



Identification of Cotton Physio-Morphological Marker for the Development of Cotton Resistant Varieties against Sucking Insect Pests: A Biorational Approach for Insect-Pest Management

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ABSTRACT

Cotton is one of the important crops of Pakistan and is attacked by many chewing and sucking pest. Chemical insecticides are used abundantly to suppress the pest population. The use of host-plant resistance is an alternative tool to control cotton insect-pests. The current research was aimed to identify the cotton physio-morphological marker to manage pressure of sucking pests such as jassid (*Amrasca bigutulla bigutulla* Ishida), thrips (*Thrips tabaci* Lind.) and whitefly (*Bemisia tabaci* Gen.) on cotton. To this end, the present research was conducted on various cotton varieties classified on the basis of their genetic characteristics such as nectard (CIM-554, CIM-557 and MNH-786), nectariless (Stoneville-701, Stoneville-697, and Stoneville-857), high gossypol (CIM-496 and LAHG 1838-1488) and gossypol free (Greeg-25-V and 3-508 OP), Bt-703 and standard cotton variety (CRIS-342). The incidence of sucking pest on cotton was recorded fortnightly. The physio-morphic characters (density and length of trichome on lamina, midrib and vein, gossypol glands on midrib and lamina) of above mentioned cotton varieties were correlated with the incidence of sucking pest. Result revealed that cotton varieties had significantly different physio-morphic characters. There was a negative and significant correlation of TDM (Trichome density on midrib), (r -value = -0.615) and TDV (Trichome density on vein) (r -value = -0.574) with jassid population, while TDL (Trichome density on lamina), TDM and TDV was positively and significantly correlated with whitefly population. Stepwise regression analysis revealed that TDM, TDL and GGL (Gossypol gland on lamina) contributed 27.5%, 33.9% and 36.6% in population variation of jassid, whitefly and thrips, respectively. High TDM and TDV was considered morphological marker for jassid while low TDL, TDM and TDV was thought of as morphological marker for whitefly. The cotton variety 3-508 OP having relatively less dense but long TLL (Trichome length on lamina), TLM (Trichome length on midrib) and TLV (Trichome length of vein) showed highest host-plant resistance level against jassid and thrips, while Bt variety Bt-703 with relatively less TDL, TDM, TDV, TLL, TLM and TLV exhibited highest resistance against whitefly, hence recommended for farmer field cultivation and as base material in cotton breeding to produce cotton varieties resistant against sucking pest.

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Authors' Contribution

GHA and TSA conceived the idea. SS and ASB designed the experimental protocols and performed the experiment. MAR and SA prepared the manuscript and analyzed the data. MAR and MZM provided assistance in experimentation and manuscript preparation.

Key words

Cotton, Jassid, Thrips, Whitefly, Physio-morphic marker

INTRODUCTION

Cotton is one of the important crops in Pakistan and attacked by a number of chewing and sucking pests. Sucking pests reduce the yield by 28% (Chavan *et al.*, 2010).

Farmers rely on chemical insecticides for the control of insect pests (Soomro *et al.*, 2000). In Pakistan, seventy six percent of pesticides are sprayed on cotton (Yousaf *et al.*, 2004). The extensive use of chemical insecticides results in the health hazard, development of resistance in insects against insecticides, resurgence of secondary pest, environmental pollution and destruction of natural enemies (Palumbo *et al.*, 2001; Marcombe *et al.*, 2012; Afza *et al.*, 2019). Wherefore, alternate methods of

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insect control should be used for the control of insect pests (Soomro *et al.*, 2000). Among the alternate insect control methods, host-plant resistance is one of the most important, economical and environment friendly method of pest management (Jin *et al.*, 1999; Khan *et al.*, 2003). Variations of resistance levels among the different cotton varieties against sucking pests have been reported by earlier workers (Ali *et al.*, 1999; Nath *et al.*, 2000). Development of the resistant varieties to insect pests is an important strategy of the pest management. Varietal resistance is of immense significance because of undesirable physio-morphic characters of varieties to insect pests as insects are repelled by crop plants (Khan *et al.*, 2003).

The resistance mechanisms related to morphological or structural plant features that impair normal feeding or oviposition of insects or contribute to the mortality are called phonetic resistance or host-plant resistance. The morphological characteristics of the host plant may also influence the nutrition of the insect by limiting the feeding due to shape, colour or texture of the nutritive material and influence the digestibility and utilization of food by the insect (Amin *et al.*, 2011). Some cotton varieties including CRIS-342 are sown widely in the Sindh province. Infestation of sucking pest such as whitefly, thrips and jassids is becoming out of control on widely grown cotton varieties. Farmers have to rely on pesticides to keep the sucking pest below the economic threshold level. There is a dire need to provide the farmers with alternative cotton varieties producing high seed cotton with less sucking pest attack. Keeping in view the importance of cotton in national economy, the present study was conducted on twelve varieties of cotton with different physio-morphic plant characters to determine their role in the occurrence and abundance of sucking pests and identify the physio-morphological markers for the development of cotton resistant varieties against sucking pests of cotton.

MATERIALS AND METHODS

The experiment study was performed at the Entomology section, Agriculture Research Institute, Tandojam, Sindh, Pakistan. Over the season, less fluctuation in the average temperature of Tandojam was observed, however, the gradual increase in relative humidity (Rh) was observed as shown in Table I. Twelve varieties of cotton with different genetic characters presented in Table II were sown under Randomized Complete Block Design (RCBD), with four replications having a plot size, row to row and plant to plant distance of 3.75×3.9 m, 75 cm and 30 cm, respectively. The layout of the experiment is shown in Figure 1. Each plot consisted of 5 rows with 13 cotton plants in each row. The standard variety, CRIS-

342, was also grown because it has higher seed cotton yield as compared to other varieties and sown widely in the province of Sindh (Sial *et al.*, 2014). The objective of using the standard variety was to compare it with other varieties and inform the farmers about alternative variety resistant against sucking pests of cotton under the climatic condition of central zone of Sindh. The seeds of cotton genotypes were obtained from the Central Cotton Research Institute, Multan. Seeds of cotton were not treated with any insecticides before sowing and further, no plant protection measures were applied for the control of sucking pest population and the material was screened out under natural insect pressure. All the recommended agronomic practices were adopted during the experiment. Three plants from each plot were selected randomly and the population of jassid, thrips and whitefly was counted from upper, middle and lower portion of each plant (Arif *et al.*, 2004). Data was recorded with fifteen days interval for five months until 2nd week of October. The data on population of jassid, thrips and whitefly per leaf of cotton was recorded early in the morning because most of insects become active when temperature would be around 25-30°C (Garcia *et al.*, 1982) at fortnight intervals.

Table I. Climatic condition of Tandojam during the data recording period from April to October on different cotton varieties.

Months	Rain fall (mm)	Temperature (°C)			Rh (%)
		Min.	Max.	Average	
April	0.0	19.7	37.7	28.7	51.4
May	0.0	26.1	40.3	33.2	55.5
June	0.0	27.4	38.8	33.1	59.6
July	0.0	27.0	36.6	31.8	65.8
August	6.1	25.9	34.0	30.0	77.2
September	11.3	24.8	32.6	28.7	81.1
October	0.0	19.6	34.6	27.1	60.3

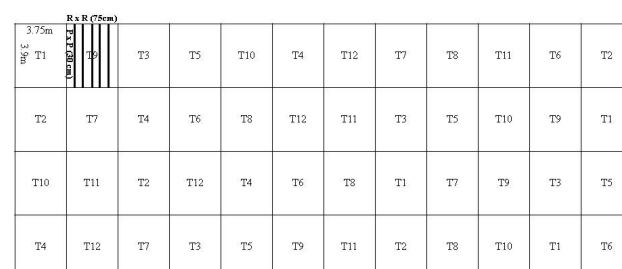


Fig. 1. Layout of the experiment with twelve cotton varieties with row to row and plant to plant distance of 75 and 30cm respectively.

Table II. Genetic characters of different cotton varieties used for experiment.

Varieties	Plant height (cm)	No. of monopodial branches	No. of sympodial branches	Leaf shape	Leaf hairiness	Special character
T1 CIM-554	178	0-4	27	Normal	H	Nectard
T2 MNH-786	135	7.5	22	Normal	H	Nectard
T3 CIM-557	122	10.8	29	Normal	PH	Nectard
T4 Stoneville-697	117.0	1.4	17	Normal	NH	Nectariless
T5 Stoneville-701	111.0	2.8	16	Normal	SH	Nectariless
T6 Stoneville-857	118.0	2.6	12	Broad	SH	Nectariless
T7 CIM-496	119	10.8	26	Normal	H	HG*
T8 LAHG-1838-1488	130	0-1	17	Normal	SH	HG*
T9 Greeg 25V	137	1.6	11	Broad	SH	LG★
T10 3-508-OP	135	4.6	14	Okra	PH	LG★
T11 BT-703	120	0-3	10	Broad	PH	Bt
T12 CRIS-342	134	5	24	Normal	H	Nectard

*HG, higher number of gossypol glands; ★LG, less number of gossypol glands.

Table III. Physio-morphic plant characters of different cotton varieties.

Varieties	TDL	TDM	TDV	TLL	TLM	TLV	GGM	GGL
Nectard								
CIM-557	1000±5.6c	1250±13.8a	1220±18.3a	117.2±1.1c	123.6±10 ef	124.8±1.8d	23±8 b	84.6± e
MNH-786	450±4.4h	287.5±4f	257.5±14.7e	126.2±1.5b	139.4±9.8cd	123.3±1.7d	27±8.2b	90±3.5cd
CIM-554	375±7.1i	250±2.6g	222.5±14.8e	88.2±1.5f	110.2±10gh	112.7±1.7e	21±8.1b	66±3.3f
Nectariless								
Stoneville697	1375±7.5a	1235.8±4.4a	1191.3±14.7a	132.5±1.5a	144±9.7bcd	122.4±1.7d	29.3±9b	89.6±1.5d
Stoneville701	991.3±4.4c	750±10.2b	686.5±38.1b	115±15.1c	186.3±11.1a	152.4±1.7a	50.3±4a	85±2.9e
Stoneville857	750±7.5g	683.8±7.2d	657.5±14.7bc	98.4±1.6e	112.5±9.6fg	105.8±1.7f	25±5.4b	63±4.3f
High Gossypol								
CIM-496	800±7.5f	677.1±2.69d	640±14.7c	116.5±1.5c	120.6±10efg	131.3±1.8c	29±8.1b	94.3±3.2c
LAHG 1838-1488	1250±4.4b	622.5±5.5e	589.2±15.1d	108.7±1.5d	132.6±9.6de	122.4±1.7d	24.3±5b	99.3±2.1b
Gossypol free								
Greeg-25-V	825±10.8e	712.5±7.3c	682.5±14.9b	77.8±1.5g	108±9.9gh	123±1.8d	1±0.1c	0 g
3-508 OP	75.7±3.7k	87.5±3.9h	57.5±15.8g	126.7±1.5b	154±11.1b	147±1.7b	0 c	2±0.1 g
BT								
Bt-703	257.5±4.2j	248.7±26.5g	100±15.1f	88.2±1.5f	98.2±9.6h	102.2±1.7g	24.3±5 b	66±4.1f
Standard								
CRIS-342	875±22.8d	625.8±6.9e	595.8±14.8d	108.6±15.7d	150.6±8.6bc	122.6±1.7d	18.6±7.1b	128±6.1a

TDL, trichome density on lamina /cm²; TDM, trichome density on midrib/cm; TDV, trichome density on vein/cm; TLL, length of trichome on lamina in µm; TLM, length of trichome on midrib in µm; TLV, length of trichome on vein in µm; GGM, gossypol glands on midrib/cm; GGL, gossypol glands on lamina/cm²; *Number sharing similar letters in column are not significantly different by DMR Test at P = 0.05.

Different physio-morphic plant characteristics like density and trichome length on leaf lamina, midrib, veins and number of gossypol-glands were studied from fully

expanded plant leaves. The plant characters were measured from three plants selected at random and one leaf from upper, middle and lower portions of each selected plant

was cut and brought to laboratory (Ali and Aheer, 2007; Saleem *et al.*, 2013). The trichome density on lamina (TDL), trichome density on midrib (TDM), trichome density on vein (TDV), trichome length on lamina (TLL), trichome length on midrib (TLM), trichome length on vein (TLV), gossypol gland on lamina (GGL) and gossypol gland on midrib (GGM) were examined from lower side of the leaves using an iron made dye of 1 cm² (Arif *et al.*, 2004) under a binocular microscope. The number of trichomes and gossypol glands was counted on one square centimeter. Micrometry was performed to determine the length of trichome in micrometers. Insect population and plant character data was subjected to analysis of variance and means were compared by Duncan Multiple Range (DMR) Test. Population density of sucking insect pest was correlated with physio-morphological characters of the plant and stepwise regression was performed to determine the contribution of each plant character to cause host-plant resistance. Data was analyzed using R-software.

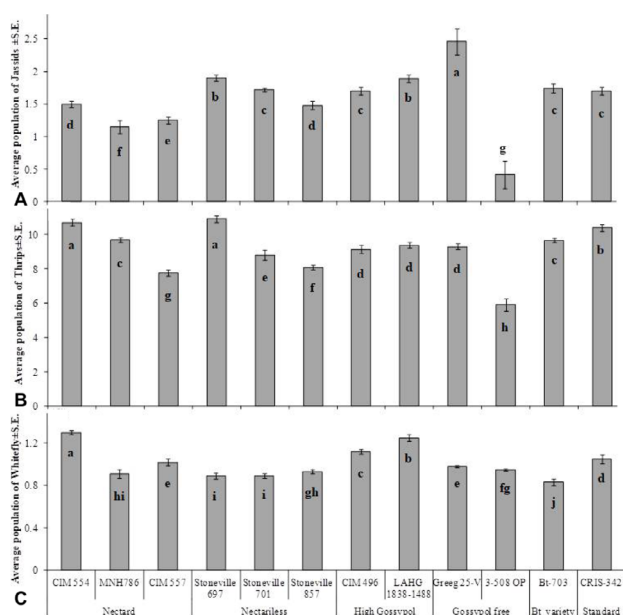


Fig. 2. Average population of jassids (A), thrips (B) and whitefly (C) on different cotton varieties. Means were compared by Duncan Multiple Range (DMR) test. Alphabets on bars indicate the level of significance. Number sharing similar letters in column are not significantly different by DMR Test at $P = 0.05$.

RESULTS

Populations of sucking insect pests on different varieties of cotton

The population of jassid, thrips and whitefly was significantly different on cotton varieties (P -value 0.0001,

0.002 and 0.009 respectively). Jassid population was significantly high on gossypol free variety Greeg 25-V (2.46 jassid/leaf) followed by Stoneville 697, LAHG 1838-1488, Bt-703, Stoneville 701, CIM 496, CRIS-342, CIM 554, Stoneville 857, CIM 557, MNH 786. Jassid population was minimum on a cotton variety 3-508 OP (0.41 jassid/leaf). In general, nectarid genotypes showed lower population of jassid as compared to nectariless varieties (Fig. 2A). The maximum population of thrips was observed on nectariless variety Stoneville 697 (10.8 thrips/leaf) and nectarid variety CIM 554 (10.68 thrips/leaf) followed by CRIS-342, MNH 786, Bt-703, LAHG 1838-1488, Greeg 25-V, CIM 496, Stoneville 701, Stoneville 857, CIM 557 and 3-508 OP (Fig. 2B). Whitefly population was maximum on nectarid variety CIM 554 (1.3 whitefly/leaf) followed by high gossypol (CIM 496 and LAHG1838-1488), standard (CRIS-342), gossypol free (Greeg 25-V and 3-508 OP), nectariless (Stoneville 697, Stoneville 701 and Stoneville 857) and Bt variety (Bt-703) (Fig. 2C).

Physio-morphic characters of different cotton varieties

Trichome density on lamina, midribs and veins of different cotton varieties

The high TDL was recorded on Stoneville 697 showing 1375 trichomes/cm² and differed significantly from all other varieties. The minimum TDL was observed on 3-508 OP (75.7 trichomes/cm²) and also differed significantly from all other varieties. The TDL was recorded to be 1250, 1000, 875, 825, 800, 750, 450, 375 and 257.5/cm² on LAHG 1838-1488, CIM-557, CRIS-342, Greeg 25-V, CIM-496, Stoneville-857, MNH-786, CIM-544 and Bt-703, respectively and these genotypes also differed significantly with one another (Table III). Significant variation was found to exist among varieties regarding TDM. The variety CIM-557 displayed maximum TDM i.e. 1250 trichomes/cm and was at par with those of Stoneville-697 (1235.8 trichomes/cm) whereas, minimum TDM was recorded to be 87.5/cm on 3-508 OP and differed significantly from all other varieties. The varieties MNH-786, Stoneville-701 and Greeg 25-V showed 287.5, 750.0 and 712.50 TDM, respectively and differed significantly with one another (Table III). The results revealed significant difference among varieties regarding TDV. The maximum TDV was recorded to be 1220 trichomes/cm on CIM-557 and showed non-significant difference with those of Stoneville-697 showing 1191.3 trichomes/cm. The minimum TDV was recorded to be 57.5 trichomes/cm on 3-508 OP and differed significantly from all varieties. Similarly, the variety Bt-703 possessed 100 trichome /cm and also had significant variation from all other varieties (Table III).

Trichome length on lamina, midribs and veins of different cotton varieties

The cotton variety Stoneville-697 having maximum TLL i.e. 132.5 μm and showed significant variation from rest of the varieties. The minimum TLL was recorded to be 77.8 on Greeg 25-V and also differed significantly from all other varieties. Non-significant difference was found among CIM-557, Stoneville-701 and CIM-496 showing 117.2, 115 and 116.5 TLL, respectively. Similarly, non-significant difference was found in between MNH-786 and 3-508 OP; CIM-554 and Bt-703; LAHG 1838-1488 and CRIS-342 having 126.2 and 126.7; 88.6 and 88.2; 108.7 and 108.6 TLL, respectively. The cotton variety Stoneville-701 possessed maximum TLM i.e. 186.3 and differed significantly from all other varieties. The minimum TLM was 98.2 μm on BT-703 and did not show significant variation as compared with Greeg 25-V (1080.6 μm) and CIM-554 (110.2 μm). Non-significant difference was also found among Stoneville-697, MNH-786, LAHG 1838-1488, 3-508 OP and CRIS-342 having 144, 139.4, 132.6, 154 and 150.6 TLM, respectively. Maximum TLV was observed on Stoneville-701 with 152.4 μm and differed significantly from all other varieties. The minimum TLV was recorded to be 102.2 μm on BT-703. The varieties, CIM-557, MNH-786, and Stoneville-697, LAHG-1838-1488, Greeg 25-V and CRIS-342 were non-significantly different from one another showing 124.8, 123.3, 122.4, 122.4, 123 and 122.6 TLV, respectively. The variety 3-508 OP showed 1470.6 TLV followed by CIM-496, CIM-554, Stoneville-857 and BT-703 with 131.3, 112.7, 105.8 and 102.2 μm , respectively and differed significantly from one another (Table III).

Gossypol glands on midribs and lamina of different cotton varieties

The maximum GGM (50.3/cm) was found in nectariless genotype Stoneville-701 and differed significantly from rest of the varieties. The minimum GGM (0.00 to 1.00/cm) was exhibited in gossypol free genotypes i.e. 3-508 OP and Greeg-25-V and differed significantly from all other varieties. The number of GGM were recorded to be 18.67/cm on CRIS-342 (a standard variety) and did not show significant variation with those of CIM-544, CIM-557, MNH-786 (nectard genotypes), Stoneville-697, Stoneville-857 (nectariless genotype), Bt-703 and LAHG-1838-1488 and CIM-496 (high gossypol genotype). The maximum GGL were recorded to be 128/cm² on CRIS-342 (standard variety) and showed significant variation from all other varieties. The minimum GGL were recorded to be 0.00 to 2.00 on gossypol free varieties (3-508 OP and Greeg-25-V) and these varieties differed significantly from all other varieties. Non-significant

difference was found among CIM-554 (nectard), Stoneville-857 (nectariless) and Bt-703 demonstrating 66, 63 and 66 GGL, respectively. The variety LAHG-1838-1488 (high gossypol) possessed 99.3 GGL and differed significantly from all other varieties (Table III).

Correlation of physio-morphic plant characters with the population of insect pests

The TDM and TDV showed negative and significant correlation with the jassid population (r-values of -0.615 and -0.574 respectively). While, TDL, TDM and TDV exhibited positive and significant correlation with the whitefly population (r-values of 0.582, 0.654 and 0.649, respectively) (Table IV).

Table IV. Correlation of physio-morphic plant characters with the population of sucking insect-pests on cotton varieties.

Characters	Jassid	Thrips	Whitefly
TDL	-0.397 (0.201)	0.397 (0.200)	0.582* (0.046)
TDM	-0.615* (0.033)	0.246 (1.00)	0.654* (0.020)
TDV	-0.574* (0.050)	0.275 (1.00)	0.649* (0.022)
TLL	-0.091 (1.00)	0.304 (0.336)	0.054 (1.00)
TLM	0.188 (1.0)	0.308 (0.329)	0.055 (1.00)
TLV	0.172 (1.0)	0.195 (1.00)	-0.084 (1.00)
GGM	-0.206 (1.00)	-0.013 (1.00)	0.320 (0.310)
GGL	-0.261 (1.00)	-0.047 (1.00)	0.241 (1.00)

For abbreviations, see Table III. Number outside the parenthesis represents the correlation coefficient (r-value) and number in the parenthesis shows the probability values; * Significant at $p \leq 0.05$.

Contribution of physio-morphic plant characters in host plant resistance against sucking insect pests

TDM showed maximum impact in the population fluctuation of jassid i.e. 27.5 percent and found to be the most important factors followed by TDL, TDV, TLM, GGM, GGL, TLV and TLL displaying 15, 4.8, 4.4, 3.7, 3.6, 1.3 and 0.2 percent role in population fluctuation of the pest, respectively. The 100-R² value was calculated to be 60.5 when all the factors were computed together. None of the regression model was found to be good fitted. GGL was found to be the most important character and contributing 36.6 percent in population fluctuation of thrips followed by GGM, TDL, TLL, TDV, TDM, TLV and TLM showing 16.3, 15.8, 9.1, 2.7, 2.5, 0.5 and 0.1 percent impact in the fluctuation of thrips population, respectively. The 100-R² value was obtained to be 83.6 when all the factors were computed together. All the regression models showed non-significant effect and were not fitted good. TDL contributed 33.9% in population fluctuation of

Table V. Multiple regression analysis of variance through steps between population of insect pests and physio-morphic plant characters.

	Regression equations	R ²	100R ²	Role (%)	F. ratio	p-value
Jassid						
Y1=	1.665 – 0.0089x1	0.150	15.0	15.0	1.87	0.201
Y2=	1.696 + 0.00858x1 – 0.0217x2	0.425	42.5	27.5	3.33	0.082
Y3=	1.634 + 0.017x1 – 0.011x2 – 0.018 x3	0.473	47.3	4.8	2.40	0.143
Y4=	1.532 + 0.018x1 – 0.011x2 – 0.018x3 + 0.003x4	0.475	47.5	0.2	1.58	0.279
Y5=	1.393 + 0.014x1 – 0.006x2 – 0.020x3 – 0.012x4 – 0.018x5	0.519	51.9	4.4	1.29	0.376
Y6=	1.028 + 0.177x1 – 0.008x2 – 0.020x3 – 0.009x4 + 0.007x5 + 0.021x6	0.532	53.2	1.3	0.95	0.535
Y7=	1.323 + 0.022x1 – 0.001x2 – 0.029x3 – 0.008x4 + 0.015x5 – 0.001x6 – 0.028x7	0.569	56.9	3.7	0.75	0.652
Y8=	1.274 + 0.033x1 – 0.037x2 – 0.007x3+0.023x4 – 0.010x5+0.003x6 + 0.077x7 – 0.066x8	0.605	60.5	3.6	0.57	0.764
Thrips						
Y1=	2.691 + 0.009x1	0.158	15.8	15.8	1.80	0.200
Y2=	2.700 + 0.014x1 – 0.006x2	0.183	18.3	2.5	1.01	0.403
Y3=	2.653 + 0.021x1 + 0.001x2 – 0.013x3	0.210	21.0	2.7	0.71	0.572
Y4=	1.936 + 0.023x1 + 0.002x2 – 0.018x3 + 0.022x4	0.301	30.1	9.1	0.75	0.586
Y5=	1.913 + 0.023x1 + 0.003x2 – 0.019x3 + 0.019x4 + 0.002x5	0.302	30.2	0.1	0.52	0.755
Y6=	1.697 + 0.024x1 + 0.002x2 – 0.019x3 + 0.021x4 – 0.004x5 + 0.012x6	0.307	30.7	0.5	0.37	0.871
Y7=	2.325 + 0.033x1 + 0.018x2 – 0.037x3 + 0.024x4 + 0.024x5 – 0.035x6 – 0.616x7	0.470	47.0	16.3	0.51	0.797
Y8	2.169 + 0.070x1 – 0.097x2+0.030x3+0.126x4 – 0.069x5 – 0.022x6 + 0.280x7 – 0.214x8	0.836	83.6	36.6	1.91	0.321
Whitefly						
Y1=	1.008 + 0.004x1	0.339	33.9	33.9	5.13	0.046
Y2=	1.001 + 0.001x1 + 0.005x2	0.432	43.2	9.3	3.43	0.078
Y3=	1.011 – 0.0004x1 + 0.003 x2 + 0.003x3	0.441	44.1	0.5	2.11	0.177
Y4=	1.071 – 0.001x1 + 0.003x2 + 0.003x3 – 0.002x4	0.446	44.6	0.7	1.41	0.324
Y5=	1.050 – 0.001x1 + 0.004x2 + 0.003x3 – 0.004x4 + 0.002x5	0.453	45.3	0.7	0.99	0.492
Y6=	1.379 – 0.004x1 + 0.006x2 + 0.003x3 – 0.006x4 + 0.014x5 – 0.019x6	0.526	52.6	7.3	0.92	0.545
Y7=	1.374 – 0.004x1 + 0.006x2 + 0.003x3 – 0.006x4 + 0.014x5 – 0.018x6 + 0.0005x7	0.526	52.6	0.0	0.63	0.719
Y8=	1.398 – 0.009x1+0.023x2 – 0.006x3 – 0.022x4+0.028x5 – 0.021x6 – 0.051x7 + 0.032x8	0.586	58.6	6.0	0.53	0.789

x1, TDL (trichome density on lamina /cm²); x2, TDM (trichome density on midrib/cm); x3, TDV (trichome density on vein/cm); x4, TLL (length of trichome on lamina inµm); x5, TLM (length of trichome on midrib inµm); x6, TLV (length of trichome on vein in µm); x7, GGM (gossypol glands on midrib/cm); x8, GGL (gossypol glands on lamina/cm²).

whitefly and was found to be the most important characters followed by TLM, TLV and GGL showing 9.3, 7.3, and 6 percent role in the population fluctuation of the pest, respectively. The other factors showed negligible impact. The regression equation in model-1 was found to be good fitted with a p-value of 0.046 (Table V).

DISCUSSION

Cotton is attacked by sucking insect pest. In the present research, the role of physio-morphic plant characters in host-plant resistance against sucking pest was determined. To this end, cotton varieties having

different physio-morphic characters were selected for this research. Physio-morphic characters of cotton varieties were measured and correlation between these characters and incidence of sucking pests was determined.

The results described that one of the cotton variety Greeg 25-V (present in gossypol free groups) hosted maximum population of jassid, while another variety, 3-508 OP belongs to the same group got the minimum population of jassid. Nectariless, high gossypol, Bt and standard varieties have the same level of jassid infestation. These results suggested on the basis of pest incidence that the variety 3-508 OP and Greeg 25-V had relatively higher and lower level of host plant resistance against jassid,

respectively. Similarly, the highest level of host-plant resistance was observed in a variety 3-508 OP (gossypol free group) and the lowest in Stoneville 697 (nectariless) and CIM 554 (nectard) against thrips. While, Bt-703 displayed highest and nectariless varieties (Stoneville 697, Stoneville 701) showed lowest host-plant resistance against whitefly.

Taken together, these results suggested that nectariless and gossypol free varieties had higher host-plant resistance against sucking pests as compared to high gossypol and standard varieties. On the contrary, MNH 786 (nectard variety) exhibited higher host-plant resistance against whitefly. On the whole, our results revealed that the cotton varieties showed variable host-plant resistance against sucking pests. It is likely that the group of cotton varieties such as nectard, nectariless, high gossypol glands, gossypol free, Bt variety and standard does not specifically cause host-plant resistance against sucking pests. The individual host-plant physio-morphic characters are important to classify the host plant for resistance against sucking pests. These results also suggest that the attack of sucking pest is linked with physio-morphic characters. This difference of response to insect pest could be attributed to genetic variability in cotton varieties.

The cotton varieties of different groups were subjected to the measurement of physio-morphic characters. Our results revealed that nectariless varieties have higher density and length of trichome as compared to other varieties, while, gossypol free varieties have relatively lower density and length of trichome. These results suggested that the all cotton varieties had variable physio-morphic characters.

Further, the physio-morphic characters were correlated with the incidence of sucking pests to screen out the characters responsible for host-plant resistance against sucking pests. Our results of correlation analysis depicted that the TDM and TDV exerted negative and significant correlation with jassid population. As the jassid feed near the leaf vein, it is probable that higher hair density on midrib and vein deter the jassid from feeding. Previous studies support these findings. It has already been reported that trichomes act as barrier for insects to mate on leaves, hence, it determines the resistance against insects (Butler *et al.*, 1991; Murugesan and Kavitha, 2010). For example, cotton plants having lower number of trichomes on leaves are more attacked by jassid (Kanheer *et al.*, 2016). On the other hand, TDL, TDM and TDV exerted positive and significant effect on the population of whitefly. These findings are in conformity with those of Chu *et al.* (2003) who reported that density of branched stellate trichomes on under leaf surfaces was the primary factor influencing the varietal susceptibility to adult *B. tabaci*. Similarly,

Khalil *et al.* (2015) reported that whitefly adult and nymphal population correlated positively with hair density on leaf lamina and vein and length of hair on leaf midrib. Regression analysis also revealed that TDM and TDL contributed a maximum role in the population fluctuation of jassid and whitefly, respectively. Our results are also in agreements with Chu *et al.* (1999), Soomro *et al.* (2000), Raza *et al.* (2000), Bashir *et al.* (2001), Arif *et al.* (2004), Zia *et al.* (2011).

Surprisingly, none of the plant character was found significantly correlated with thrips population. Erstwhile, it was corroborated that hair density on midrib and vein of upper leaves showed significant and negative correlation with thrips population (Arif *et al.*, 2005; Naveed *et al.*, 2011). But stepwise regression analysis revealed that number of GGL contributed in thrips population fluctuation. The present findings can be compared with those of Ali *et al.* (1999) and Khalil *et al.* (2015). Hence, the variability in pest infestation could be attributed to the physio-morphic features.

Conclusively, it is likely that a single character is not enough for the development of host-plant resistance against insect pest; a combination of physio-morphic characters could play a role in resistance against sucking pests. These findings could be important for cotton breeder to select varieties resistant against sucking pest. The hair density and number of gossypol glands could be contemplated as physio-morphic marker for sucking pests.

CONCLUSIONS

All cotton varieties have different physio-morphic characters. Few morphological characters such as high trichome density on midrib and veins and low trichome density on lamina, midrib and veins were considered as morphological marker for jassid and whitefly respectively. Two cotton varieties, 3-508 OP and Bt-703 showed good host-plant resistance level against sucking pest of cotton, hence recommended for cultivation on farmer field and cotton breeding to produce cotton varieties resistant against sucking pest.

Statement of conflict of interest

The authors have declared no conflict of interest.

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