Heritability and correlation analysis of morphological and yield traits in genetically modified cotton

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Research

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Abstract

Background: Cotton is known for fiber extraction and it is grown in tropical and sub-tropical areas of the world due to having hot weather. Cotton crop has a significant role in GDP of Pakistan. Therefore, the two-years research was conducted to estimate heritability and association among various yield contributing parameters of cotton, *i.e.,* plant height, number of bolls per plant, number of sympodial branches per plant, seed cotton yield, boll weight, seed index, ginning outturn (GOT), fiber length, fiber strength, and fiber fineness.

Results: Association analysis revealed that seed cotton yield had significant positive correlation with plant height, number of bolls per plant, number of sympodial branches per plant, ginning outturn (GOT), staple length and fiber strength. Staple length and fiber strength were negatively linked with each other. Estimates of heritability were high for all of the traits except number of sympodial branches per plant and boll weight.

Conclusion: The parent IUB-222 was found to be the best for plant height, number of bolls per plant, boll weight, ginning outturn (GOT), seed cotton yield and seed index. The genotypes namely NIAB-414 and VH-367 were identified as the best parents for fiber length, strength and fineness. Among the crosses NIAB-414 × IUB-222 was the best for number of bolls per plant, seed index, seed cotton yield and fiber fineness, whereas, cross of NIAB-414 × CIM-632 was good for plant height. The combination of A555 × CIM-632 was the best for number of sympodial branches per plant, boll weight, fiber length and strength, and VH-367 × CIM-632 proved the best for ginning outturn (GOT).

Introduction

Cotton is also known as white gold due to its white and soft fiber, also called vegetable fiber. The cotton plant was grown like shrub in nature and its fiber is pure cellulose. The cotton fiber is used to spin into yarn which is further used for making socks, curtains and towels, etc. Its fiber also consumed in textile industry for cloth making (Stewart and Rossi 2010). A significant amount of oil (16%-27%) is extracted from cotton seed and seed cake is used in livestock industry. The oil extracted from cotton seed is used as vegetable oil for making fries etc., because taste of cottonseed oil is similar to coconut oil. In addition, it is an important source of vitamins, fat and antioxidants (Dowd et al. 2010). During 2018-2019 survey, cotton was cultivated on an area of 2 373 thousand hectares with 9.861 million bales production. It shares 0.8% in GDP and 4.5% in value addition (Govt. of Pakistan, 2018-19).

The world population is increasing day by day; therefore, it is necessary to increase the productivity of crop to meet the requirement of textile industry. Utilization of various breeding tools is one of method to meet the demand of textile industry (Farooq et al., 2014). Understanding the genetic basis of important yield contributing traits is the pre-requisite and information about their relationship must be available to cotton breeder. All of yield related traits are correlated with each other in a way that increase or decrease in one trait directly effects on other traits. So, estimation of genotypic and phenotypic correlations among these traits are helpful to initiate the breeding programs. The knowledge about association among various plant characters is useful in the selection of appropriate breeding method (Teklewold et al., 2000). Phenotypic correlation shows the visual observation while genotypic correlation estimates the inheritance of characters (Desalegn et al., 2009). It was indicated that number of bolls and number of sympodial branches per plant were positively linked with each other. Weight of a boll had negative relationship with number of bolls per plant. Seed cotton yield and number of bolls were also positively correlated with each other. Heritability values were also high for these traits (Shar et al., 2017). Investigations revealed that association and inheritance for various quantitative and fiber related parameters of American cotton (Haq et al., 2017). In addition, yield of seed cotton was positively linked with plant height, sympodial branches, monopodial branches and bolls per plant whereas negatively correlated with days to 1st flowering. While seed cotton yield had positive correlation with 100-seed weight, number of bolls per plant, plant height and boll weight (Memon et al., 2017; Mukoyi et al., 2018). Lint index, number of bolls per plant, boll weight, sympodial branches per plant and ginning outturn (GOT) exhibited positive linkage with yield of seed cotton per plant. Heritability was high for number of bolls per plant, monopodial branches per plant, internode distance and sympodial branches per plant (Monisha et al., 2018). High heritability and positive correlation were reported for monopodia per plant, number of bolls per plant, yield of seed cotton and fiber fineness (Khokhar et al., 2017; Komala et al., 2018). Positive correlation and high heritability were observed for plant height, sympodial branches, number of bolls, boll weight, seed cotton yield and fiber fineness. Hence, it is concluded that these traits may be considered as selection criteria for improvement in seed cotton yield (Jarwar et al., 2018; Rathinavel et al., 2017). The presented research was planned to determine correlation among various yield contributing traits due to increased demand of cotton in the country. In addition, heritability of these parameters was also computed which could be used for the selection of suitable traits from certain parents for the development of new germplasm of upland cotton.

Materials And Methods

Due to technical limitations, the Materials and Methods section is only available as a download in the supplementary files section.

Results

The analysis of variance (ANOVA) exhibited significant differences and confirmed the presence of variations among genotypes for the traits, namely plant height, number of bolls per plant, number of sympodial branches per plant, boll weight, yield of seed cotton, seed index, fiber length, fiber strength and fiber fineness (Table 1). In later stage this data was used for correlation and heritability analysis. The significant results of these traits allowed the researcher to proceed for correlation and heritability analysis.

Correlation coefficient analysis

Correlation coefficient analysis measures the relationship between various plant characters. The estimation of genotypic and phenotypic correlations among studied traits are helpful for initiating breeding programs. If the correlation between two traits is positive and significant then improvement in one trait will exert significant impact on the other. Hence, selection for one character will also improve other associated traits. In present study, plant height exhibited positive and significant linkage with the number of bolls per plant, the number of sympodial branches per plant, ginning outturn (GOT), seed cotton yield, fiber length and fiber fineness whilst non-significant association with boll weight (Table 2). However, plant height showed negative but non-significant relationship with fiber strength. The number of bolls per plant showed positive and significant association with plant height, number of sympodial branches per plant, boll weight, seed index, seed cotton yield and fiber strength whereas negative correlation was observed for fiber length. Number of sympodial branches per plant had positive and significant relationship with all of traits except seed index and staple length. Boll weight had positive and significant correlation with number of bolls per plant, number of sympodial branches per plant, 100-seed weight, staple length and fiber fineness whereas the rest had positive but non-significant association except ginning outturn (GOT) which have positive and significant linkage with plant height, seed cotton yield, number of sympodial branches per plant and fiber length. It had positive but non-significant association with number of bolls per plant. However, ginning outturn (GOT) had negative and non-significant correlation with boll weight, 100-seed weight, fiber strength and fiber fineness. Seed index had positive and significant linkage with number of bolls per plant, boll weight and fiber length while had positive but non-significant correlation with plant height, number of sympodial branches per plant, yield of seed cotton and fiber fineness. It had negative and non-significant relationship with ginning outturn (GOT) and fiber strength.

Seed cotton yield had positive and significant association with plant height, number of bolls per plant, number of sympodial branches per plant, ginning outturn (GOT), staple length and fiber strength. Seed index showed positive but non-significant correlation with boll weight, seed index and fiber fineness whereas negative and non-significant association with fiber strength. Fiber length presented positive and significant linkage with plant height, boll weight, ginning outturn (GOT), seed index, fiber fineness and seed cotton yield while positive but non-significant correlation with number of sympodial branches per plant. Staple length exhibited negative and significant association with fiber strength while negative and non-significant relationship with number of bolls per plant and fiber fineness. Fiber strength had positive and significant association with number of bolls per plant, number of sympodial branches per plant, and seed cotton yield whereas positive and non-significant correlation with boll weight. Whereas, revealed negative and significant linkage with fiber length while had negative and non-significant relationship with plant height, ginning outturn (GOT) and seed index. Fiber fineness had positive and significant correlation with plant height, number of sympodial branches per plant, boll weight, and staple length whereas positive and non-significant association with number of bolls per plant and seed index. It showed negative and non-significant linkage with ginning outturn (GOT), yield of seed cotton and fiber strength.

Estimates of heritability

Heritability (BS) was ranged from medium to high for various yield and fiber related traits (Table 3). The traits namely plant height, number of bolls per plant, ginning outturn (GOT), seed index, seed cotton yield, fiber length, strength and fineness showed high heritability estimates, *i.e.,* 74.48, 53.87, 90.65, 53.42, 54.56, 52.95, 59.66 and 70.42, respectively. While the traits including sympodial branches per plant and boll weight exhibited medium estimates of heritability, *i.e.,* 48.06 and 46.66. The process of selection could be useful for characters with high heritability values.

Mean comparison for certain traits

Among parents, the genotype A555 had the lowest mean value 99.93 cm, while CIM-632 exposed maximum mean value was 124.73 cm for plant height (Figure 1-A). Whereas, Hybrid IUB-222 × NIAB-414 exhibited minimum mean value 88.07 cm, whereas NIAB-414 × CIM-632 showed the highest mean value 127.2 cm. VH-367 exposed minimum number of bolls per plant with the lowest mean value 16.26 whereas IUB-222 showed maximum value 32.13 followed by CIM-632, NIAB-414 and A555 having mean estimates of, *i.e.,* 26.53, 23.26, 23.13 correspondingly (Figure 1-B). Cross, VH-367 × CIM-632 indicated the highest mean value of 32.93 followed by NIAB-414 × IUB222, NIAB-414 × CIM-632 and A555 × IUB-222, having mean values, *i.e.,* 32.53, 31, 30.4 and 28.2, respectively. VH-367 showed the highest mean value of 23.13 followed by A555 (22.66), NIAB-414 (20.93) and IUB-222 (20.93) for number of sympodial branches per plant (Figure 1-C). A555 × IUB-222 revealed minimum mean value of 18.86, whereas VH-367 × NIAB-414 indicated maximum number of sympodial branches of 25.73. Genotype, CIM-632 had minimum mean value for boll weight 1.83 g whereas VH-367 exposed maximum mean value of 2.46 g (Figure 1-D). Hybrids, IUB-222 × VH-367 revealed the lowest but VH-367 × NIAB-414 showed maximum boll weight. NIAB-414 had minimum mean value for ginning outturn (GOT) 38.03 % while IUB-222 had maximum ginning outturn (GOT) 42.32 % (Figure 1-E). NIAB × IUB-222 showed minimum value of 35.46 % whilst hybrid VH-367 × CIM-632 revealed maximum ginning outturn (GOT) 46.33 % followed by CIM-632 × VH-367, CIM-632 × A555 and A555 × NIAB-414 with estimates of 45.62, 44.33 and 43.22%, respectively.

The accessions NIAB-414 and A555 exhibited the minimum and maximum mean estimates 5.07 and 5.64g, respectively for 100-seed weight (Figure 1-F). Hybrid CIM-632 × VH-367 presented minimum seed index 4.62 g whereas CIM-632 × A555 exhibited maximum mean value 5.70g. While studying the seed cotton yield it was observed that IUB-222 revealed maximum mean value 74.81g (Figure 1-G) whilst IUB-222 × A555 showed minimum seed cotton yield 42.39 g but the hybrid VH-367 × CIM-632 revealed the highest mean value 80.17g as compare with A555 × IUB-222 and NIAB-414 × IUB-222 with mean values of 73.95 and 72.84, respectively. CIM-632 indicated the lowest value 24.71mm, while NIAB-414 had maximum fiber length 26.86mm (Figure 1-H). Among the hybrids, A555 × VH-376 had minimum fiber length 24.29 mm, while the highest mean value 28.33 mm was shown by CIM-632 × NIAB-414. In case of fiber strength, VH-367 indicated maximum mean value 29.83 $gtex^{-1}$ followed by A555, NIAB-414 and CIM-632 having mean values of 26.35, 26.28 and 25.47 $gtex^{-1}$, respectively (Figure 1-I). Furthermore, CIM-632 × IUB-222 had minimum fiber strength 23.29 $gtex^{-1}$, while VH-367 × NIAB-414 revealed the highest value 27.96 $gtex^{-1}$. IUB-222 exhibited the lowest value 3.31$\mu ginch^{-1}$ for fiber fineness, while NIAB-414 had the highest mean value 5.06 μginch^{-1} (Figure 1-J). While among the hybrids, IUB-222 × NIAB-414 exposed minimum mean value 3.23 μginch^{-1}, but NIAB-414 × IUB-222 had the highest mean value 5.44 μginch^{-1}.

Discussion

Plant height was positively linked with sympodial branches per plant, number of bolls per plant, ginning outturn (GOT), seed cotton yield, staple length and fiber fineness (Table 2). Azhar and Ajmal (1999), Rao and Gopinath (2013) and Shahzad et al.(2015) also had similar findings. Tulasi et al. (2012) also observed positive association with ginning outturn (GOT), fiber length and fineness. Heritability (BS) for plant height was 74.48% (Table 3). Kapoor and Kaushik (2003), Ahmad et al. (2011) and Baloch et al. (2015) also found high heritability 94%, 81% and 96.4% correspondingly for plant height. High heritability estimates indicated that selection for plant height can be effective. Bolls per plant had positive association with plant height, boll weight, sympodial branches per plant, seed index, seed cotton yield and fiber strength. Ahmad and Azhar (2000), Djaboutou et al. (2005), Gul et al. (2014), Magadum et al. (2012), Alkuddsi et al. (2013) and Farooq et al. (2014), also found same results. Heritability value for bolls per plant was 53.87% (Table 3). Desalegn et al. (2009), Ahmad et al. (2011), Baloch et al. (2015) and Rathinavel et al. (2017) estimated 59%, 88%, 93% and 60.21% high broad sense heritability, respectively, for bolls per plant. High estimates of heritability revealed that successful and effective selection can be helpful in the improvement of this trait.

Sympodial branches per plant had positive relationship with plant height, number of bolls per plant, boll weight, seed cotton yield, ginning outturn (GOT), fiber strength and fiber fineness (Table 2). Pujer et al. (2014), Joshi et al. (2006), Anandan (2009) indicated that sympodial branches per plant positively correlated with seed cotton yield, plant height, ginning outturn (GOT) and boll weight. Whereas, Killi et al. (2005) found that sympodial branches per plant were positively linked with fiber strength. Rauf et al. (2004) also observed that sympodial branches per plant had positive relationship with number of bolls per plant and fiber fineness. Moderate heritability for this trait was observed, *i.e.,* 48.06% (Table 3). Ahmed et al. (2006), Mustafa et al. (2007), Neelima and Reddy (2008) and Kulkarni et al. (2011) also observed medium heritability 50.72%, 59%, 61.30% and 43%, respectively, for sympodial branches per plant. Boll weight was positively linked with bolls per plant, sympodial branches per plant, 100-seed weight, staple length and fiber fineness (Table 2). Jatt et al. (2007) revealed that boll weight had positive association with yield of seed cotton. Abdullah et al. (2016) and Shaheen and Yaseen (2014) observed that boll weight was positively correlated with fiber length, fiber fineness and sympodial branches per plant. Do Thi et al. (2008) and Kale et al. (2007) reported that boll weight positively linked with seed index and number of bolls per plant. Whilst heritability value was moderate 46.66% for this trait (Table 3). Huangjun and Myers (2011), Naveed et al. (2004) and Ahmed et al. (2006) estimated 57%, 22% and 50.0% medium heritability, respectively, for boll weight.

Ginning outturn (GOT) had positive relationship with plant height, seed cotton yield, sympodial branches per plant and fiber length (Table 2). Monicashree and Balu (2018), Pujer et al., 2014) and Chattha et al. (2013) observed that ginning outturn (GOT) had positive linkage with plant height and sympodial branches per plant and yield of seed cotton. Shahzad et al. (2015) observed that ginning outturn (GOT) had positive association with staple length. Heritability for ginning outturn (GOT) was 90.65% (Table 3). Devidas et al. (2017), Shahzad et al. (2015), Kumar and Katageri (2017) and Jarwar et al. (2018) found high heritability values 72.5%, 80.73%, 90.0% and 85.46% for ginning outturn (GOT). Seed index had positive linkage with bolls per plant, boll weight and fiber length (Table 2). Patil (2010), Komala et al. (2018), Memon et al. (2017), Isong et al. (2017), Ashokkumar and Ravikesavan (2010), Shabbir et al. (2016) and Méndez et al. (2012) depicted similar findings. Heritability (B.S) for this trait was 53.42% (Table 3). Dhivya et al. (2014), Kaleri et al. (2016), Kumar and Katageri (2017) and Rajamani et al. (2015) estimated 60.01%, 72.24%, 51.63% and 66.72% heritability correspondingly for seed index. Significant progress is possible through selection for this character.

Seed cotton yield had positive association with plant height, number of bolls per plant, sympodial branches per plant, ginning outturn (GOT), fiber length and fiber strength (Table 2). Majeedano et al. (2014), Joshi et al. (2006), Gite et al. (2006) and Latif et al. (2015) indicated that seed cotton yield was positively linked with plant height, sympodial branches per plant and number of bolls per plant. Monisha et al. (2018) determined positive correlation among ginning outturn (GOT), fiber strength and seed cotton yield. Heritability value for seed cotton yield was 54.56% (Table 3). Desalegn et al. (2009), Reddy and Reddy (2007), Hussain et al. (2010), Ullah et al. (2015) and Ahmad et al. (2011) estimated 61%, 80%, 50%, 98% and 76% heritability, respectively, for this trait. This trait could be improved through selection process. Fiber length was positively linked with plant height, boll weight, ginning outturn (GOT), seed index, fiber fineness and seed cotton yield. Fiber length had negative correlation with fiber strength (Table 2). Ali and Awan (2009) and Echekwu (2001) indicated that fiber length was negatively associated with fiber strength. Bechere et al. (2014) indicated that fiber length had positive linkage with. Killi et al. (2005) determined positive association among fiber length, plant height and seed cotton yield. Abbas et al. (2013) observed that staple length was positively associated with fiber fineness. Shabbir et al. (2016) observed that fiber length had positive association with seed index. Khan and Azhar (2000) found that fiber length had positive relationship with boll weight. Heritability in broad sense for fiber length was 52.95% (Table 3). Killi et al. (2005), Abbas et al. (2013), Khan and Azhar (2000) and Ahmed et al. (2006) found 94%, 52%, 96% and 56% heritability estimates, respectively, for fiber length. It is concluded from results that selection can be useful for fiber length. Fiber strength had positive association with bolls per plant, sympodial branches per plant, and seed cotton yield whereas had negative linkage with fiber length (Table 2). Ahmad and Azhar (2000), Thiyagu et al. (2010) and Farooq et al. (2014) found that fiber strength was positively correlated with yield of seed cotton and number of bolls per plant. Ali and Awan (2009) revealed that fiber strength was negatively linked with fiber length. For this trait heritability value was 59.66% (Table 3). Desalegn et al. (2009), Killi et al. (2005), Shahzad et al. (2015), Rasheed et al. (2009) and Khokhar et al. (2017) determined 33%, 73%, 62%, 70% and 68% heritability for this character. Fiber fineness was positively correlated with plant height, sympodial branches per plant, boll weight, and staple length (Table 2). Ali and Awan (2009), Zeng and Meredith (2009), Tang and Xiao (2014) and Yaqoob et al. (2016) found positive linkage between fiber fineness and staple length. Abbas et al. (2013) and Altaher and Singh (2003) revealed that fiber fineness had positive linkage with plant height, sympodial branches per plant. Abdullah et al. (2016) reported that fiber fineness was positively correlated with boll weight. Heritability value for fiber fineness was 70.42% (Table 3). Hendawi et al. (1999) and Lu et al. (2002) estimated 67% and 73% heritability, respectively, for fiber fineness.

Conclusion

The correlation results from this study would be helpful to breed cotton cultivars with good yield and quality characters. Broad sense heritability was high for all of parameters which provides the strong evidence that selection in early generations can improve the performance of these traits.

Declarations

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Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and material

Not applicable.

Conflict of interest

Authors declare that they have no conflict of interest for the publication of the manuscript.

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Authors' contributions

Mustafa N and Rehman A conducted experiment and wrote the initial draft of the manuscript. Azhar MT played role in designing and statistics of the experiment, in addition Azhar MT supervised Mustafa N for her master studies. Xiongming Du proofread the manuscript before submission to JCR.

Abbreviations

GDP: Gross domestic product; PH: Plant height; BP: Bolls per plant; SB: Number of sympodial branches per plant; BW: Boll weight; GOT: Ginning outturn; SI: Seed index; SCY: Seed cotton yield; FL: Fiber length; FS: Fiber strength; FF: Fiber fineness; BS: Broad sense; RCBD : Randomized complete block design; ANOVA: Analysis of variance

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Tables

Table 1. Analysis of variance of various quantitative traits for F_1 population and parents in upland cotton formulated by using MINITAB 16.

SOV	DF	PH	NB	SB	BW	GOT	SI	SCY	FL	FS	FF
Rep.	2	2.21^{ns}	2.88^{ns}	4.39*	4.77*	5.88^{ns}	0.29^{ns}	4.63^{ns}	4.65*	5.68*	0.35^{ns}
Gen.	24	3.92**	2.17*	1.93*	1.86*	10.70**	2.15*	16.21**	2.13*	2.48**	3.37**
Err.	48	-	-	-	-	-	-	-	-	-	-

** = Highly significant $p \leq 0.01$, *= Significant $p \leq 0.05$
Where, PH (plant height), BP (bolls per plant), SB (number of sympodial branches per plant), BW (boll weight), GOT (ginning outturn), SI (seed index), SCY (seed cotton yield), FL (fiber length), FS (fiber strength) and FF (fiber fineness).

Table 2. Correlation among various traits of Upland cotton grown in filed conditions by using correlation analysis

Traits	PH	BP	SB	BW	GOT	SI	SCY	FL	FS
BP	0.16*								
SB	0.63**	0.17*							
BW	0.05	0.21**	0.07*						
GOT	0.34**	0.02	0.22*	-0.04					
SI	0.08	0.25*	0.09	0.51**	-0.02				
SCY	0.29**	0.54**	0.39**	0.18	0.28**	0.02			
FL	0.20*	-0.04	0.06	0.20*	0.19*	0.17*	0.03*		
FS	-0.16	0.19*	0.27*	0.12	-0.06	-0.05	0.33**	-0.02*	
FF	0.08*	0.04	0.17*	0.27*	-0.14	0.26	-0.06	0.11*	-0.05

Where, PH (plant height), BP (bolls per plant), SB (number of sympodial branches per plant), BW (boll weight), GOT (ginning outturn), SI (seed index), SCY (seed cotton yield), FL (fiber length), FS (fiber strength) and FF (fiber fineness).

Table 3: Range of heritability of various traits of cotton grown in field conditions according ti the formula fiven by Burton and Devance (1953)

Traits	Heritability %	Status
Plant height	74.48	High
Sympodial branches per plant	48.06	Medium
Number of bolls per plant	53.87	High
Boll weight	46.66	Medium
Ginning out turn	90.65	High
Seed index	53.42	High
Seed cotton yield	54.56	High
Fiber length	52.95	High
Fiber strength	59.66	High
Fiber fineness	70.42	High

High > 0.5, Medium 0.2-0.5, Low < 0.2

Figures

Figure 1

Mean comparison for plant height of parents and crosses of upland cotton where, A for PH (plant height), B-BP (bolls per plant), C- SB (number of sympodial branches per plant), D- BW (boll weight), E- GOT (ginning outturn), F- SI (seed index), G- SCY (seed cotton yield), H- FL (fiber length), I- FS (fiber strength) and J- FF (fiber fineness).

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