Effect of Different Locations, Varieties and Micronaire Values upon the Non-Cellulosic and Metal Contents of Cotton

[1]NASIR MAHMOOD*, [1]MUHAMMAD QAMAR TUSIEF, [1]DANISH IQBAL,
[2]MAHMOOD AHMED KHAN AND [3]WAJID ISHAQUE
[1]*Department of Fiber and Textile Technology, University of Agriculture Faisalabad, Pakistan.*
[2]*Department of Math & Statistics, University of Agriculture Faisalabad, Pakistan.*
[3]*Nuclear Institute for Agriculture and Biology Faisalabad (NIAB), Pakistan.*
nasirmahmood23uaf@yahoo.com*

(22nd January 2011, accepted in revised form 21st September 2011)

Summary: Cotton fibres contain naturally occurring non-cellulosic materials such as sugars, wax, metals and other organic species that may influence fibre characteristics, i.e. physical and chemical properties, yarn processing efficiency as well as product quality. Chemical and physical tests were conducted on raw cottons from different growing areas of Pakistan to determine the effect of different chemical components/materials on fibre properties, spinning performance and yarn properties. The present research study was planned to explore the location's effect upon the non-cellulosic content of raw cotton and its ultimate effect on end product. In this concern four different growing areas (Multan, Bahawalpur, Rahim Yar Khan and Faisalabad), four cotton varieties CIM-473, CIM496, NIAB-111 and NIAB-999 with four micronaire values (4.4,4.6, 4.8 and5.0) were analyzed for wax, alcohol extractable, residual sugars, fibre ash contents and light metal content. Determined values were significantly correlated to spinning consistency.

Introduction

Non-cellulosic materials of raw cottons can influence fibre physical properties, yarn processing efficiency and quality of the end product. Concentrations generally depend on a number of factors such as area of growing, genetics, degree of fibre maturity, field weathering, length of growing season, growing and harvest aid chemical treatments, honeydew presence and possible contaminations practiced in handling during the picking, ginning, and baling processes. Modern trends in the expansion of textile machinery are to increase manufacture speeds, so greater stresses and demands are sited on fibres to perform. Surface related materials such as plant sugars, wax, metals, and other organic compounds can easily exceed 3% of the fibre weight and have increasing potential to impact fibre and yarn properties, processing efficiency, and quality of the product [1]. The cotton fibre is composed of concentric layers. The cuticle layer on the fibre itself is divisible from the fibre and consists of wax and pectin material. The primary wall is composed of cellulose crystalline fibrils. The secondary wall of cotton fibre consists of three distinct layers. The entire three layers of the secondary wall include very much packed parallel fibrils with spiral twisting of 25-35° and represent the mass of cellulose within the fibre. The lumen is innermost part of cotton fibre. The lumen is filled with liquid containing the cell nucleus and protoplasm. The twist and convolutions of the dried fibre are as a result of the removal of the liquid. The largely contents are broken down into the components of 80-90% cellulose, 6-8% water, 0.5-1% waxes and fats, 0-1.5% proteins, 4-6% hemi cellulose and pectin's 1-1.8 % ash [2]. Cotton fibre quality can be enhanced through genetics, crop managing, and post harvest handing out.Awareness of the effect of fibre properties on processing and their inheritance, interaction and environmental influences is essential to originate improvement strategies. Cotton contains non-cellulose materials such as plant waxes, changeable amounts of ionic species and metals that are present throughout yarn spinning), and non-fibrous materials e.g. plant leaf trash, seed coat fragments, oils, man-induced contaminants and other naturally occurring materials [3]. Oils and man-induced contamination normally represent a very small part of the overall annual cotton crop. In such cases, special managing techniques are necessary. Cotton alcohol extractable (which include wax, small amounts of certain metals, and other non-fibrous materials) may vary from 10 to over 20 g/kg (1.0% to 2.0%) of the weight of the fibre. Extracted wax concentrations generally differ from 2 to 10 g/kg (0.2% to 1.0%) and concentrations of the most abundant metals (e.g. potassium, calcium, and magnesium) may vary from 2 to 7 g/kg (0.2% to 0.7%). Concentrations of total solvent extractable materials and residual metals are heavily dependent upon the growing area, variety, length of growing season, weathering record, and fibre maturity. These materials are considered to be "surface related" and their collective concentrations may represent up to 30 g/kg (3.0%) of the weight of the fibre. Metal cat-ions are present as salts, or complex, either on the cotton

*To whom all correspondence should be addressed.

fibre surface or enclosed within the chemical matrices of the variety. These cat-ions can contribute to a number of issues connected with processing of yarn, fabric production, bleaching and dyeing process. The presence of salts on the outer surface of the fibre and in the lumen have been linked with a possible beneficial effect to quality of yarn and processing efficiency owing to their anti-static properties [4].The most abundant metals on cotton fibre are potassium, calcium, magnesium, and sodium. Other metals observed at a much lesser relative concentration are iron, copper, manganese, zinc, nickel, silicon, cobalt, and aluminum [5]. Some of these metals, such as calcium and potassium are necessary for the normal growth of the cotton fibre [6].

Results and Discussion

Wax Content

The analysis for variance of the data regarding wax content is given in Table-1, which shows that the effect of the Location (L), Variety (V) and Miconaire value (M) has highly significant effect while all of the possible interactions generated non significant results upon the data. Comparison of individual treatment means for different Locations presented in Table-1(a) shows that the mean values of wax content for L_1, L_2, L_3, and L_4 are 0.51, 0.55, 0.57 and 0.46 percent respectively. The results show that wax content values for different Locations are significantly different from each other. The results further indicate that the maximum value for wax content is recorded for L_3 followed by L_2, L_1 and L_4 respectively. These results get support from the finding that for naturally grown coloured cotton the range of wax is 0.40-0.65[7].

Table-1: Analysis of Variance for Wax content.

S.O.V.	D.F.	S.S.	M.S.	F. Value.	Prob.
L	3	0.10395	0.03465	49.34	0.0000**
V	3	0.22619	0.07540	107.36	0.0000**
M	3	0.15326	0.05108	72.98	0.0000**
LxV	9	0.01317	0.00146	2.08	N.S
LxM	9	0.00452	0.00050	0.72	N.S
VxM	9	0.01219	0.00135	1.93	N.S
LxVxM	27	0.03307	0.00123	1.75	N.S
Error	192	0.13440	0.00070		
Total	255	0.68075			

**=Highly significant NS=Non significant CV=5.01%

Table-1a: Comparison of individual means for Wax content.

Location(L)	Variety(V)	Micronaire value(M)
L1=0.51c	V1=0.50c	M1=0.55a
L2=0.55b	V2=0.55b	M2=0.50c
L3=0.57a	V3=0.61	M3=0.52b
L4=0.46d	V4=0.45d	M4=0.48d

Mean values having different letters, differ significantly at 0.05% level of probability

Comparison of individual treatment means for different Varieties indicate that the mean values of wax content for V_1, V_2, V_3 and V_4 were, 0.50, 0.55, 0.61 and 0.45 percent respectively . While for different Micronaire Values, the results for wax contents are also significantly different. These finding are as par with the observations that the natural wax present in cotton play a significant role in physical and chemical processing (dyeing and finishing). Also wax plays an important role in the strength and elongation properties of the end product [8].

Alcohol Extractable

The analysis of variance of the data regarding alcohol extractable is given in Table-2, which shows that the effect of the Location (L), Variety (V) and Micronaire value (M) was highly significant, while the effect of all possible interactions on alcohol extractable were non significant Comparison of individual treatment means for different Locations presented in Table-2(a) show that the mean value of alcohol extractable for L_1, L_2, L_3 and L_4 were 1.99, 1.87, 1.25 and 1.37 percent respectively. The results indicate that alcohol extractable values for different Locations are significantly different from each other. Similarly different kinds of varieties and various micronaire values significantly affect the alcohol extractable.

Table-2: Analysis of variance for Alcohol Extractable.

S.O.V.	D.F.	S.S.	M.S.	F. Value.	Prob.
L	3	7.28337	2.42779	297.93	0.0000**
V	3	0.25226	0.08409	10.32	0.0000**
M	3	0.26224	0.08741	10.72	0.0000**
LxV	9	0.06326	0.00703	0.86	N.S
LxM	9	0.06525	0.00725	0.89	N.S
VxM	9	0.05290	0.00588	0.72	N.S
LxVxM	27	0.17604	0.00652	0.80	N.S
Error	192	1.56481	0.00815		
Total	255	9.72013			

**=Highly significant NS=Non significant. CV=5.49%

Table-2a: Comparison of individual means for Alcohol.

Location (L)	Variety (V)	Micronaire value (M)
L_1=1.99a	V_1=1.63b	M_1=1.69a
L_2=1.87b	V_2=1.55c	M_2=1.52c
L_3=1.25d	V_3=1.42d	M_3=1.60b
L_4=1.37c	V_4=1.72a	M_4=1.44d

Mean values having different letters; differ significantly at 0.05% level of probability

Residual Sugars

The analysis of variance of the data regarding residual sugars is given in Table-3, which show that the effect of the Location (L), Variety (V) and Mic value (M) was highly significant while the

effect of all possible interactions on residual sugars were non significant.

Table-3: Analysis of Variance for Residual sugar.

S.O.V.	D.F.	S.S.	M.S.	F. Value.	Prob.
L	3	0.54474	0.18158	471.73	0.0000**
V	3	0.03469	0.01156	30.04	0.0000**
M	3	0.04086	0.01362	35.38	0.0000**
LxV	9	0.00625	0.00069	1.81	N.S
LxM	9	0.00240	0.00027	0.69	N.S
VxM	9	0.00521	0.00578	1.52	N.S
LxVxM	27	0.01959	0.00073	1.91	N.S
Error	192	0.07296	0.00038		
Total	255	0.72671			

**=Highly significant NS=Non significant CV=4.30%

Comparison of individual treatment means for different Locations presented in table 3(a) shows that the mean value of residual sugars for L_1, L_2, L_3 and L_4 were 0.46, 0.56, 0.31 and 0.49 percent respectively. The result shows that residual sugars values for different Locations are significantly different from each other. Because electrolytes and sugars present on the surface of cotton fiber, as well as pectin present in the primary cell wall, exhibited significant correlations with single fiber friction and surface wax indicate a substantially weaker correlation [9]. Comparison of individual treatment means for different Varieties presented in table 3(a) shows that the mean values of residual sugars for V_1, V_2, V_3 and V_4 were, 0.43, 0.45, 0.48 and 0.41 percent respectively. This indicates that residual sugars values for different varieties are significantly different from each other. The result indicated that the maximum value for residual sugars was recorded for V_3 followed by V_2, V_1 and V_4 respectively. As carbonyl, hydroxyl, ether, amide and amine functional groups associated with non-cellulosic components [10].

Table-3a: Comparison of individual means for Residual sugar.

Location (L)	Variety (V)	Micronaire value (M)
L_1=0.46c	V_1=0.43c	M_1=0.41d
L_2=0.56a	V_2=0.45b	M_2=0.44c
L_3=0.31d	V_3=0.48a	M_3=0.47b
L_4=0.49b	V_4=0.41d	M_4=0.49a

Mean values having different letters, differ significantly at 0.05% level of probability

Ash Content

The analysis of variance of the data regarding ash content is given in Table-4, which shows that the effect of the Location (L), Variety (V) and Mic value (M) was highly significant while the effect of all possible interactions on ash content generated non significant upon the results.

Comparison of individual treatment means for different Locations presented in table 4(a) indicates that the mean values of ash content for L_1, L_2, L_3 and L_4 were 1.62, 1.69, 1.20 and 1.44 percent respectively. The result showed that ash content values for different Locations are significantly different from each other. The results indicated that the maximum value for ash content was recorded for L_2 followed by L_1, L_4 and L_3 respectively. This predicts that the strongest yarn was produced by least ash content. Comparison of individual treatment means for different Varieties presented in table 4(a) shows that the mean values of ash content for V_1, V_2, V_3 and V_4 were 1.48, 1.40, 1.33 and 1.56 percent respectively. The result showed that ash content values for different varieties are significantly different from each other. The results indicated that the maximum value for ash content was recorded for V_4 followed by V_1, V_2 and V_3 respectively. These findings are in line with the results as given by [11] who noted the range of ash contents as 1.39 to 1.526 percent. Further stated that ash content had a greater effect on yarn strength and tensile properties

Table-4: Analysis of Variance for Ash content.

S.O.V.	D.F.	S.S.	M.S.	F. Value.	Prob.
L	3	2.30813	0.76938	429.14	0.0000**
V	3	0.28226	0.09409	52.48	0.0000**
M	3	0.05033	0.01678	9.36	0.0000**
LxV	9	0.01121	0.00124	0.69	N.S
LxM	9	0.01251	0.00139	0.78	N.S
VxM	9	0.00622	0.00069	0.39	N.S
LxVxM	27	0.04398	0.00163	0.91	N.S
Error	192	0.34368	0.00179		
Total	255	3.05832			

**=Highly significant NS=Non significant CV=2.85%

Table-4a: Comparison of individual means for Ash content.

Location (L)	Variety (V)	Micronaire value (M)
L_1=1.62b	V_1=1.48b	M_1=1.52a
L_2=1.69a	V_2=1.40c	M_2=1.45b
L_3=1.20d	V_3=1.33d	M_3=1.38c
L_4=1.44c	V_4=1.56a	M_4=1.31d

Mean values having different letters, differ significantly at 0.05% level of probability

Metal Contents

Magnesium

The analysis of variance of the data regarding magnesium is given in Table-5, show that the effect of the Location (L), Variety (V) and Mic value (M) was highly significant while the effect of all possible interactions on magnesium remained non significant.

Comparison of individual treatment means for different Locations presented in Table-5(a) indicated that the mean values of magnesium for L_1, L_2, L_3 and L_4 were 675, 644, 455 and 577 ppm respectively. The result shows that magnesium values for different locations are significantly different from each other. The results indicated that the maximum

value for magnesium was recorded for L_1 followed by L_2, L_4 and L_3 respectively. These results get support from the research study by [12] concluded that the dominant metal in the cottons was potassium (ca., 2000-6500 ppm); followed by calcium and magnesium (ca., 400-1200ppm); sodium (ca., 100-300 ppm); iron (ca., 20-90 ppm) and zinc, manganese and copper(ca.,1-110ppm)

Table-5: Analysis of Variance for Magnesium.

S.O.V.	D.F.	S.S.	M.S.	F. Value.	Prob.
L	3	454362	151454	1063.75	0.0000**
V	3	4147	1382	9.71	0.0000**
M	3	12244	4081	28.67	0.0000**
LxV	9	2161	240	1.69	N.S
LxM	9	2639	293	2.06	N.S
VxM	9	749	83	0.58	N.S
LxVxM	27	7591	281	1.98	N.S
Error	192	27264	142		
Total	255	511157			

**=Highly significant, NS=Non significant CV=2.03%

Table-5a: Comparison of individual means for Magnesium.

Location (L)	Variety (V)	Micronaire value (M)
L_1=675a	V_1=537c	M_1=608a
L_2=644b	V_2=566b	M_2=592b
L_3=455d	V_3=509d	M_3=582c
L_4=577c	V_4=597a	M_4=570d

Mean values having different letters, differ significantly at 0.05% level of probability

Comparison of individual treatment means for different Varieties presented in Table-5(a) showed that the mean value of magnesium for V_1, V_2, V_3 and V_4 were, 537, 566, 509 and 597 ppm respectively. The results indicate that magnesium values for different varieties are significantly different from each other.

Potassium

The analysis of variance of the data regarding potassium is given in Table-6 which shows that the effect of the location (L), Variety (V) and Micronaire value (M) was found highly significant while the effect of all possible interactions on potassium were non significant. Duncan's multiple range test and the comparison of individual treatment means for different Locations presented in Table-6(a) shows that the mean values of potassium for L_1, L_2, L_3 and L_4 were 5258.6, 6084.3, 3862.4 and 4216.2 ppm, respectively. The results showed that potassium values for different Locations are significantly different from each other. The results indicated that the maximum value for potassium was recorded for L_2 followed by L_1, L_4 and L_3 respectively. It was noted that fibre total light metal contents were seen to be correlated positively with yarn single strand strength and the fibre yellowness (+b) measurement. As the light metal contents were increased, yarn single strand strengths and fibre yellowness increased [3].

Table-6: Analysis of Variance for Potassium.

S.O.V.	D.F.	S.S.	M.S.	F. Value.	Prob.
L	3	49080000	16360000	262.18	0.0000**
V	3	35210000	11730000	187.21	0.0000**
M	3	42010000	14030000	224.85	0.0000**
LxV	9	568848	63205.3	1.01	N.S
LxM	9	561508	62389.8	1.00	N.S
VxM	9	557329	61925.4	0.99	N.S
LxVxM	27	1768884	65514.2	1.05	N.S
Error	192	11979744	62394.5		
Total	255	142000000			

**=Highly significant NS=Non significant CV=2.03%

Table-6a: Comparison of individual means for Potassium.

Location (L)	Variety (V)	Micronaire value (M)
L_1=5258.6b	V_1=4890.6b	M_1=5412.6a
L_2=6084.3a	V_2=4562.8c	M_2=4168.9d
L_3=3862.4d	V_3=3985.5d	M_3=4875.0b
L_4=4216.2c	V_4=5253.5a	M_4=4564.9c

Mean values having different letters, differ significantly at 0.05% level of probability

Duncan's multiple range test and the comparison of individual treatment means for different varieties showed that the mean values of potassium for V_1, V_2, V_3 and V_4 were, 4890.6, 4562.8, 3985.5 and 5253.5 ppm, respectively. The results show that potassium values for different Varieties are significantly different from each other, further indicated that the maximum value for potassium were recorded for V_4 followed by V_1, V_2 and V_3.

Calcium

The analysis of variance of the data regarding calcium is given in Table-7, which show that the effect of the Location (L) and Mic value (M) was highly significant while the effect of Variety (V) and all possible interactions on calcium were non significant. Comparison of individual treatment means for different locations presented in Table-7(a) showed that the mean value of calcium for L_1, L_2, L_3 and L_4 were 1488, 525, 655 and 913 ppm respectively. The results show that calcium values for different locations are significantly different from each other. The result indicated that the maximum value for calcium was recorded for L_1 followed by L_4, L_3 and L_2 respectively. Comparison of individual treatment means for different varieties presented in table 7(a) showed that the mean value of calcium for V_1, V_2, V_3 and V_4 were, 893, 893, 902 and 893 ppm respectively. The results showed that calcium values for different varieties are not significantly different from each other. The results indicated that the maximum value for calcium was recorded for V_3 followed by V_1, V_2 and V_4 respectively.

Table-7: Analysis of Variance for Calcium.

S.O.V.	D.F.	S.S.	M.S.	F. Value.	Prob.
L	3	8735604	2911868	1181.41	0.0000**
V	3	893	298	0.12	N.S
M	3	37166	12389	5.03	0.0000**
LxV	9	23583	2620	1.06	N.S
LxM	9	29727	3303	1.34	N.S
VxM	9	24797	2755	1.12	N.S
LxVxM	27	81197	3007	1.22	
Error	192	473280	2465		
Total	255	9406247			

**=Highly significant NS=Non significant CV=5.55%

Table7a: Comparison of individual means for Calcium.

Location(L)	Variety(V)	Micronaire Value(M)
L1=1488a	V1=893a	M1=873b
L2=525d	V2=893a	M2=921a
L3=655c	V3=902a	M3=826c
L4=913b	V4=893a	M4=780d

Mean values having different letters, differ significantly at 0.05% level of probability

Sodium

The analysis of variance of the data regarding sodium is given in Table-8. Which show that the Effect of the Location (L), Variety (V) and Mic value (M) was highly significant while the effect of all interactions was non significant . Duncan's multiple range tests and other Comparison of individual treatment means for different Locations presented in Table-8(a) shows that the sodium values for different Locations were significantly different from each other. The mean value of sodium for L_1, L_2, L_3 and L_4 were 186, 141, 106 and 100 ppm respectively. It was noted that fibre total light metal contents seen to be correlated positively with tensile properties of the yarn, specially with single end strength and fibre yellowness (+b) measurements .As the light metal contents were increased positive correlation was also observed on yarn properties .

Table-8: Analysis of Variance for Sodium.

S.O.V.	D.F.	S.S.	M.S.	F. Value.	Prob.
L	3	71405	23801.6	276.17	0.0000**
V	3	3964	1321.3	15.33	0.0000**
M	3	20833	6944.4	80.58	0.0000**
LxV	9	1067	118.5	1.38	N.S
LxM	9	2185	242.8	2.82	N.S
VxM	9	558	62.1	0.72	N.S
LxVxM	27	4376	162.1	1.88	N.S
Error	192	16550	86.2		
Total	255	120938			

**=Highly significant NS=Non significant CV=6.93%

Table8a: Comparison of individual means for Sodium.

Location(L)	Variety(V)	Micronaire Value(V)
L1=186a	V1=139a	M1=161a
L2=141b	V2=131b	M2=138b
L3=106c	V3=119d	M3=125c
L4=100d	V4=125c	M4=112d

Mean values having different letters, differ significantly at 0.05% level of probability

Experimental

Material and Methodology

The present research study was initiated in the Department of Fibre and Textile Technology, University of Agriculture, Faisalabad. The chemical tests were carried out in the Nuclear Institute for Agriculture and Biology (NIAB) Faisalabad. In this concern four different growing areas (Multan, Bahawalpur, Rahim Yar Khan and Faisalabad), with four cotton varieties CIM-473, CIM496, NIAB-111 and NIAB-999 and four micronaire values (4.4, 4.6, 4.8 and 5.0) were analsized for wax, alcohol extractable, residual sugar, fibre ash contents and light metal content. These samples were collected from different research stations of Pakistan.

Non-Cellulosic Constituents

Wax Contents

The wax contents were estimated by the method as prescribed by AOAC [13].The amount of wax was represented on the basis of original cotton weight.

Alcohol Extractable

The alcohols extractable were estimated by the method as prescribed by AOAC [13].The amount of alcohol extractable were represented on the basis of original cotton weight.

Residual Sugars

The residual sugars were estimated by the method as prescribed by Riazi [14].

Ash Content

Ash content was determined by the method as adopted and recommended by AOAC [13]. The Amount of ash was calculated on the basis of original cotton weight.

Metal Contents

Determination of Potassium and Sodium by Flame Photometer

Chemical analysis of fibrous materials was done at physiological maturity of the fibrous material. The fibrous raw material was dried at 70C^o for 24 hours. The dried material (0.5g) was digested with sulphuric acid and hydrogen peroxide according to the method as mentioned by Wolf [15]. For Potassium extraction, one ml extract was diluted to make it up to 100 ml. and was analyzed on flame photometer model (Jenway PFP 7). The values of

potassium were compared with standard curve separately and total quantities were calculated. Sodium (Na) was also analyzed on flame photometer as per recommendations of Jenway PFP 7.

Determination of Calcium and Magnesium by Titration with EDTA (versenate)

Determination of Calcium (Ca) and Magnesium (Mg) was carried out according to the method as proposed by United States salinity staff [16].

Atmospheric Conditions

The testing work was carried out under the standard laboratory conditions, which were maintained at (65±2) % relative humidity and (20±2) $^{\circ}$C temperature.

Analysis of Data

The data thus obtained was statistically analyzed as suggested by Montgomery [17] using SPSS (Statistical Package for the Social Sciences) micro-computer statistical program

Conclusions

The study showed that effects of different locations, varieties and micronaire values were significant for non cellulosic constitutes like wax content, alcohol extractable, residual sugar, ash and metal contents. The wax, alcohol extractible, fibre ash content and light metal contents for all four cottons from four different locations decreased, and residual sugars increased, with increase in micronaire value. This is because; the non-cellulosic constituents depend upon the secondary cell wall thickness of the cotton fibre. Decreasing levels of the metal contents, correlated with the decreasing yarn lea strength, CLSP, single end strength, evenness, breaking length, thin places and neps. Hence it is concluded that cotton varieties of different locations and micronaire values significantly affect the non cellulosic constituents and metal contents and that is directly correlated with yarn quality [18. 19].

References

1. D. E. Brushwood, *Textile Research Journal*, **75**, 1 (2005).
2. Anonymous. Cotton Wikipedia [online]: Available http://en.wikipedia.org/wiki/ cotton (verified 12 December 2009)
3. D. E. Brushwood, *American Society of Agricultural Engineers*, **20**, 407 (2004).
4. G. R. Gamble, *Journal of Cotton Science*, **10**, 61 (2006).
5. I. Rezic and I. Steffan, *Microchemical Journal*, **85**, 46 (2006).
6. X. L Cui, J. B. Price, T. A. Calamari JR, J. M. Hemstreet and W. Meredith, *Textile Research Journal*, **72**, 399 (2002).
7. B. Anwar, Physico-chemical studies of naturally colored cottons and their spinning potential. *M.Sc. Thesis*, *Dept. of Fib. Tech. Uni. of Agri.*, *Faisalabad*. **40-45** (2001).
8. R. S. Dhindsa, C. A. Beasley and I. P. Ting, *Plant Physiology*, **56**, 394 (1975).
9. G. R. Gamble, *Journal of Cotton Science*, **8**, 198 (2004).
10. M. M. H. Lawson and Y. L. Hsieh, *Textile Research Journal*, **70**, 810 (2000)
11. I. A. Naeem, Pyhsico-chemical studies on MNH-93 and other cotton varieties with special reference to spinning performance. *M.Sc. Thesis*, *Dept. of Fib. Tech. Univ.*, *of Agri.*, *Faisalabad*: **29-60**. (1982)
12. D. E. Brushwood and H. H. Perkins Jr., *Analytical Techniques*, **26**, 32 (1994).
13. AOAC, Official methods of analysis of the association of official analytical chemists*. 2200 Wilson Boulevard Arlington*, *Virginia 22201: USA*, **15** Edition (1990)
14. A. Riazi, K. Matsuda and A. Arslan, *Journal of Experimental Botany*, **36**, 1716 (1985).
15. B. A. Wolf, *Communication in soil and Plant Analysis*, **13**, 1035 (1982)
16. U.S. Salinity Lab. Staff. Diagnosis and improvement of saline and alkali soils. USDA Hand b.60. 198-204. (2003)
17. D. C. Montgomery, Design and analysis of experiments. *Arizona state university*. ISBN: **978-0-470-12866-4.** (2009).