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Inheritance study on jassid (*Amrasca biguttula biguttula*) tolerance in F_2 population of upland cotton (*Gossypium hirsutum* L.)

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Abstract
India is one of the largest producers of cotton in the world, but the productivity of cotton is comparatively low. One of the major factors limiting the productivity in cotton is pest infestation. Earlier cotton production was inhibited by the boll worms which is now coped up with Bt cotton but sucking pest infestation is still a prime concern. This study was conducted in the F_2 population of four upland crosses- TVH002 x RAHC1039, TCH1894 x NDLH32, CO17 x KC2 and TVH002 x KC3, which were evaluated for the inheritance pattern of jassid tolerance. Three of the four crosses segregated in 3:1ratio (Resistant, susceptible) and the fourth cross segregated in 13:3 ratio (Resistant, susceptible), showing digenic interaction. Further molecular investigation is essential to confirm this pattern of inheritance and progress the work in this direction.

Keywords: Jassid tolerance, inheritance, jassid injury, grading

1. Introduction
Cotton is a significant natural fibre crop, grown in a wide range of agro-climatic zones. In India cotton is cultivated in an area of 124 lakh hectares, producing around 340 lakh bales annually. The average production per hectare is accounted for 469 kgs (COCPC, 2022) [5]. Cotton plays an eminent role in Indian economy in terms of creating direct and indirect employment opportunities in the agricultural and industrial sectors. Cotton inputs about 14% to the industrial production, contributes 4% to the GDP and 13% to the country's export revenue (Palanisingh *et al.*, 2017) [8].
Numerous insect pests are of serious concern in cotton, which deteriorate the lint quality and reduce the crop yield. The major pests of cotton are classified as defoliators and sap suckers. The defoliators are controlled to some extent by the cultivation of Bt cotton. However, the sap suckers possess a great threat to both Bt and non-Bt cultivars (Sahu *et al.*, 2020) [4]. Sucking pest infestation is reported to cause about 21.2% yield loss in cotton (Bhosle *et al.*, 2009) [3]. One of the major damages caused to the production of cotton is by jassids (*Amrasca biguttula biguttula*), it infects the leaves by sap sucking and cause symptoms called hopper burn due to which the edges of leaves curl downwards, turn yellowish and later become reddish brown (Atakan, 2009) [2]. This study deals with analysing the inheritance pattern of jassid resistance in F_2 population of upland cotton.

2. Materials and Methods
The study materials included F_2 progeny of four crosses, TVH002 x RAHC1039, TCH1894 x NDLH32, CO17 x KC2 and TVH002 x KC3 and the seeds to raise F_2 progenies were obtained from Department of Cotton, Tamil Nadu Agricultural University, Coimbatore. The F_2 progenies were evaluated for inheritance pattern of jassid tolerance.
The experiment was conducted in summer 2022 at field no. E1, Department of cotton, Tamil Nadu Agricultural University, Coimbatore. Each cross was raised in 25 rows with the spacing of 90 cm x 30 cm. The agronomical and plant protection measures were implemented from the date of sowing as per the standard recommendation. In F_2 population selfing was done to pass on the desirable lines to subsequent generations. Wet clay and thread methods were used for selfing each plant of crosses. Selfing was done continuously for three weeks from 65 days after sowing. 35 F_2 plants of TVH002 x KC3 were artificially screened for jassid tolerance under protected condition.

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The F_2 population of four crosses was visually evaluated for jassid tolerance (Table 1). The plants were classified into four grades on basis of the symptoms exhibited as per the Indian Central Cotton Committee (ICCC), 1960 (Table 2). The scoring for the jassid injury was given at 30 DAS, 60 DAS, 90 DAS and 120 DAS.

Table 1: List of crosses along with the number of progenies in each cross

S. No.	Cross	Population Studied
1	TVH002 x RAHC1039	241
2	CO17 x KC2	200
3	TVH002 x KC3	146
4	TCH1894 x NDLH32	157

Table 2: Jassid injury grading according to ICCC

Grades	Symptoms
1	Leaves free from crinkling or with no yellowing, bronzing and drying
2	Few leaves on lower portions of the plant show curling, crinkling and slight yellowing
3	Crinkling and curling all over, yellowing, bronzing and browning in the middle and lower portion, plant growth is hampered
4	Extreme curling, yellowing, bronzing and browning, drying of leaves and defoliation, stunted growth

The Mendelian inheritance pattern for jassid tolerance in the F_2 population was evaluated using the Chi square test. The importance of the difference between observed and predicted frequencies was investigated using Klug and Cummings' technique (1999).

$$X^2 = \Sigma\ (O- E)^2/\ E$$

Where
O = Observed Frequencies
E = Expected Frequencies

The chi square values were compared to table values with n-1 degrees of freedom (n being the number of classes) or the probability value was used to determine if the null hypothesis should be rejected or accepted.

3. Result and Discussion
The plants in all the four crosses were categorised into four grades based on the injury level. Plants in grade 1 and grade 2 are taken into account as resistant and moderately resistant. The part of population in grade 3 and grade 4 are Moderately susceptible and highly susceptible. In the cross TVH002 x RAHC1039, 84 plants were grouped into grade 1, 109 plants as grade 2, 34 plants as grade 3 and 14 plants as grade 4 (Table 3). The cross CO17 x KC2 has shown 57 plants in grade 1, 84 plants in grade 2, 40 plants in grade 3 and 19 plants in grade 4 (Table 4). TVH002 x KC3 cross displayed 17 grade 1 plants, 83 grade 2 plants, 34 grade 3 plants and 12 grade 4 plants (Table 5). The cross TCH1894 x NDLH32 had 79 plants in grade 1, 56 plants in grade 2, 14 plants in grade 3 and 8 plants in grade 4 (Table 6).
The chi square test results for three crosses, TVH002 x RAHC1039, CO17 x KC2 and TVH002 x KC3 showed no significant deviation from the 3:1 whereas, the cross

TCH1894 x NDLH32 had no significant variation from 13:3 phenotypic ratio inheritance pattern. In the examination of all crosses, a p value greater than 0.05 is obtained, indicating that the null hypothesis is accepted. This demonstrated that the crossings TVH002 x RAHC1039, CO17 x KC2 and TVH002 x KC3 fit in 3:1 ratio and the crossing TCH1894 x NDLH32 fits in 13:3 ratio with a significance level of 0.05 at df =1.
This supports monohybrid plant inheritance in F_2 generation of TVH002 x RAHC1039, CO17 x KC2 and TVH002 x KC3, with $3/4^{th}$ of population being resistant to jassid infestation and the quarter of the population being susceptible exhibiting simple dominance- recessive relationship, this kind of interaction was also reported in upland cotton by Sikka *et al.*, 1953. F_2 population of TCH1894 x NDLH32 shows 13:3 ratio of resistant and susceptible plants, indicating dominant recessive epistasis. F_2 population of upland cotton in few crosses has shown similar ratios of resistant and susceptible plants (Pushpam *et al.*, 2005) [5]. In the *Gossypium hirsutum* x *Gossypium barbadense* inter-specific cross the susceptible to resistant ratio was observed as 13:3 (Roy *et al.*, 2018) [11]. The jassid infestation is said to be negatively correlated with the trichome density of the leaves (Amin *et al.*, 2017) [1], however further investigation on trichome density and molecular confirmation of genes related to jassid tolerance will give an appropriate confirmation on the inheritance pattern involved in the above crosses. The higher yielding plants in the crosses along with jassid tolerance can pave way for crop improvement, mitigating the yield loss due to one of the major sucking pests.

Table 3: Chi square test for cross TVH002 x RAHC1039

Phenotype	Class	Observed	Expected	X^2 value	p value
Resistant (Grade 1&2)	3	193	180.75	3.32	0.07
Susceptible (Grade 3&4)	1	48	60.25		
Total	4	241	241		

Table 4: Chi square test for cross CO17 x KC2

Phenotype	Class	Observed	Expected	X^2 value	p value
Resistant (Grade 1&2)	3	141	150	2.16	0.14
Susceptible (Grade 3&4)	1	59	50		
Total	4	200	200		

Table 5: Chi square test for cross TVH002 x KC3

Phenotype	Class	Observed	Expected	X^2 value	p value
Resistant (Grade 1&2)	3	99	109.5	3.29	0.07
Susceptible (Grade 3&4)	1	47	36.5		
Total	4	146	146		

Table 6: Chi square test for cross TCH1894 x NDLH32

Phenotype	Class	Observed	Expected	X^2 value	p value
Resistant (Grade 1&2)	13	135	127.57	2.31	0.13
Susceptible (Grade 3&4)	3	22	29.43		
Total	16	157	157		

4. Conclusion
The F_2 progenies of four crosses evaluated for jassid tolerance have shown two types of segregation ratios i.e., 3;1 and 13:3. The 3:1 ratio indicates monogenic interaction and 13:3 is indicative of digenic interaction. However further molecular investigation in the population can confirm the precise pattern of inheritance.

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