 1.0), moderately resistant (Grade index 1.1 - 2.0), susceptible (Grade index 2.1 - 3.0) and highly susceptible (Grade index 3.1 - 4.0).

Senguttuvan et al. [13] assessed hopper burn injury in 1 to 4 grades as per the methodology enumerated by Indian Central Cotton Committee (1960) (now ICAR-CICR) and calculated leafhopper injury grade index (LIGI) or leafhopper resistance index (LHRI) in four categories with grade index ≤ 1.0 grouped as resistant, 1.0 > ≤ 2.0 as moderately resistant, 2.0 > ≤ 3.0 as susceptible and 3.0 > ≤ 4.0 as highly susceptible as proposed by Nageswara Rao (1973). Madhu et al. [14] graded cotton plants in I to IV grades by visually for leafhopper injury grade (LIG) as per Indian Central Cotton Committee (ICCC) and calculated leafhopper injury index (LII) as per Nageswara, 1973. They adopted resistance rating in five categories *viz*., immune plant (LII 0, LIG 0, 0% intensity), resistant (LII 0.1-1.0, LIG I, 1-10%), moderately resistant (LII 1.1-2.0, LIG II, 10.1-25%), susceptible (LII 2.1-3.0, LIG III, 25.1-50%) and highly susceptible (LII 3.1-4.0, LIG IV, >50% intensity).

3. RESULTS AND DISCUSSION

The results obtain during present studies are presented in Table 1 to 3 and illustrated in Figs. 1 and 2.

3.1 Population of Jassid

The data on population of jassid on different cotton varieties/genotypes presented in Table 1 indicated that none of the cotton genotype was found completely free from the attack of jassid during 2016-17. Significantly the lowest population of jassid was recorded in resistant check DHY-286 (3.60 jassids/3 leaves) which was statistically at par with NH-615 (3.80 jassids/3 leaves), GBHV-204 (4.60 jassids/3 leaves), GBHV-209 (4.70 jassids/3 leaves), GBHV-201 (4.90 jassids/3 leaves), G.Cot-16 (5.10 jassids/3 leaves), NDLH 1938 (5.20 jassids/3 leaves) and G.N.Cot-26 (5.40 jassids/3 leaves). The highest jassid population (24.60 jassids/3 leaves) was recorded in susceptible check DCH-32. Jassid population was above economic threshold level (> 6 jassids/ 3 leaves) in GBHV-206, Suraj, Bunny BG II, Bunny non *Bt* and DCH-32.

Table 1. Population of jassid in cotton varieties/genotypes under rainfed conditions at Bharuch

Sr. No.	Cotton varieties/genotypes	Mean number of jassids/ 3 leaves			
		2016-17	2018-19	2019-20	Pooled
1	GBHV-201	2.32^{ab}(4.90)*	1.70^{a}(2.40)	2.11^{a}(4.00)	2.05^{a}(3.77)
2	GBHV-204	2.26^{a}(4.60)	2.51^{b}(5.80)	2.05^{a}(3.70)	2.27^{ab}(4.70)
3	GBHV-206	2.81^{bc}(7.40)	2.55^{b}(6.00)	2.61^{abc}(6.30)	2.66^{abc}(6.57)
4	GBHV-209	2.28^{a}(4.70)	1.84^{ab}(2.90)	2.37^{a}(5.10)	2.16^{a}(4.23)
5	G.Cot-16	2.36^{ab}(5.10)	4.14^{cd}(16.70)	2.83^{abc}(7.50)	3.11^{abc}(9.77)
6	G.N.Cot-26	2.42^{ab}(5.40)	2.32^{ab}(4.90)	2.51^{ab}(5.80)	2.42^{abc}(5.37)
7	Suraj	3.22^{c}(9.90)	3.74^{c}(13.50)	2.20^{a}(4.40)	3.06^{abc}(9.27)
8	NH-615	2.07^{a}(3.80)	2.14^{ab}(4.10)	2.15^{a}(4.40)	2.12^{a}(4.10)
9	DHY-286 (JR)	2.02^{a}(3.60)	2.21^{ab}(4.40)	2.14^{a}(4.10)	2.13^{a}(4.03)
10	NDLH-1938 (JR)	2.39^{ab}(5.20)	2.53^{b}(5.90)	2.66^{abc}(6.60)	2.53^{abc}(5.90)
11	DCH-32 (JS)	5.01^{d}(24.60)	4.86^{d}(23.20)	4.40^{d}(18.90)	4.76^{d}(22.23)
12	Bunny BG II	2.98^{c}(8.40)	3.75^{c}(13.70)	3.37^{bc}(10.90)	3.37^{bc}(11.00)
13	Bunny Non *Bt*	3.16^{c}(9.50)	3.50^{c}(11.80)	3.60^{cd}(12.50)	3.42^{c}(11.27)
Mean		2.72(7.47)	2.91(8.87)	2.69(7.25)	2.77(7.86)
S. Em.±	Treatment (T)	0.10	0.16	0.18	0.23
	Year (Y)				0.04
	T x Y	--	--	--	0.15
C.D. at 5%	T	Sig.	Sig.	Sig.	Sig.
	T x Y	--	--	--	0.44
C.V. %		5.36	7.83	9.55	7.77

Note:

*1. *Figures in the parentheses are original mean values and those outside are $\sqrt{X+0.5}$ transformed values.*

2. Treatment mean(s) with the letter(s) in common are not significant by DNMRT at 5 % level of significance.

3. Significant interactions: T, T x Y, where T=Treatment and Y=Year

4. Check varieties: DHY 286 (Jassid resistant), NDLH 1938 (Jassid resistant), DCH 32 (Jassid susceptible)

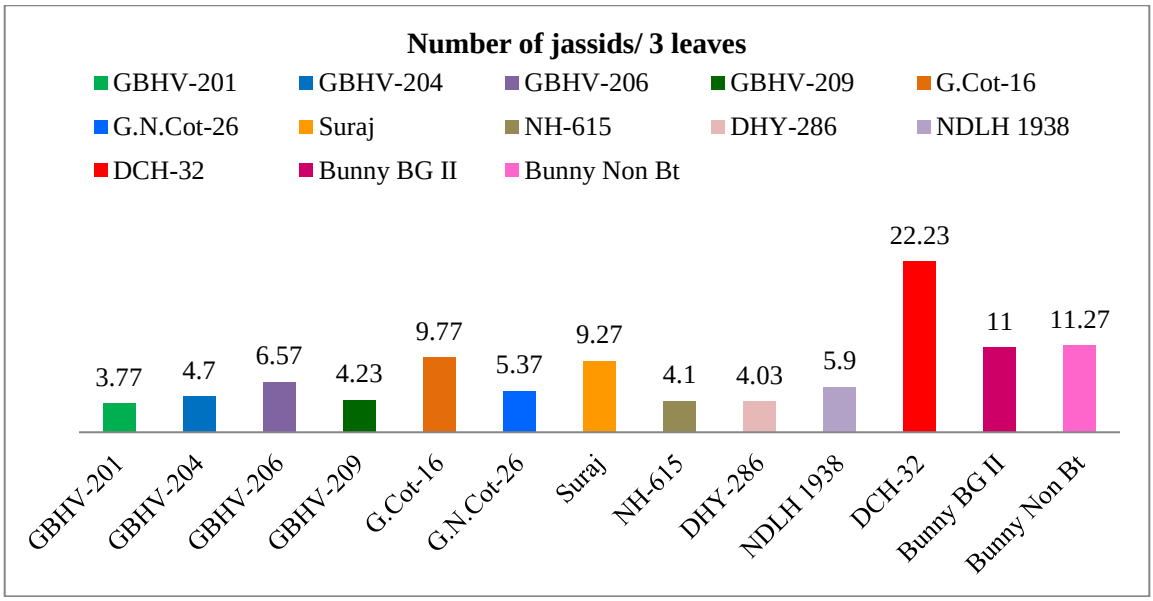

Fig. 1. Jassid population on different cotton varieties/genotypes (Pooled of three seasons)

During 2018-19, the jassid population was lowest in cotton genotype GBHV-201 (2.40 jassids/3 leaves) which was statistically at par with GBHV-209 (2.90 jassids/3 leaves), NH-615 (4.10 jassids/3 leaves), DHY-286 (4.40 jassids/3 leaves) and G.N.Cot-26 (4.90 jassids/3 leaves). The population of jassid was also recorded below economic threshold level in GBHV-204 (5.80 jassids/3 leaves) as well as in resistant check *i.e.* NDLH-1938 (5.90 jassids/3 leaves). The highest jassid population (23.20 jassids/3 leaves) was recorded in susceptible check DCH-32.

Jassid population was lowest in cotton genotype GBHV-204 (3.70 jassids/3 leaves) during 2019-20 and it was statistically at par with GBHV-201, resistant check DHY-286, NH-615, Suraj, GBHV-209, G.N.Cot-26, GBHV-206, NDLH-1938 and G.Cot-16 with jassid population of 4.00, 4.10, 4.40, 4.40, 5.10, 5.80, 6.30, 6.60 and 7.50 per 3 leaves, respectively. The highest jassid population (18.90 jassids/3 leaves) was recorded in susceptible check DCH-32 which was statistically at par with Bunny non *Bt* (12.50 jassids/3 leaves).

The pooled data of three seasons presented in Table 1 and illustrated in Fig. 1 demonstrated that jassid population was lowest in cotton genotype GBHV-201 (3.77 jassids/3 leaves) which was statistically at par with resistant check DHY-286, NH-615, GBHV-209, GBHV-204, G.N.Cot-26, resistant check NDLH-1938, GBHV-206, Suraj and G.Cot-16 with jassid population of 4.03, 4.10, 4.23, 4.70, 5.37, 5.90, 6.57, 9.27 and 9.77 per 3 leaves, respectively. The highest jassid population (22.23 jassids/3 leaves) was recorded in susceptible check DCH-32. Jassid population was above economic threshold level (> 6 jassids/ 3 leaves) in GBHV-206, Suraj, G.Cot-16, Bunny BG II, Bunny non *Bt* and DCH-32. The ascending order of jassid population on different cotton varieties/genotypes was GBHV-201 < DHY-286 < NH-615 < GBHV-209 < GBHV-204 < G.N.Cot-26 < NDLH-1938 < GBHV-206 < Suraj < G.Cot-16 < Bunny BG II < Bunny non *Bt* < DCH-32. The interaction (Treatment x Year) was showed significant effects which indicated non-consistent performance of cotton varieties/genotypes over the year.

The present results are in agreement with the findings of many researchers. Asif et al. [15] screened “eighteen cotton genotypes for their relative resistance against sucking insect pests (jassid, whitefly and thrips) and bollworms (spotted and pink) and revealed that NIA-HM-323 was found to be the most tolerant genotype and recorded the lowest number of jassids (0.52/leaf), followed by NIA-H-13 (0.53/leaf) and NIA-81 (0.58/leaf) whereas, NIA-85 was the most susceptible one showing higher jassids attack of 1.26/leaf which was statistically at par to NIA-H-303 (0.99/leaf) and Sohni (0.93/leaf)”. Manivannan et al. [16] conducted “screening of 350 cotton genotypes against leafhopper, *A. biguttula biguttula* (Ishida) and found no genotypes were resistant, 50 genotypes were categorized as tolerant, 158 genotypes moderately tolerant, 91 genotypes susceptible

and 51 genotypes highly susceptible with a population ranged from 0.10 to 0.78, 0.79 to 1.57, 1.58 to 2.36 and 2.37 to 6.25 leafhopper/3 leaves/plant respectively based on the standard deviation value". Muhammad et al. [17] screened "fifteen genotypes of *G. hirsutum* cotton for population dynamics of *A. biguttula biguttula* (Ishida) and showed that FH-142 proved to be least attractive cultivar with 0.33 jassid/leaf and 0.67 jassid /leaf in October and September-2016, respectively while it was 0.67 jassid/leaf, 1.67 jassid/leaf, and 2.67 jassid/leaf in October & May, September and June, respectively. The maximum population of *A. biguttula biguttula* was recorded on FH-490 (7.33/leaf) followed by FH-152 and FH-453 (7.00/leaf) during 2017. On a cumulative basis, highest peak of *A. biguttula biguttula* was observed on FH-450 (6.00/leaf)".

In past, Patel and Radadia [18] screened "sixteen cotton varieties/genotypes against *A. biguttula biguttula* and revealed that none of the cotton variety/genotype was totally free from attack of jassids and categorized as resistant based on population of jassid. Eleven varieties/genotypes *viz.,* G.Cot.-12, GSHV-01/1338, GISV-267, G.N.Cot.-22, GSHV-159, GISV-272, GBHV-177, GBHV-170, GBHV-180, GBHV-164 and G.Cot.-16 were designated as moderately resistant to jassid by recording the population ranged from 2.41 to 6.37 jassids/3 leaves. The susceptible cotton varieties/genotypes comprised G.Cot.-10, LRA-5166 and G.Cot.-100 which registered population ranged from 8.11 to 11.38 jassids/3 leaves. However, genotype Cocker-310 and GSB-21 were categorized as highly susceptible to jassid with population of more than 11.73 jassids/3 leaves". Guru PN et al. [19] screened 17 *Bt* cotton hybrids with susceptible check (Bunny Non-*Bt*) against major sucking pests and revealed that the incidence of leafhoppers was least on Bio Hy. 15-2 BG II (2.96 per 3 leaves) and Ankuryesh BG II, 72SS 66 BG II and Bio Hy. 1101-2 BG II were on par with it whereas, higher incidence was recorded on VBCH 1545 BG II (7.61 per 3 leaves). Patel and Radadia [20] recorded peak population of jassid in the susceptible cotton cultivar GSB-21 *i.e.* 37.22 jassids/3 leaves and 38.48 jassids/ 3 leaves during *kharif* seasons of 2015-16 and 2016-17, respectively.

The present findings are close in conformity with the findings of Appala et al. [21] screened "fourteen cotton genotypes against leafhoppers and showed that the overall mean population of leafhoppers varied between 5.35-24.0 no./3 leaves/plant. The mean population of leafhoppers was low in the genotypes such as GISV-267 (5.3/3 leaves/plant), GSHV-173 (5.6/3 leaves/plant), GJHV-517 (5.7/3 leaves/plant) and GJHV-497 (6.0/3 leaves/plant). But statistically there were no significant differences among the genotypes. However, all the genotypes recorded significantly lesser population of leafhoppers when compared to standard checks *i.e.* Bunny *Bt* (16.9/3 leaves/plant), Bunny non-*Bt* (19.3/3 leaves/plant) and susceptible check DCH-32 (24.0/3 leaves/plant)". Manivannan et al*.* [5] screened 54 cotton genotypes along resistant check (NDLH 1938) and susceptible check (DCH 32) for resistance against the leafhopper *A. biguttula biguttula* (Ishida) in field. Based on initial resistance evaluation studies at field level, 21 genotypes were selected for further studies such as host preference studies and nymphal emergence studies in greenhouse and host plant resistance by pest infestation evaluation in field. In field screening, nine genotypes namely AKH 1355, GISV 216, AKH 2012–8, GSHV 173, GISV 267, AKH 1301, GSHV 171, NDLH 2010 and AKH 2006–2 constantly showed resistance on par with resistant check (NDLH 1938). Both host preference studies and nymphal emergence tests identified seven genotypes RS 2711, GISV 267, LHDP 1, AKH 1355, RS 2765, F 2164, and GISV 216, which performed on par with resistant check. Rajashekar et al*.* [22] evaluated eight *Bt* cotton hybrids against *A. biguttula biguttula* (Ishida) under unprotected conditions and recorded the lowest population of jassids in hybrid NCS-2778 (3.76 jassids per 3 leaves), followed by RCH-659 (5.41 jassids per 3 leaves), Pradeep (6.27 jassids per 3 leaves), Moksha (6.43 jassids per 3 leaves). The highest population of jassids were recorded in Jadhu (9.91 jassids per 3 leaves) and Money Maker (7.70 jassids per 3 leaves).

3.2 Jassid Resistance Index (JRI)

The data presented in Table 2 demonstrated that jassid resistant check DHY-286 recorded the lowest (1.10) Jassid Resistance Index (JRI) during 2016-17. Seven cotton varieties/genotypes *viz.*, NH-615, GBHV-204, GBHV-201, GBHV-209, G.Cot-16, G.N.Cot-26 and resistant check NDLH 1938 showed lower JRI of 1.20 to 1.60. Jassid susceptible check DCH-32 recorded the highest JRI of 4.00 followed by Suraj (3.20), Bunny non *Bt* (3.10) and Bunny BG II (2.80).

The DHY-286 also recorded the lowest JRI of 1.00 followed by NH-615 (1.10) during 2018-19. Another five cotton varieties/genotypes *viz*., GBHV-201, GBHV-209, G.N.Cot-26, NDLH 1938 and GBHV-204 showed below 2.00 JRI. The highest JRI was observed in susceptible check DCH-32 (3.90).

During 2019-20, two cotton varieties/genotypes *i.e.* NH-615 and DHY-286 indicated the lowest JRI of 1.00. Five cotton varieties/genotypes *viz*., GBHV-201, GBHV-204, Suraj, GBHV-209 and G.N.Cot-26 demonstrated JRI in range of 1.20 to 1.70. Jassid susceptible check DCH-32 recorded the highest JRI of 4.00 and it was nearly followed by Bunny non *Bt* (3.80). The Bunny BG II showed the JRI of 3.10.

The mean data of three seasons presented in Table 2 and illustrated in Fig. 2 indicated that jassid resistant check DHY-286 recorded the lowest Jassid Resistance Index (1.03) and it was nearly followed by NH-615 (1.10). Jassid susceptible check DCH-32 recorded the highest JRI of 3.97. The ascending order of Jassid Resistance Index on different cotton varieties/genotypes was DHY-286 < NH-615 < GBHV-201 < GBHV-204 < GBHV-209 < G.N.Cot-26 < NDLH-1938 < GBHV-206 < G.Cot-16 < Suraj < Bunny BG II < Bunny non *Bt* < DCH-32.

Table 2. Jassid Resistance Index on cotton varieties/genotypes under rainfed conditions at Bharuch

Sr. No.	Cotton varieties/genotypes	Jassid Resistance Index (JRI)			
		2016-17	2018-19	2019-20	Mean
1	GBHV-201	1.50	1.20	1.20	1.30
2	GBHV-204	1.40	1.70	1.20	1.43
3	GBHV-206	2.20	2.10	2.20	2.17
4	GBHV-209	1.50	1.30	1.70	1.50
5	G.Cot-16	1.60	3.10	2.40	2.37
6	G.N.Cot-26	1.60	1.30	1.70	1.53
7	Suraj	3.20	3.10	1.20	2.50
8	NH-615	1.20	1.10	1.00	1.10
9	DHY-286 (JR)	1.10	1.00	1.00	1.03
10	NDLH 1938 (JR)	1.60	1.50	2.00	1.70
11	DCH-32 (JS)	4.00	3.90	4.00	3.97
12	Bunny BG II	2.80	2.90	3.10	2.93
13	Bunny Non *Bt*	3.10	2.50	3.80	3.13
Mean		2.06	2.05	2.04	2.05

Note: Check varieties: DHY 286 (Jassid resistant), NDLH 1938 (Jassid resistant), DCH 32 (Jassid susceptible)

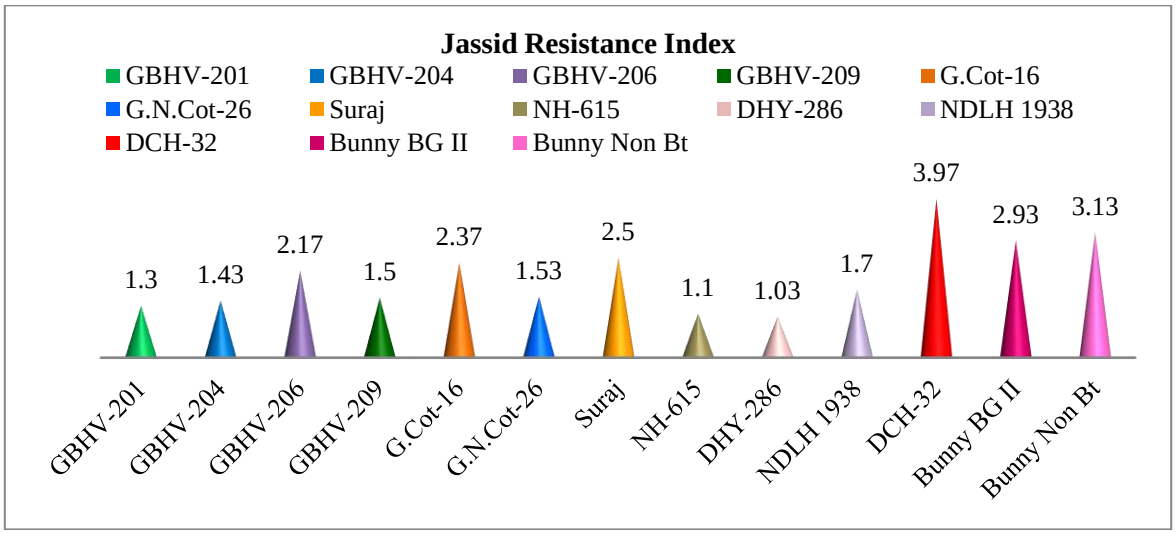

Fig. 2. Jassid Resistance Index on different cotton varieties/genotypes (Pooled of three seasons)

Table 3. Reaction of cotton varieties/genotypes against jassid under rainfed conditions at Bharuch (Maximum jassid population and JRI among three seasons)

Sr. No.	Cotton varieties/genotypes	Jassids/ 3 leaves	Reaction	Jassid Resistance Index	Reaction
1	GBHV-201	4.90	MR	1.50	MR
2	GBHV-204	5.80	MR	1.70	MR
3	GBHV-206	7.40	MR	2.20	S
4	GBHV-209	5.10	MR	1.70	MR
5	G.Cot-16	16.70	HS	3.10	HS
6	G.N.Cot-26	5.80	MR	1.70	MR
7	Suraj	13.50	S	3.20	HS
8	NH-615	4.40	MR	1.20	MR
9	DHY-286 (JR)	4.40	MR	1.10	MR
10	NDLH-1938 (JR)	6.60	MR	2.00	MR
11	DCH-32 (JS)	24.60	HS	4.00	HS
12	Bunny BG II	13.70	S	3.10	HS
13	Bunny Non *Bt*	12.50	S	3.80	HS
Mean ($\overline{X}$):		9.65			
Standard Deviation (SD):		6.16			

	Categorization based on Mean and Standard Deviation			Categorization based on Jassid Resistance Index	
	Category of resistance	Scale of resistance		Jassid Resistance Index (JRI)	Category/ Reaction
1	Resistant (R)	$\overline{X}i < (\overline{X} - SD)$	1	0.1 – 1.0	Resistant (R)
2	Moderately Resistant (MR)	$\overline{X}i > (\overline{X} - SD) < \overline{X}$	2	1.1 – 2.0	Moderately Resistant (MR)
3	Susceptible (S)	$\overline{X}i > \overline{X} < (\overline{X} + SD)$	3	2.1 – 3.0	Susceptible (S)
4	Highly Susceptible (HS)	$\overline{X}i > (\overline{X} + SD)$	4	3.1 – 4.0	Highly Susceptible (HS)

3.3 Categorization of Cotton Varieties/Genotypes Based on Population of Jassid

The data presented in Table 3 revealed that none of the cotton varieties/genotypes fall under category as resistant by considering maximum jassid population among three seasons of 2016-17, 2018-19 and 2019-20. Eight cotton varieties/genotypes *viz.,* NH-615, resistant check DHY-286, GBHV-201, GBHV-209, GBHV-204, G.N.Cot-26, resistant check NDLH-1938 and GBHV-206 were designated as moderately resistant to jassid which recorded the population ranged from 4.40 to 7.40 jassids/3 leaves. Among eight moderately resistant varieties/genotypes, NDLH-1938 (6.60 jassids/3 leaves) and GBHV-206 (7.40 jassids/3 leaves) recorded above economic threshold level of jassid population. The susceptible varieties/genotypes comprised Suraj, Bunny BG II and Bunny Non *Bt* which registered population ranged from 12.50 to 13.70 jassids/3 leaves. However, G.Cot-16 (16.70 jassids/3 leaves) and susceptible check DCH-32 (24.60 jassids/3 leaves) were categorized as highly susceptible to jassids.

3.4 Categorization of Cotton Varieties/Genotypes Based on Jassid Resistance Index

The data presented in Table 3 indicated that none of the cotton varieties/genotypes fall under category as resistant by considering maximum Jassid Resistance Index (JRI) among three seasons of 2016-17, 2018-19 and 2019-20. Seven varieties/genotypes *viz.,* DHY-286, NH-615, GBHV-201, GBHV-204, GBHV-209, G.N.Cot-26 and NDLH-1938 were grouped into moderately resistant with 1.10 to 2.0 JRI. Only the genotype GBHV-206 was found susceptible with 2.20 JRI. Five cotton varieties *viz.,* G.Cot-16, Bunny BG II, Suraj, Bunny Non *Bt* and DCH-32 emerged as highly susceptible to jassid by indicating JRI in range of 3.10 to 4.00.

Present studies are more or less in similar with earlier studies. Murugesan and Kavitha [10]

carried out screening of twenty six cotton accessions against the leafhopper, *A. devastans* (Distant) and reported that the susceptibility of cotton entries varied significantly. Based on the leafhopper resistance index (LHRI), entries were grouped under five categories as, Highly resistant- KC 2, SVPR 2; Resistant-TKH 1128; Intermediate- MCU 5, MCU 10, NISD 2, TKH 1143,TKH 1175; Susceptible- TKH 1789, TKH 1173, TKH 1174, TKH 1178, TKH 1179, TKH 1185, TKH 1186, TKH 1209, TKH1225, TKH 1233 and Highly susceptible- ICMF 20, LRA 5166, TKH 1133, TKH 1172, TKH 1176, TKH 1182,TKH 1197, TKH 1198. Neelima et al. [23] screened fifty six cotton genotypes for their reaction against leafhopper, *A. devastans* under rainfed conditions at Lam, Guntur (AP) and showed that based on Resistance/Injury index, four genotypes of *G. arboreum* and one genotype of *G. hirsutum* were resistant (Injury index: 0.1-1.0), forty genotypes were moderately resistant (1.1-2.0), eleven genotypes were susceptible (2.1-3.0) and one genotype was highly susceptible (3.1-4.0). However, these investigators screened different cotton genotypes. Appala et al. [21] screened fourteen cotton genotypes against leafhoppers and evaluated that the leaf hopper resistance injury index had ranged from 1.26 to 3.65. The lowest resistance injury index exhibited by the genotype GISV-267 (1.26) and GSHV-173 (1.35).

Sasikumar and Rathika [24] screened of 67 cotton genotypes with check entries NDLH 1938 (Resistant), DCH 32 (Susceptible) against leafhopper, *A. biguttula biguttula* (Ishida) and found 9 genotypes were highly resistant (Leaf Hopper Injury Grade 1), 29 genotypes resistant (LHIG 2), 25 genotypes susceptible (LHIG 3) and 4 genotypes highly susceptible (LHIG 3) with a population ranged from 0.57 to 3.57, 0.63 to 3.97, 1.43 to 4.90 and 3.93 to 5.83 leafhopper/3 leaves/plant respectively based on the standard deviation value. Avinash et al. [25] evaluated 26 cotton genotypes against jassid with resistant (Ajeet-155 and NDLH-1938) and susceptible (DCH-32) checks based on population and Jassid Injury Grade and found 19 genotypes *viz.*, NDLH-1938, Ajeet-155, RHC-688, RHC-03, RHC-04, RHC-1409, RHC-1416, RHC-577/3-3, RHC-014, RHC-Hd-1312, RHC–566/1-1, RHC-1629, RHC-1433, RHC-513, RHC-06, RHC-1466, RHC-1217, RHC-717 and RHC-1438 as moderately resistant, 4 genotypes *viz.*, RHCr-515, RHC-208, RHC–Hd-1433 and RHC-1430 as susceptible and 3 genotypes *viz.*, RHCr-0712, RHC-Hd-1406 and DCH-32 were highly susceptible. Jassid population and Jassid Injury Grade was the lowest in NDLH-1938 (2.65 per 3 leaves, JIG I) and highest in DCH-32 (16.14 per 3 leaves, JIG IV). These findings are in conformity with present studies however they screened different cotton genotypes at different places.

In past, Gangavati and Maralappanavar [26] evaluated fifteen *G. hirsutum* stabilized cotton genotypes for jassids tolerance and reported that none of the genotypes were completely resistant to jassid. However, two entries DHS-9 and DHS-62 were found to be moderately resistant with grade II. Eight genotypes DHS-16, DHS-18, DHS-20, DHS-21, DHS-29, DHS-67, DHS-68, DHS-72 were categorized as susceptible. Whereas, DHS-35, DHS-39, DHS-53, DHS-69, DHS 71 registered as highly susceptible to jassid incidence. Karishma et al. [11] studied 41 cotton genotypes for leafhopper resistance against biochemicals and recorded mean leafhopper incidence ranged from 1.13 (NDLH 1938) to 4.78/3 leaves (DCH 32). Based on the leafhopper injury grade index (LIGI), seventeen genotypes were identified as moderately resistant *viz*., C14 × GSHB 5-3-6-3, C14 × GSHB 180 7-1-5-2, TCH 1608 × 1822-6-2-1-1, TCH 1608 × 1822-6-2-2-3, TCH 1608 × 1822-6-2-2-4, TCH 1608 × 1822-7-2-1-5, TVH/JR/2021-22 2, JR/AKH/2021-22 9631, VS9 -S11-1× 1608 -8-1-2-3, C14 × GSHB 180 7-1-2-1, C14 × GSHB 180 7-1-2-2, C14 × GSHB 180 7-1-2-4, C14 × GSHB 180 7-1-2-3, JR/AKH/2021-22 9637, TVH/JR/2021-22 3, TCH 1608 × 1822-6-2-1-2 and Suraj with comparatively low leafhopper population (1.48 – 2.35 nos./3 leaves) and on par with standard check NDLH 1938. Twenty-one genotypes were recorded as susceptible and TCH 2024 was highly susceptible to leafhopper which was on par with the susceptible check, DCH 32. Senguttuvan et al. [13] screened twenty-nine cotton genotypes (*G. hirsutum*) against the leafhopper *A. biguttula biguttula* Ishida and revealed that fifteen genotypes *viz.*, TCH 357, TCH 1809, TCH 1828, TCH 1895, TCH 1897, TCH 1941, TSH 383, TVH 002, TVH 003, TKH 0762, TKH 1225, SVPR 6, CO 15, KC3 and Suraj as moderately resistant. Leafhopper population was comparatively low in these entries with leafhopper injury grade II which was on par with resistant check, NDLH 1938. Eleven genotypes were recorded as susceptible and TCH 13/22 was highly susceptible to leafhopper which was on par with the susceptible check, DCH 32. Mean leafhopper incidence ranged from 1.25 (KC 3) to 5.25/3 leaves (DCH 32). They

screened different cotton genotypes at different places.

4. CONCLUSION

Jassid, *A. biguttula biguttula* infestation was noticed in all cotton varieties/genotypes of screening studies and none of cotton variety/genotype was categorized as resistant by considering jassid population as well as Jassid Resistance Index. Based on population of jassid, eight cotton varieties/genotypes *viz.,* NH-615, resistant check DHY-286, GBHV-201, GBHV-209, GBHV-204, G.N.Cot-26, resistant check NDLH-1938 and GBHV-206 were found as moderately resistant to jassid with population ranged from 4.40 to 7.40 jassids/3 leaves. Based on Jassid Resistance Index, seven cotton varieties/genotypes *viz.,* DHY-286, NH-615, GBHV-201, GBHV-204, GBHV-209, G.N.Cot-26 and NDLH-1938 were showed as moderately resistant to jassid with 1.10 to 2.0 JRI. Overall, five varieties/genotypes of *G. hirsutum* cotton *viz*., NH-615, GBHV-201, GBHV-209, GBHV-204 and G.N.Cot-26 were found moderately resistant to jassids under rainfed conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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