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Research Article

Association of Leaf Related Traits and Boll Weight in Cotton

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Abstract | Cotton is an important cash crop that provides financial assistance to many people across the world. Leaf morphology and physiology provides a balance between leaf temperature, leaf energy exchange and photosynthesis. The experiment was undertaken to study the association of leaf related traits i.e. leaf area (LA), leaf angle position (LP), number of lobes per leaf (NL), leaf chlorophyll contents (SV), relative water content (RWC), leaf hairiness (HL), leaf color (LC) and yield related traits i.e. boll weight (BW), number of seeds per boll (NS), number of locules per boll (NLB), seed index (SI) and seed volume (SEV). Twenty cotton genotypes were grown using randomized complete block design with three replications. Significant variation among the genotypes was observed for studied traits by analysis of variance. Pearson correlation analysis depicted significant positive association between NL and BW. SV also revealed positive association with SI. BW showed positive association with NLB, NS and SI. LA showed positive association with NL. Path coefficient analysis was utilized to partition the direct and indirect effects of different traits on BW. Path coefficient analysis revealed positive direct effect of NS on BW. Similarly, SI illustrated positive indirect effect on BW via LA. The genotype V-89 was found a best performing genotype with high yield and moderate leaf traits.

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Introduction

Cotton, (*Gossypium hirsutum* L.) popularly referred as "White Gold", is an important fiber crop grown in tropical and sub-tropical regions around the globe (Dinakarana, 2012). Cotton is extensively cultivated in more than eighty countries across the globe and it provides financial stability to many people (Latif et al., 2015). Pakistan's economy largely depends upon cotton production.

Cotton yield can be determined on the basis of following traits such as boll weight, number of bolls per plant, number of plants, seed index and number of seeds per boll. Leaf plays important role in plants phenotype. Leaf is a "power house" of plant as it synthesizes food with the help of chlorophyll (Gitelson et al., 2003). Researchers have theshape and size of leaf is a balance between leaf energy exchange, leaf temperature and photosynthesis. Physiological process such as photorespiration protects cotton plant from damaging? of oxygen level and high intensities of light (Givnish et al., 1976). Different leaf traits have shown vital significance in final plant yield. Some leaf traits such as leaf color, leaf hairiness have been extensively used by plant breeders to produce resistant genotypes (Nawab, 2014). In cotton, life cycle of a leaf starts with initiation of a bud and become

Table 1: *Mean square values of the studies traits.*

SOV	DF	LA	LP	SV	NL	RWC	BW	NS	NLB	SEV	SI
Replication	2	4.51	34.20	19.42	0.14	11.45	0.17	13.61	0.06	5.45	1.13
Genotype	19	8.83*	643.35*	122.16*	1.02*	31.23*	1.29*	42.28*	0.32*	15.89*	3.52*
Error	38	1.59	137.726	13.38	0.21	7.65	0.31	18.26	0.15	10.01	1.26

***:** *Significant at 5% significance level;* **SOV:** *source of variation;* **DF:** *Degree of freedom;* **LA:** *leaf Area;* **LP:** *leaf angle position;* **SV:** *chlorophyll contents/Spad Value;* **NL:** *Number of lobes per leaf;* **RWC:** *relative water content;* **BW:** *boll weight;* **NS:** *number of seeds per boll;* **NLB:** *number of locules per boll;* **SEV:** *seed volume;* **SI:** *seed index*

net exporter of carbohydrates within few days. Emerging bolls extract maximum of their nutrition from the subtending leaves. During the period of boll filling, leaves age quickly. Therefore, breeding efforts and management practices should be designed to incorporate additional carbohydrates into bolls and fewer into leaves. Competition for photosynthates prevails during various developmental stages (Stewart, 1989). Raper et al. (2013) reported close positive correlation between leaf nitrogen status and yield. Leaf area was also found positively associated with yield (Samba Murthy and Chamundeswari, 2006). Similarly, Nawab (2014) reported a strong association between leaf hairiness and insect resistance. Yield is defined as a composite measureable trait, which is influenced by environment. Therefore, yield is not only single effective measurable trait for selection. Selection had to be made for the components of yield also. Boll weight is considered as a major component of yield. Previously some leaf traits were found to be associated with boll weight. Therefore, current research was carried out to (i) observe association of leaf and yield related traits (ii) to observe direct and indirect effect of different traits on boll weight.

Materials and Methods

The experiment was undertaken at the research area of the department of Plant Breeding and Genetics, Faculty of Agricultural Sciences and Technology Bahauddin Zakariya University, Multan, situated on latitude: 30°15'29.09" and longitude: 71°30'50.54" during 2014. The physio-chemical exploration of soil indicated loamy in texture (silt 46.36%, sand 38.36% and clay 15.28%). During crop cultivation temperature was ranged from30° 76.C to 37° C. The study comprises of 20 genotypes of tetraploid cotton. The experiment was replicated three times using randomized complete block design. Plant to plant (P*P) and Row to row (R*R) distance was maintained 9 cm and 12 cm, respectively. The data was collected from five tagged plants from each replication for the leaf related traits such as leaf area (LA), leaf angle position (LP), number of lobs per leaf (NL), leaf chlorophyll contents/spad value (SV), relative water content (RWC), leaf hairiness (HL), leaf color grading (LC) and yield related traits such as boll weight (BW), number of seeds per boll (NS), number of locules per boll (NLB), seed index (SI) and seed volume (SEV). For leaf color grading, leaves showed dark green color were assigned with letter (A), medium green color (B) and light green color with (C). Genetic divergence among genotypes was accounted using analysis of variance (ANOVA) with the help of Statistix 8.1 (Ahmad et al., 2012). Correlation analysis was performed with the help of SAS code v 9.4 software and path coefficient analysis was done using Ms XL stats, diagrammatic illustration was developed with the help of Smart Draw Ci v 22.0.1

Results and Discussion

Please describe your results

Analysis of variance showed significant variation among studied genotypes for leaf related traits LA, LP, NL, SV, RWC and yield traits such as BW, NSl, NLB, SI, SEV as illustrated in Table 1. This high degree of variation suggested that genetic material is diverse in nature and should be given due importance for further studies. Some other researchers also found variation for leaf and yield related traits (Ahmad et al., 2012; Haidar et al., 2012; Rahman et al., 2013; kitajima, 1996). This variation provides sufficient scope to plant breeders because high degree of variability is essential for effective breeding programs to enhance various traits (Ahsan et al., 2015).

First discuss your results and conclude your work with other subtests

Several researchers have executed mean performance of cotton genotypes for physiological, morphological and yield traits in upland cotton (Arshad et al., 1993). In current study, for LA, MPS-11 showed maximum value (14.16cm^2) and genotype Trend-1 showed minimum

Table 2: *Average performance of genotypes.*

Genotypes	LA	LP	SV	NL	RWC	BW	NS	NLB	SEV	SI
VH-300	13.80	47.33	59.45	3.66	32.67	2.82	26.00	4.00	10.00	6.99
V-85	12.99	60.33	66.96	4.33	21.76	3.12	24.66	4.00	12.00	8.30
CIM-598	10.37	86.33	51.03	4.33	34.36	1.95	24.00	4.66	9.33	5.52
CAM-5	10.92	71.00	43.94	3.00	36.10	2.24	22.66	4.00	13.33	5.32
VS-303	13.11	81.33	49.50	3.66	27.11	2.36	19.66	4.00	9.33	5.77
MNH-846	12.72	81.00	49.58	3.66	33.33	1.54	19.33	4.33	8.00	4.73
SLH-4	13.66	82.67	45.73	4.33	30..61	2.97	28.66	4.33	10.66	6.04
CIM-506	10.37	100	46.43	3.00	34.55	1.87	19.33	4.00	11.33	6.14
MPS-11	14.16	80.67	46.09	5.00	28.75	2.02	22.33	4.00	13.33	6.78
MNH-456	13.25	81.33	51.22	3.66	24.94	2.81	29.66	4.33	11.33	5.15
V-89	13.14	70.33	51.44	4.33	29.94	3.72	30.00	4.33	16.00	8.00
CRIS-510	10.33	81.00	49.36	3.66	24.94	2.29	22.33	4.66	8.00	6.01
SAYBAN-201	11.44	80.00	59.33	5.00	24.13	3.59	27.66	4.33	13.33	7.62
Gomal-93	11.38	60.67	44.90	3.00	21.88	3.15	26.00	4.00	10.66	7.64
Trend-1	9.44	59.67	59.86	3.66	29.94	2.31	20.00	4.33	10.66	6.38
AGC-707	10.94	60.33	49.62	4.33	23.56	3.22	27.33	5.00	11.00	6.27
V-68	7.77	83.33	52.49	3.00	31.07	2.18	25.66	4.33	8.00	4.78
V-17	9.55	50.67	44.20	3.00	28.79	2.44	26.33	4.00	16.00	6.77
CRIS-510	11.10	44.67	43.98	5.00	25.32	1.44	22.00	4.00	11.66	4.70
V-93	10.99	70.33	44.82	5.00	27.53	1.79	15.66	5.00	11.00	5.67

LA: *leaf Area;* **LP:** *leaf angle position;* **SV:** *chlorophyll contents/Spad Value;* **NL:** *Number of lobes per leaf;* **RWC:** *relative water content;* **BW:** *boll weight;* **NS:** *number of seeds per boll;* **NLB:** *number of locules per boll;* **SEV:** *seed volume;* **SI:** *seed index*

Table 3: *Pearson correlation analysis among studied traits.*

	LA	LP	NL	SV	RWC	BW	NLB	SB	SI	SEV
LA	1									
LP	0.063	1								
NL	0.210*	-0.052	1							
SV	0.040	-0.145	-0.184	1						
RWC	-0.077	0.139	0.189	-0.220	1					
BW	0.234	-0.171	0.274*	0.267	-0.203	1				
LB	0.193	-0.063	0.029	0.240	0.421	0.463**	1			
SB	0.212	-0.062	0.026	0.121	0.008	0.722**	0.124**	1		
SI	0.240	-0.251	0.172	0.274*	-0.236	0.670**	0.329*	0.137	1	
SEV	0.013	-0.240	0.315	-0.01	-0.040	0.284	0.295	0.318**	0.282*	1

:** *Significant;* *:** *Highly Significant;* **LA:** *leaf Area;* **LP:** *leaf angle position;* **SV:** *chlorophyll contents/Spad Value;* **NL:** *Number of lobes per leaf;* **RWC:** *relative water content;* **BW:** *boll weight;* **NS:** *number of seeds per boll;* **NLB:** *number of locules per boll;* **SEV:** *seed volume;* **SI:** *seed index*

value (9.44cm^2). Similarly for BW, the genotype V-89 accounted maximum boll weight (3.72gm) whereas; the genotype CRIS-510 depicted lowest value (1.44gm) of boll weight. Widespread ranges of values for rest of the traits are depicted in Table 2.

Some traits of leaves were qualitative in nature. Therefore, there biometrical measurements could not be made. Qualitative leaf traits such as leaf color and leaf hairiness also contributes to yield. Leaf color is commonly used to measure plant leaf nitrogen level

Table 4: *Path coefficient analysis results showing direct and indirect effect of various traits in boll weight.*

	BW	LA	LP	NL	SV	RWC	LB	SB	SI	SEV	PRC
BW	0.221	0.209	-0.060	-0.174	0.310	-0.721	0.175	0.709	0.711	0.292	-1.8816
LA	0.289	0.121	-0.012	0.420	0.103	-0.106	0.284	0.259	0.165	0.097	0.0564
LP	-0.160	-0.014	-0.011	-0.221	-0.204	0.354	-0.417	-0.085	-0.289	-0.144	-0.0279
NL	0.174	0.142	-0.295	-0.073	-0.023	0.013	0.342	0.231	0.103	0.044	-0.0145
SV	0.423	0.114	-0.204	-0.053	0.311	-0.071	-0.206	0.084	0.401	-0.053	0.0542
WC	-0.437	-0.106	0.354	0.023	-0.227	0.351	-0.019	-0.261	-0.301	-0.077	-0.0540
LB	0.237	0.284	-0.417	0.342	-0.326	-0.321	0.245	0.502	0.210	0.371	0.0293
SB	0.783	0.283	-0.095	0.231	0.189	-0.266	0.472	0.615	0.199	0.186	0.5387
SI	0.748	0.301	-0.289	0.143	0.463	-0.401	0.521	0.359	0.512	0.241	0.4602
SEV	0.396	0.059	-0.349	-0.054	-0.053	-0.077	0.371	0.280	0.514	0.213	0.0215

BW: *Boll Weight;* **LA:** *Leaf Area;* **LP:** *Leaf angleposition;* **NL:** *Number of lobs per leaf;* **SV:** *Chlorophyll contents/Spad Value;* **RWC:** *Relative Water Content;* **LB:** *Number of locules per boll;* **SB:** *Seeds per Boll;* **SI:** *Seed Index;* **SEV:** *Seed Volume;* **PRC:** *Partial Regression Coefficient*

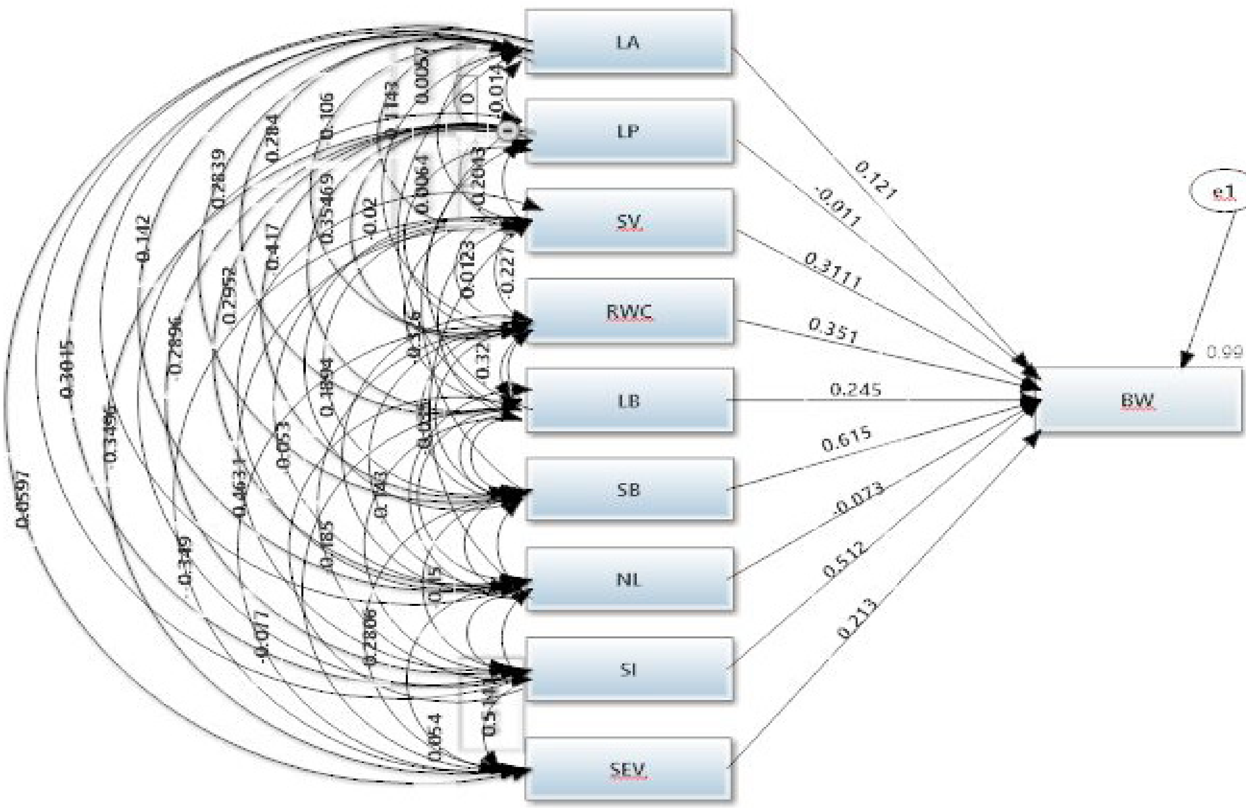

Figure 1: *Diagrammatic illustration of direct and indirect effects of various traits on boll weight*

(Murakami et al., 2005). Cotton genotypes V-85, Sayban-201, Trend-1and V-68 showed (grad A) dark green color of leaf. Similarly VH-300, CIM-598, VS-303, MNH-846, CIM-506, MNH-456, V-89, AGC-707 and V-93 showed (grade B) green color leaves. Moreover, CAM-5, SLH-4, MPS-11, CRIS-510, Gomal-93, V-17, and CRIS-510 were ranked grade C (light green) leaves. Qualitative grading was done to find out distribution of trichomes on leaves demonstrated by Kloth (1995). VH-300, V-85, CIM-598, VS-303, MNH-846, Gomal-93 and AGC-707 have pilose type hairiness on leaves. While CAM-5, SLH-4, MPS-11, MNH-456, V-89, CRIS-510, Sayban-201, Trend-1, V-68, V-17, CRIS-510 and V-93 showed intermediate type of hairiness.

To determine the association among different traits, Pearson correlation analysis was performed (Farooq et al., 2014) which revealed various levels of association among these traits Table 3. LA expressed significant and positive association with NL. NL showed positive and significant association with BW. Positive and significant association was found between SV and SI. The association among BW was highly significant with LB, SB and SI. NLB showed highly significant association with SB and significant correlation with SI. Similarly high significant correlation was found among SB and SEV. Significant and positive association was found among SI and SEV.

High significant and positive correlation of BW with NS and SI had been reported by many researchers (Boggs et al., 2003; Killi et al., 2005; Karademir, 2009). Ahmad et al. (2008) revealed positive association between BW and cotton seed yield. In this study chlorophyll value showed positive significant association with seed index, whereas previously some researchers reported conversely. Researchers suggested that chlorophyll reduction in leaf may provide better yield because chloroplasts are rich in nutrients and reduction in their quantity may give rise to existing nutrients for progress and development of plant fruit bearing (Hamblin et al., 2014).

A straightforward association does not provide ideal picture of the contribution of numerous traits in total yield. Therefore, Path coefficient analysis was performed to partition the correlation into direct and indirect effects on boll weight (Dinakaran et al., 2012; Shahriari et al., 2014). Path coefficient revealed positive direct effect of SB on BW Table 4. Similar results were also reported by (Hazem and Baytay, 2005; Ahmed et al., 2003). SI illustrated positive indirect effect on BW via LA (Wendt et al., 1967). V-89 showed moderate trichomes and medium green color of leaf. Similar results had been reported by (Knight, 1952; Niles, 1980). Direct and indirect effects of various plant traits on boll weight are well represented in Figure 1.

Cotton genotype V-89 performed best in yield traits but the leaf traits found in V-89 were surprisingly moderate. Varieties having larger LA like MPS-11 ($14.17cm^2$), VH-300 ($13.81cm^2$) and MNH-456 ($13.28cm^2$) or LP like CIM-506 (100.00°) and V-68 (83.33°) or SV like V-85 ($66.97\mu mol/m^2$) and Trend-1 ($59.87\mu mol/m^2$) or RWC like CAM-5 (36.10%) and CIM-506 (34.55%) were found having moderate or low yield traits. Previously some researchers also reported that genotypes having moderate leaf traits perform better in terms of yield (Monks et al., 1999; Kerby et al., 1980; Ekinci et al., 2008; Hamblin, 2014). Therefore on the basis of results of this research we are of the view that breeders should develop plants having moderate leaf traits instead of bigger in size to get higher yields. When plant uses all its energy to strengthen the vegetation, less potential remains in it to perform best in terms of yield (Hamblin, 2014). It does not mean that plant with poor leaf traits will perform best in yield. A moderate and balance performance is required to achieve goals.

Authors Contribution

MQA planned the research work; FHA recorded the data and wrote the manuscript and AQ and WM reviewed the manuscript. RWA and AH performed statistical analysis. MAS presented the data graphically and ABM did the final revision of the manuscript.

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