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GENOTYPE-BY-SOWING DATE INTERACTION EFFECTS ON COTTON YIELD AND QUALITY IN IRRIGATED CONDITION OF DERA ISMAIL KHAN, PAKISTAN

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Abstract

Cotton is a major export commodity of Pakistan. It is affected by variable environmental conditions throughout the country which limits its production. A 2-year field study was conducted in 2012 and 2013 at Cotton Research Station, Dera Ismail Khan, Pakistan to evaluate the effects of six sowing dates on yield and quality attributes of four cotton genotypes. The experiments were laid out in split-plot within a randomized complete block design with three replications. Main plots treatments were six sowing dates, namely March 20, April 4, April 19, May 4, May 19, and June 3 while subplots treatments were four approved transgenic varieties of cotton (CIM-598, CIM-599, CIM-602, and Ali Akber-703). Results revealed that earlier planting produced more vegetative growth rather than lint yield while late planting induced flowering and boll formation when temperature was much cold that adversely affected cotton yield and quality. The results further indicate that the genotype CIM-599 scored first rank in number of bolls plant^{-1}, boll weight, seed cotton yield, ginning out turn, fiber length, fiber strength, fiber fineness, and fiber uniformity when sown on April 19. CIM-598 was the next suitable genotype after CIM-599 which produced higher yield and quality traits in April 19 sowing. Earlier and later sowing than April 19 resulted in lower cotton yield and quality characters due to unfavorable environmental conditions and shorter growth period, respectively. Thus it is concluded that the genotype, CIM-599 sown on April 19 suits well to the study area and had the potential to optimize cotton yield and quality in irrigated condition of Dera Ismail Khan, Pakistan.

Key words: Cotton, Genotype, Sowing date, Yield and quality.

Introduction

Interaction of genotype by sowing date (G × S) is an important strategy to analyze crop yield and quality in an environment (Campbell & Jones, 2005). High cotton yield could not be obtained previously due to many biotic and abiotic stresses such as weeds infestation, insect pests and diseases, sowing too early or too late, nutrients stress and improper use of genotypes at different agro-ecological zones (Arshad *et al*., 2007; Zia-ul-Hassan *et al*., 2014). Optimum sowing date plays key role in yield potential; similarly, suitable genotype for a region is essential for optimum growth and development. Genotype selection and sowing date management are important factors that can have a large impact on yield and quality attributes of a cotton crop (Deho *et al*., 2012). These two factors mostly limit cotton growth, yield and quality as growth is a function of the product of genotype and environment (Sarwar *et al*., 2012; Zeng *et al*., 2014). Optimum sowing time for different genotypes varies with regions depending on environmental conditions of the area. Cotton genotype is mainly selected for higher yield plus fiber quality, greater tolerance to adverse conditions and earlier maturity.

Potential genotypes for higher yield and quality traits could be assessed by sowing them at different times i.e. early, late, and normal time. Both late and early sowing adversely affect cotton yield and quality. Research results revealed that early sown cotton contributes more towards vegetative growth rather than to yield (Iqbal *et al*., 2012). Moreover, early sown cotton reaches reproductive phase in the hottest month of the year that causes serious yield loss (Rahman *et al*., 2007). Contrary to this, late planting causes flowering and maturity when temperature is much cold. Consequently, cotton yield and quality is affected due to unfavorable environmental conditions and shorter growth period (Elayan *et al*., 2015). Karavina *et al*. (2012) reported that change in sowing date not only affects cotton yield and quality but it also affects insect pest management. Therefore, sowing date management has become more important in recent farming. Optimum sowing date provides sufficient time to crop to complete its vegetative and reproductive cycles in a timely and efficient way. This also allows the grower to harvest crop in time and save from risk of late season insect pest attack particularly from those insects which attack on reproductive structures causing about 80% damage to cotton (Pedigo, 2004). The strategy of planting a crop at suitable time thwarts danger of early and late planting either due to adverse weather conditions or insect pests attack; both may result in increasing rates of fruit loss and abortion (Bange *et al*., 2008). Tibugari *et al*. (2012) & Jowah (1994) reported that there is much use of pesticides to control cotton pests such as Jassids (*Empoasca fabae*), Heliothis (*Helicoverpa armigera*), bollworms (*Diparopsis castanea*), *Tetranychus* spp, *Dysdercus* spp., whitefly (*Bemisia tabaci*) and aphids (*Aphis gossypii*) which cause significant yield losses. Although cotton pests can be effectively controlled with pesticides, however, over use of pesticides is not eco-friendly and leads to killing of beneficial insects and develops resistance in the harmful insects (Karavina *et al*., 2012). There are several other practices which can lessen dependency on synthetic chemicals such as crop rotation, resistant cotton cultivars, and appropriate sowing time. Insect pest can also be managed with late planting but this approach has lost its vitality due to the increasing use of transgenic cotton varieties which are resistant to pink bollworms. Some genotypes have the potential to resist insect pest and perform better in a specific environmental conditions such as temperature, rainfall, humidity, and day length. Therefore, it needs constant efforts to match genotype with suitable time of sowing in an environment in which all the components of climate are in the best favor of crop growth and development. Moreover, cotton genotypes are highly responsive to their surrounding environments and differ in their yield potential and many fiber properties. Thus it is important to study interaction of sowing date and genotype to determine optimum sowing date for enhancing cotton yield and quality in irrigated condition of D.I. Khan, Pakistan.

Materials and Methods

Study site: In 2012 and 2013, a field study was conducted at Cotton Research Station, Dera Ismail Khan (31º49´N, 70°55´E, 166 m a.s.l.), Pakistan, in clay loam soil. The site is fairly flat with dominant clay characteristics. It is an arid to semi arid region having limited rain fall (about 200 mm mean annual rainfall) which is not enough for growing crops. The soil of the experimental field is Hyperthermic, and Typic Torrifluvents (Anon., 2009). It is a bit saline in nature, less fertile and irrigated from the adjacent canal water. The water samples were taken from the canal water and analyzed according to procedure described by Richards (1954). Electrical conductivity was measured with the help of conductivity meter. Water pH was measured with pH meter model Jenway 3310 using combination electrode. Calcium and Magnesium were determined by titration with EDTA using NH_4Cl+NH_4OH buffer and Eriochrome Black-T indicator. Sodium was measured by flame photometer. Carbonates and bicarbonates were measured by titration with standard H_2SO_4 using phenolphthalein and methyl orange indicators, respectively. Chloride was determined by titration with $AgNO_3$ using K_2CrO_4 indicator. Sulphate was determined by difference: [TSS in meq L^{-1} – (CO_3^{2-} + HCO_3^-+Cl^-]. Sodium Adsorption Ratio (SAR) was determined by formula: SAR=Na+ [Ca^{+2} + Mg^{+2})\2]1\2. Residual Sodium Carbonate (RSC) was determined by formula: RSC = [(CO_3^{-2} + HCO_3^-) - (Ca^{+2}+Mg^{+2})] (all concentrations expressed in meq L^{-1}). Chemical analysis of canal water is given in Table 1. For soil analysis, composite soil sample was taken from 0–30 cm depth from the experimental field. Dried soil sample was ground to <2 mm size and preserved in polythene bag for chemical analysis. Soil organic matter was determined through wet oxidation based upon Walkley and Black method (Nelson & Sommers, 1982) while total soil N was determined through Kjeldhal method (Bremner & Mulvaney, 1982). Phosphorus (P) and potassium (K) were determined through spectrophotometer and flame photometer, respectively. The detail physico-chemical properties are given in Table 2. Weather data was monitored on Meteorological Station located near the study site. Detail about seasonal temperature, rainfall, and pan evaporation is presented in Figs. 1 & 2, respectively.

Table 1. Chemical analysis of canal water used for irrigation.

Characteristics	Values
Electrical conductivity (µS cm^{-1})	557
pH	7.60
Ca^{2+}+ Mg^{2+} (meq L^{-1})	3.66
Na+ (meq L^{-1})	1.90
CO_3^{2-} (meq L^{-1})	NIL
HCO_3^- (meq L^{-1})	2.59
Cl^- (meq L^{-1})	0.89
SO_4^{2-} (meq L^{-1})	1.99
Sodium adsorption ratio (mmol $L^{-1})^{0.05}$	1.40
Residual sodium carbonate (meq L^{-1})	0.09

Table 2. Physico-chemical properties of the experimental soil.

Characteristics	Values
Electrical conductivity (EC)	2.66 dSm^{-1}
Soil pH (1:1)	7.90
Organic Matter	0.87 %
NO_3-N	5.51 mg kg^{-1}
Available K (mg kg^{-1})	190 mg kg^{-1} soil
AB-DTPA extractable P	7.8 mg kg^{-1} soil
Total N	0.99 g kg^{-1} soil
Sand	151 g kg^{-1}
Silt	450 g kg^{-1}
Clay	400 g kg^{-1}

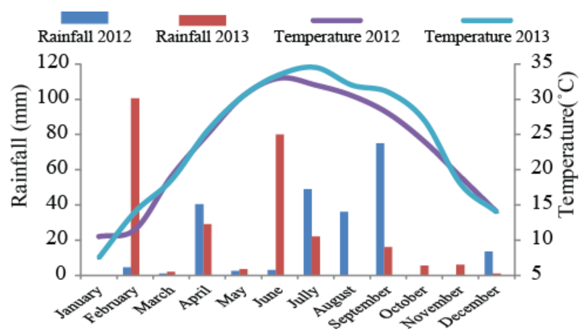

Fig. 1. Mean monthly rainfall and temperature during 2012 and 2013 at experimental site, Cotton Research Station, D. I. Khan, Pakistan (Source: Arid Zone Research Institute (PARC), Ratta Kulachi, D.I. Khan, Pakistan).

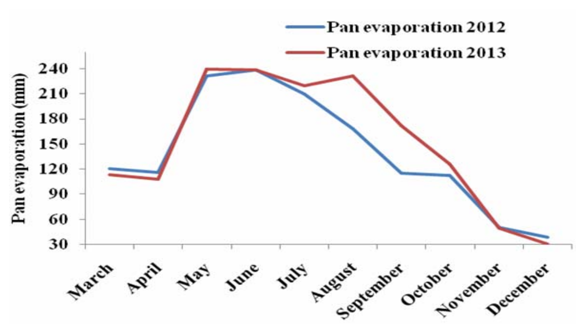

Fig. 2. Mean monthly pan evaporation (mm) during 2012 and 2013 cotton growing periods at experimental site, Cotton Research Station, D. I. Khan, Pakistan (Source: Arid Zone Research Institute (PARC), Ratta Kulachi, D.I. Khan, Pakistan).

Experimental treatments and design: The experiment was designed with split-plot arrangement in a randomized complete block with three replications. The main plots treatments comprised of six sowing dates namely March 20, April 4, April 19, May 4, May 19, and June 3 while subplots included four genotypes namely, CIM-598, CIM-599, CIM-602, and Ali Akber-703. Each subplot consisted of four rows of 10 m length and 0.75 m intra row width. Genotypes selected for this study were all transgenic improved cotton genotypes. All plots were managed uniformly regarding land preparation, sowing method, irrigation, pest control and fertilization. The land was prepared with disk plough (once) followed by tiller (twice) and rotavator (once) to break the clods and uprooting/destroying the roots and crop leftovers. The field was then leveled and divided into 24 sub plots. Cotton seeds were treated with sulfuric acid (1kg H_2SO_4/10 kg cotton seed). Delinted cotton seeds were dibbled manually in rows as per scheduled sowing dates. Cotton seeds were sown in well prepared dry field followed by irrigation. The experimental plots were irrigated at 15 days interval till the crop maturity. Since there was sufficient rain in September 2012 and June 2013, scheduled irrigations were not given in the respective months. In this way experimental plots sown on March 20, April 4, April 19, May 4, May 19, and June 3 received total of 14, 13,12, 11, 10, and 9 irrigations, respectively. Water was given at a depth of 10 cm during each irrigation. Moreover, last irrigation was given in the month of November. Pre-sowing herbicide, Pendimethaline [N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine], was sprayed at the rate of 1.2 kg ha^{-1} to control weeds. Post emergence herbicide, Haloxyfop-p-ethyl (Percept 10.8% EC @ 350 ml/acre) was also sprayed to control grassy weeds in their early growth stages. The insecticide, Novastar 56 EC (bifenthrin+abamectin) was sprayed at the rate of 500 ml per acre two times on cotton crop with the help of a knapsack hand - sprayer at 15 days intervals starting from the time when the population of sucking insects such as whitefly, jassid and thrips, and mites reached the economic threshold level. Thinning was done within 25 days after sowing in the respective plots. The fertilizers phosphorus and nitrogen were applied in the form of triple super phosphate and urea at the rate of 90 and 150 kg ha^{-1}, respectively. Phosphorus was applied all at sowing while nitrogen was applied half at sowing and half in two equal splits with subsequent irrigations.

Procedure for data recording: Data were recorded on plant height (cm), sympodial branches $plant^{-1}$, bolls $plant^{-1}$, boll weight (g), seed cotton yield (kg ha^{-1}), ginning out turn (GOT, %), fiber length (mm), fiber strength (g tex^{-1}), micronaire and uniformity ratio (%). Five representative plants were tagged in each treatment for the purpose of recording data. Plant height was recorded by measuring height of five representative plants in cm from the base of the stem to the terminal bud at maturity and results were presented on the basis of average plant height. Similarly data on bolls $plant^{-1}$ were recorded by counting bolls from randomly selected five plants in each treatment at maturity and converted to average number of bolls $plant^{-1}$.

For recording boll weight, 50 bolls were randomly selected from already tagged plants in each plot. Total bolls weight was divided by 50 and mean boll weight was recorded in gram. Seed cotton yield was recorded by harvesting central 2 rows of each plot manually. Seed cotton samples were sundried and cleaned by removing inert matter from the samples. After drying and cleaning they were weighed and ginned separately by using electric ginning machine. GOT is the ratio of the lint weight to the total seed cotton weight. The lint of each sample was weighed and ginning out turn (GOT) was calculated by applying formula, GOT (%) = (lint yield/ seed cotton yield)*100 (XIAN *et al*., 2014). For fiber length, representative samples of cotton lint were taken from each plot and mean length was obtained by using high volume instrument (HVI) system in laboratory. Similarly, micronaire (which indicates fiber fineness), fiber strength, and fiber uniformity all were determined in laboratory through HVI system in Central Cotton Research Institute, Multan, Pakistan.

Statistical analysis: Data were subjected to analysis of variance (ANOVA) using a split-plot within a randomized complete block design accordance to procedures outlined by Steel & Torrie (1980). Least significant difference tests were applied where data were found statistically significant according to MSTATC software.

Results and Discussion

Plant height (cm): Analysis of variance indicated that sowing dates significantly affected plant height in 2012, 2013 and mean over years while genotypes effects were significant only in 2013 (Table 3). Generally, plant heights were significantly greater for the third and fourth sowing date i.e., April 19 and May 4 during the study years (Table 4). Among genotypes, Ali Akbar-703 had lower plant height compared to CIM-598, CIM-599 and CIM-602. It is also evident from the results that late sown genotypes had lower plant heights probably due to shorter growth period.

However, interaction effects of sowing date and genotypes were not significant. The differences in plant heights were perhaps due to the differences in genetic makeup of different genotypes, soil characteristics, and environmental factors as communicated by Hussain *et al*. (2007) who reported that plant height differed significantly due to genotypes and environmental factors. Batool *et al*. (2010) also reported genetic variability for plant height among different cotton cultivars.

Sympodial branches $plant^{-1}$: The analysis of variance for sympodial branches was significantly different for sowing dates and genotypes; however, sowing date × genotype interaction was not significant (Table 3). Sympodial branches were significantly higher in April 19 sowing compared to all other sowing dates (Table 4). Generally, too early or too late sowing resulted in lower sympodial branches. Among genotypes, CIM-599 produced more sympodial branches than all other genotypes. Sympodial branch is a boll bearing branch which is an important quantitative character that contributes directly to seed cotton yield. Khan *et al*. (2015) reported highly positive and significant relationship between sympodial branch and plant yield. The differences in number of sympodial branches may be attributed to differences in genetic materials of the genotypes used in this study as well as environmental factors. Bolonhezi ***et al.*** (2000) reported analogous results who reported that different cultivars were different in number of sympodial branches due to differences in their genetic makeup.

Table 3. Analysis of variance (mean squares) of bolls per plant, boll weight (g), seed cotton yield (kg ha^{-1}), ginning out turn (GOT, %) fiber length (mm), fiber strength (g tex^{-1}), micronaire, and uniformity ratio (%) as affected by sowing date and genotypes during 2012 and 2013 growing seasons.

Source	D.F	*Ph.	*Sym. P^{-1}	BP^{-1}	BW	SCY	GOT	FL	FS	Mic	Unif
						2012					
Replication	2	181	7	24	0.1	776258	9	2	5	0.1	53
Sowing dates	5	594**	82**	217**	1.8**	1675517**	22**	8**	11**	0.4**	45**
Error a	10	77	3	0	0.0	1180	0	0	0	0.0	0
Varieties	3	59ns	77**	164**	0.1**	1412966**	35**	12**	3**	0.3**	25**
*D × V	15	48ns	1ns	6**	0.0**	84493**	1**	0ns	1**	0.0ns	0ns
Error b	36	48	1	0	0.0	1096	0	0	0	0.0	1
						2013					
Replication	2	102	11	19	0.0	770761	4	2	1	0.0	63
Sowing dates	5	730**	51**	214**	1.8**	1639738**	23**	7**	13**	0.3**	45**
Error a	10	45	3	0	0.0	963	0	0	0	0.0	1
Varieties	3	198**	54**	179**	0.1**	1382829**	32**	10**	4**	0.3**	35**
D × V	15	26ns	1ns	6**	0.0**	85776**	1ns	0*	1**	0.0ns	1*
Error b	36	42	2	0	0.0	1207	0	0	0	0.0	0
						2012-2013					
Replication	2	120	10	22	0.1	773172	6	2	2	0.0	57
Sowing dates	5	613**	60**	216**	1.8**	1657121**	23**	7**	12**	0.3**	44**
Error a	10	67	3	0	0.0	991	0	0	0	0.0	0
Varieties	3	82ns	61**	171**	0.1**	1397394**	33**	11**	3**	0.3**	29**
D × V	15	26ns	1ns	6**	0.0**	84664**	1ns	0*	1**	0.0**	0ns
Error b	36	47	1	0	0.0	920	0	0	0	0.0	0

*Sympodial branches plant^{-1}, Ph-Plant height, BP^{-1}-Bolls plant^{-1}, BW-Boll weight, SCY-Seed cotton yield, FL-fiber length, FS-Fiber strength, Mic-Micronaire, Unif-Uniformity

*, **, Significant at 5% and 1% level of probability, respectively. ns, No-significant difference at 5%. *D = Sowing dates, V = Varieties

Bolls plant^{-1}: Bolls plant^{-1} results were significant for sowing dates, genotypes and their interactions (Table 3). Mean values for sowing dates revealed that April 19 sowing produced maximum bolls while June 3 sowing produced minimum bolls during 2012 and 2013 growing seasons (Table 4). The results further revealed that the response of genotypes was modified by sowing dates during both the growing seasons. The results indicate that CIM-599 sown on April 19 produced 25 % more bolls than CIM-602 (Fig. 3a, b & c). In contrast to this too early (March 20) or too late sowing (June 3) resulted in lower number of bolls for all genotypes. In early sowing, flowering coincided with high temperature stress (June to early August) that probably resulted in abortion of flowers and young bolls and thus there were lower boll retention per plant as reported by some researchers (Reddy, 1992; Hodges *et al*., 1993). They examined temperature effects on cotton reproductive development by growing cotton under natural sunlight condition in temperature regulated growth chambers. Their work revealed that fruit retention declined quickly when the mean temperature in the chamber climbed above 28°C and fruit retention was almost zero when temperature exceeded 33°C. In our study, growth conditions including temperature in April 19 sowing were much better than all other sowing dates that probably provided more favorable environment for translocation and mobilization of photosynthates which resulted in production of large number of bolls (Ali *et al*., 2009).

Boll weight (g): Boll weight was significantly affected by sowing dates, genotypes and their interactions (Table 3). Sowing on April 19 was optimum among all other sowing dates by producing highest boll weight (Table 4). May 4 was the next suitable sowing date after April 19 which produced higher boll weight than the rest of the sowing dates. Contrary to this earlier sown cotton had lower boll weight probably due to more attacks of insect pests. Generally if a variety is sown before optimum time, its germination and growth both can be affected adversely. Moreover, earlier sown crop is more prone to insect pests and diseases attack. Among genotypes, CIM-599 produced highest boll weight. Interaction effects revealed that April 19 sowing produced heavier bolls compared to all other sowing dates irrespective of the genotypes (Fig. 4a, b & c). Our results revealed that boll weight declined when sowing was delayed beyond April 19. The lowest boll weight was thus obtained from June 3 sowing date. Cold night temperature may be the probable reason for poorly developed boll from late sowing date. Boll development in May to June sowing was coincided with cold night temperature that might have adversely affected boll growth and development. Yeates *et al*. (2013) reported that night temperature colder than 12^{o}C might be detrimental for boll retention and growth. On the other hand, flowerings in too early sowing coincided with high temperature that also adversely affected boll growth and development (Yeates *et al*., 2010a). High summer temperature is a typical characteristic of the study area. That is why sterility and boll retention are common problems in cotton. Reddy *et al*. (1990) reported that three weeks exposure of cotton plants to 40°C for 2 or 12 hour per day resulted in 0% bolls.

Table 4. Effect of sowing dates and genotypes on physiological traits and yield of cotton during 2012 and 2013

Year	Sowing dates	Plant height (cm)	Sympodial branches plant^{-1}	Bolls plant^{-1}	Boll weight (g)	Seed cotton yield (kg ha^{-1})
2012	March 20	95cd	18.3b	23.8 d	2.56 d	2310 d
	April 4	99bc	18.7b	25.5 c	2.72 c	2389 c
	April 19	109a	22.3a	30.5 a	3.32 a	2688 a
	May 4	105ab	18.3b	28.0 b	3.08 b	2430 b
	May 19	99bc	16.3c	22.3 e	2.52 d	1945 e
	June 3	89d	14.5d	18.5 f	2.28 e	1650 f
	$LSD_{0.05}$	7.976	1.490	0.009	0.05753	31.24
2013	March 20	94bc	17.0b	24.9 d	2.61 d	2409 d
	April 4	99b	17.8b	26.6 c	2.76 c	2478 c
	April 19	110a	20.9a	31.6 a	3.35 a	2790 a
	May 4	106a	17.4b	29.1 b	3.12 b	2544 b
	May 19	98b	16.5b	23.3 e	2.52 e	2031 e
	June 3	89c	14.6c	19.7 f	2.34 f	1774 f
	$LSD_{0.05}$	6.129	1.668	0.283	0.07046	28.23
2012-2013	March 20	95cd	17.7bc	24.3 d	2.59 d	2360 d
	April 4	99bc	18.2b	26.0 c	2.74 c	2434 c
	April 19	109a	21.3a	31.0 a	3.34 a	2739 a
	May 4	105ab	17.8bc	28.5 b	3.10 b	2487 b
	May 19	98bc	16.3c	22.8 e	2.52 e	1988 e
	June 3	89d	14.6d	19.1 f	2.32 f	1712 f
	$LSD_{0.05}$	7.451	1.685	0.141	0.05753	28.63
	Genotype					
2012	CIM-598	99	18.2b	26.0 b	2.76 ab	2378 b
	CIM-599	102	20.9a	27.5 a	2.85 a	2487 a
	CIM-602	98	16.7c	20.5 d	2.67 b	1846 d
	Ali Akber-703	98	16.3c	25.0 c	2.71 b	2230 c
	$LSD_{0.05}$	NS	0.8191	0.003	0.1190	22.38
2013	CIM-598	100a	17.1b	27.0 b	2.81 b	2478 b
	CIM-599	103a	19.9a	28.9 a	2.88 a	2578 a
	CIM-602	99a	16.3b	21.5 d	2.68 d	1947 d
	Ali Akber-703	95b	16.2b	26.0 c	2.75 c	2348 c
	$LSD_{0.05}$	4.380	0.9257	0.239	0.06047	23.49
2012-2013	CIM-598	100	17.6b	26.5 b	2.79 b	2429 b
	CIM-599	102	20.3a	28.2 a	2.87 a	2533 a
	CIM-602	98	16.4c	21.0 d	2.68 d	1897 d
	Ali Akber-703	97	16.3c	25.5 c	2.73 c	2289 c
	$LSD_{0.05}$	NS	0.8191	0.119	0.047	20.50

Note: Means followed by similar letters do not differ significantly at 5% level of probability. NS = Non-significant

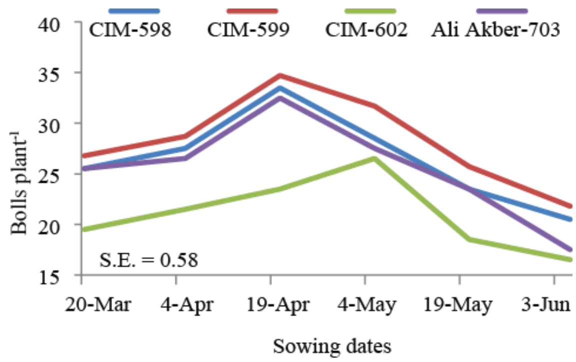

Fig. 3a. Interactive effects of sowing dates and genotypes on bolls plant^{-1} during 2012.

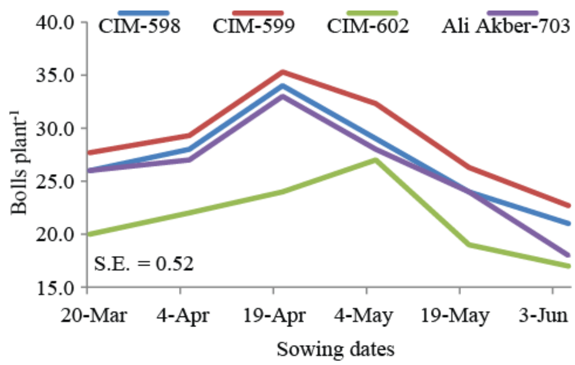

Fig. 3b. Interactive effects of sowing dates and genotypes on bolls plant^{-1} during 2013.

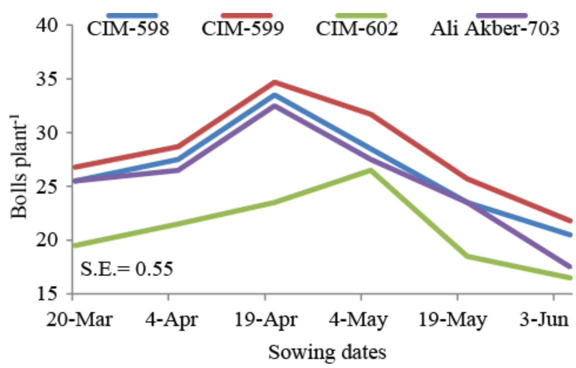

Fig. 3c. Interactive effects of sowing dates and genotypes on bolls plant^{-1} during 2012-2013.

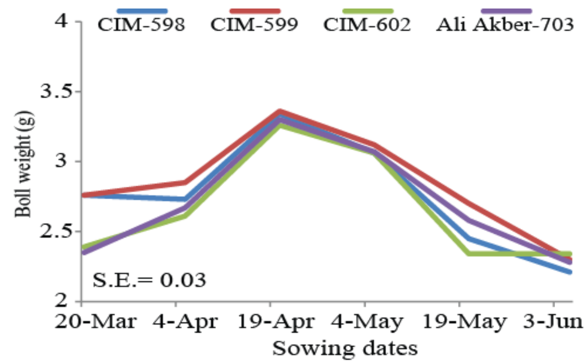

Fig. 4a. Interactive effects of sowing dates and genotypes on boll weight (g) during 2012.

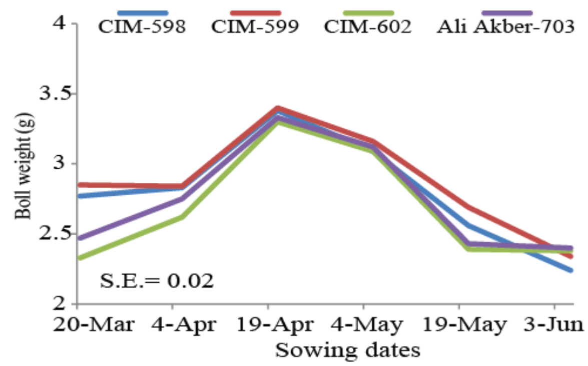

Fig. 4b. Interactive effects of sowing dates and genotypes on boll weight (g) during 2013.

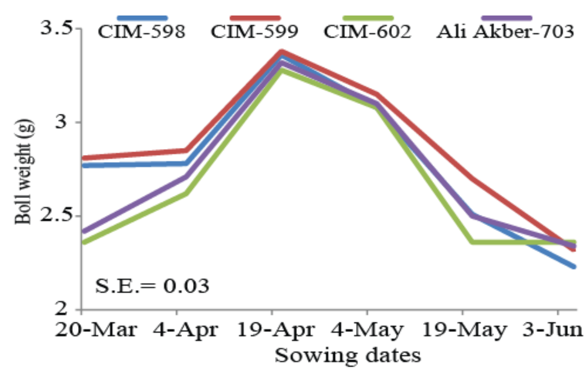

Fig. 4c. Interactive effects of sowing dates and genotypes on boll weight (g) during 2012-2013.

Seed cotton yield (kg ha^{-1}): Seed cotton yield had significant response to sowing dates, genotypes, and sowing dates × genotypes interactions (Table 3). Highest seed cotton yield was obtained from April 19 sowing while late sowing (June 3) resulted in lowest seed cotton yield (Table 4). Means for genotypes revealed that CIM-599 produced highest seed cotton yield as against CIM-602 which produced lowest seed cotton yield. Interaction effects revealed that April 19 sowing optimized seed cotton yield (Fig. 5a, b & c). May 4 was the next suitable sowing date after April 19 which produced higher seed cotton yield. The results indicate that optimum sowing date fluctuates between April 19 and May 4. All other sowing dates either earlier or later produced lower seed cotton yield. The yield was low in early sown cotton, probably the reproductive stage of the crop came in the warmest month of the year that resulted in more vegetative growth and lower seed cotton yield (Sarwar *et al*., 2012). The results indicate that there were significant variations among cultivars for seed cotton yield as also reported by Baloch (1997) & Ehsan *et al*. (2008). Regarding sowing dates, El-Akkad (1980) reported that April sowing produced more flowers more quickly than earlier and later sowing dates. The more flowers thus resulted in higher seed cotton yield. Khan *et al*. (1980)

& Khan *et al*. (1981) reported that April sowing gave higher seed cotton yield than sowing at later dates. Similarly, Arain *et al*. (2001) communicated analogous results who reported that planting on April 15 to May 1st produced maximum seed cotton yield. One possible reason for exhibiting higher seed cotton yield in April 19 sowing may be more favorable environment for production of growth hormones than all other sowing dates as reported by Rauf & Sadaqat (2007). April 19 sowing had also more number of bolls plant^{-1} and heavier boll weight compared to other sowing dates that probably resulted in more seed cotton yield (Azhar *et al*., 1999; Rauf *et al*., 2004). Our results indicate that planting earlier or later than April 19 produced lower seed cotton yield. Late sowing caused late flowering in cotton thus boll development occurred at lower temperatures. Delayed flowering in cotton caused boll maturation, boll set, fiber length, and fiber strength to occur when average temperatures were lower and declining more rapidly than temperatures for present production strategies. That is why sowing too early or too late resulted in lower number of bolls and boll weight that finally contributed to lower seed cotton yield. Similar results were reported by Elayan *et al*. (2015) who reported that late sowing resulted in lower seed cotton yield due to lower number of open bolls plant^{-1} and boll weight.

Ginning out turn (GOT, %): Ginning out turn had significant response to sowing dates, genotypes, and their interactions, however, interaction effects were not significant in second growing season (Table 3). Mean values for sowing dates revealed that GOT was highest when crop was sown on April 19 (Table 5). All other sowing dates had lower values of GOT. CIM-599 gave highest GOT among the genotypes. CIM-599 out yielded all other genotypes at all sowing dates. Interaction effects showed that CIM-599 showed highest GOT when sown on April 19 (Fig. 6). The results suggest that April sowing was higher yielding than May or June sowing. Poonia *et al*. (2002) reported that every fortnight delay in sowing beyond 20 April resulted in a significant decrease in lint yield. Late sowing resulted in reduced lint yield probably due to a shortened fruiting period and delayed maturity compared to April sowing (Bange *et al*., 2004 & Bauer *et al*., 2000). In case of late sowing, flowering initiates late in the season when temperature is low that probably affected radiation use efficiency which might have limited crop growth. While in case of April sowing favorable temperatures and water supply, contributed towards boll growth and boll filling that probably resulted in higher lint yield as reported by Yeates *et al*. (2010a).

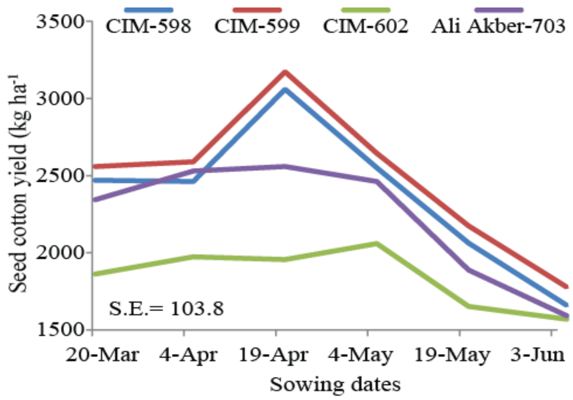

Fig. 5a. Interactive effects of sowing dates and genotypes on seed cotton yield (kg ha^{-1}) during 2012.

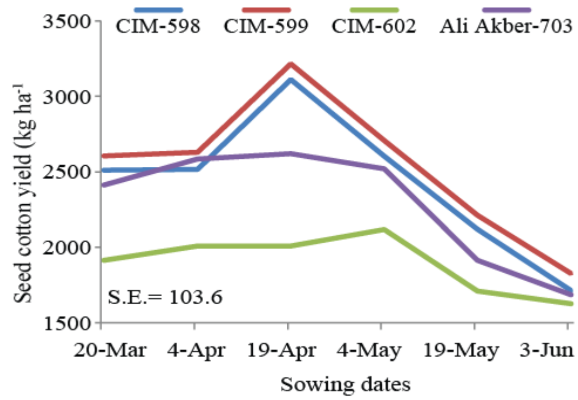

Fig. 5c. Interactive effects of sowing dates and genotypes on seed cotton yield (kg ha^{-1}) during 2012- 2013.

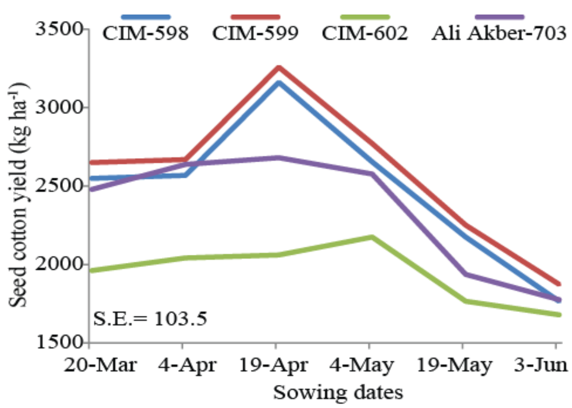

Fig. 5b. Interactive effects of sowing dates and genotypes on seed cotton yield (kg ha^{-1}) during 2013.

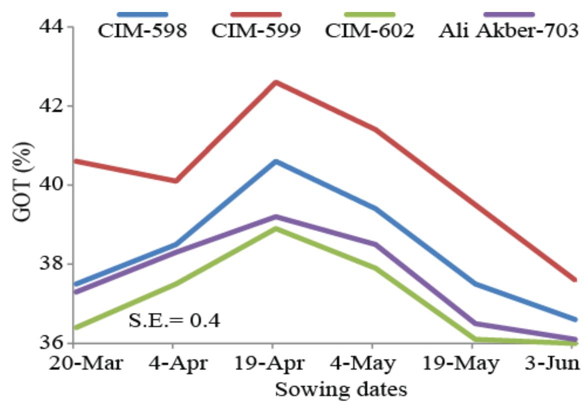

Fig. 6. Interactive effects of sowing dates and genotypes on GOT (%) during 2012

Table 5. Effect of sowing dates and genotypes on fiber quality of cotton during 2012 and 2013.

Year	Sowing dates	GOT (%)	Fiber length (mm)	Fiber strength (g tex^{-1})	Micronaire	Uniformity (%)
2012	March 20	37.9 d	27.9 d	28.4 c	4.4 bc	70.9 d
	April 4	38.6 c	28.3 c	29.2 b	4.4 bc	71.5 c
	April 19	40.3a	29.3 a	29.6 a	4.2 d	74.2 a
	May 4	39.3 b	28.6 b	29.1 b	4.3 c	72.5 b
	May 19	37.4 e	27.4 e	27.6 d	4.5 b	69.9 e
	June 3	36.6 f	27.1 f	27.2 e	4.6 a	68.7 f
	$LSD_{0.05}$	0.1864	0.2524	0.3071	0.1254	0.5615
2013	March 20	38.4 d	28.2 c	28.8 c	4.4 b	74.0 c
	April 4	39.2 c	28.5 b	29.6 b	4.4 b	74.8 b
	April 19	41.0 a	29.5 a	29.9 a	4.2 c	77.5 a
	May 4	39.9 b	28.7 b	29.5 b	4.4 b	75.3 b
	May 19	38.04 e	27.6 d	28.0 d	4.5 b	72.3 d
	June 3	37.1 f	27.3 e	27.3e	4.7 a	72.6 d
	$LSD_{0.05}$	0.2540	0.2524	0.2759	0.1318	0.6880
2012-2013	March 20	38.2 d	28.1 d	28.6 c	4.4 bc	72.5 d
	April 4	38.9 c	28.4 c	29.4 b	4.4 c	73.2 c
	April 19	40.7 a	29.4 a	29.8 a	4.2 d	75.9 a
	May 4	39.6 b	28.6 b	29.3 b	4.4 c	73.9 b
	May 19	37.7 e	27.6 e	27.8 d	4.5 b	71.1 e
	June 3	36.9 f	27.2 f	27.3 e	4.7 a	70.66 f
	$LSD_{0.05}$	0.1438	0.2458	0.2172	0.1037	0.3870
	Genotype					
2012	CIM-598	38.4 b	28.1 b	28.6 b	4.5 ab	71.3 b
	CIM-599	40.3 a	29.2 a	29.0 a	4.2c	73.0 a
	CIM-602	37.1 d	27.4 c	28.0 d	4.5 a	70.4 c
	AliAkber-703	37.6 c	27.6 c	28.4 c	4.4 b	70.5 c
	$LSD_{0.05}$	0.3270	0.2419	0.1069	0.07708	0.5843
2013	CIM-598	39.1 b	28.4 b	29.0 b	4.5 a	74.12 b
	CIM-599	40.8 a	29.3 a	29.3 a	4.3 b	76.46 a
	CIM-602	37.8 c	27.6 c	28.3 d	4.5 a	73.42 c
	AliAkber-703	38.2 c	27.8 c	28.8 c	4.5 a	73.69 c
	$LSD_{0.05}$	0.4134	0.2211	0.09561	0.07090	0.3142
2012-2013	CIM-598	38.7 b	28.3 b	28.8 b	4.5 ab	72.74 b
	CIM-599	40.6 a	29.2 a	29.2 a	4.3 c	74.69 a
	CIM-602	37.5 d	27.5 d	28.1 d	4.5 a	71.9 c
	AliAkber-703	37.9 c	27.7 c	28.6 c	4.5 b	72.1 c
	$LSD_{0.05}$	0.3596	0.07090	0.06413	0.04276	0.3812

Note: Means followed by similar letters do not differ significantly at 5% level of probability

Fiber length (mm): Fiber length showed significant response to sowing dates, genotypes and sowing dates × genotypes interactions (Table 3). CIM-599 had higher fiber length during both the growing seasons (Table 5). Sowing dates results revealed that April 19 sowing produced optimum fiber length compared to all other sowing dates. Fiber length response to genotypes was modified by sowing dates. Optimum fiber length could be achieved from CIM-599 sown on April 19 (Fig. 7a, b & c). All other combinations of sowing dates and genotypes had lower fiber length. El-Debaby *et al*. (1995) reported that April sowing produced highest fiber length. Ewida *et al*. (1985) & Yaseen (1986) also reported analogous results. The results suggest that early and late sowing both affect fiber length adversely. In case of early and late sowing, picking will commence early and late in the season, respectively. Early or late picking of cotton should be avoided because early picking gives small fiber length with shrinking quality, which results in sub-standard fabrics and immature fiber obtained from bolls that darken immediately (Ahmad & Razi, 2011). Similarly, late harvesting exposes the fiber to various environmental conditions that may cause the cotton to become more yellow and gray (Duckett *et al*., 1999).

Fiber strength (g tex^{-1}): Fiber strength was significantly affected by sowing dates, genotypes, and sowing dates × genotypes interactions (Table 3). Mean values for sowing dates revealed that April 19 sowing gave higher fiber strength followed by April 4 and May 4 sowing dates both being statistically at par (Table 5). Among genotypes, CIM-599 produced higher fiber strength followed closely by CIM-598. Interaction effects of genotypes and sowing dates revealed that April 19 sowing in combination with CIM-599 produced highest fiber strength (Fig. 8a, b & c). March 20 to April 4 was too early and May 4 to June 3 was too late to produce higher fiber strength. Our results are parallel with the findings of Arshad *et al*. (2001) & Baloch *et al*. (2001) who reported that late planting reduced fiber strength. Moreover, late sown cotton may reach maturity late in season and practically farmers harvest immature cotton that contributes to lower fiber strength, and nep formation, and poor dye uptake (Bradow & Bauer, 1997).

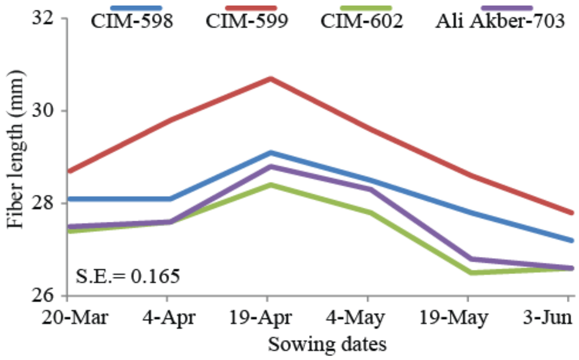

Fig. 7a. Interactive effects of sowing dates and genotypes on fiber length during 2012.

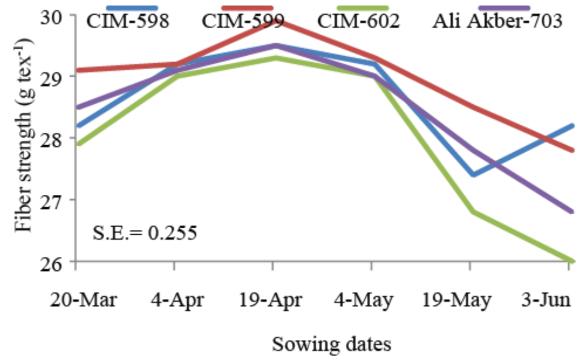

Fig. 8a. Interactive effects of sowing dates and genotypes on fiber strength during 2012.

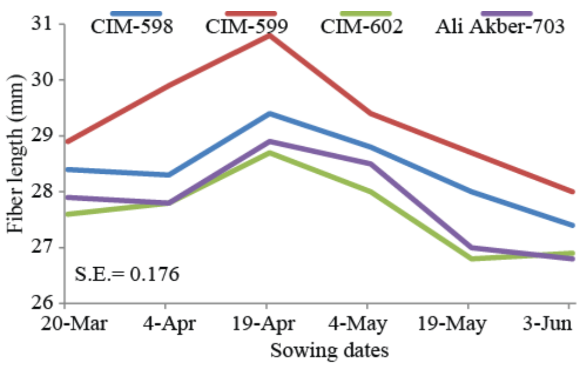

Fig. 7b. Interactive effects of sowing dates and genotypes on fiber length during 2013.

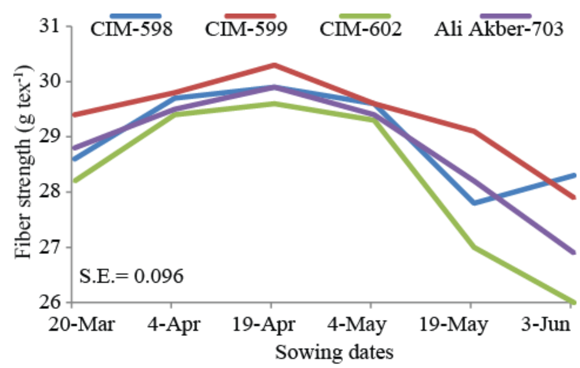

Fig. 8b. Interactive effects of sowing dates and genotypes on fiber strength during 2013.

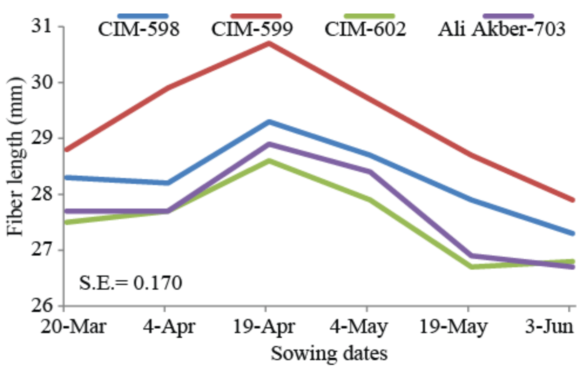

Fig. 7c. Interactive effects of sowing dates and genotypes on fiber length during 2012-2013.

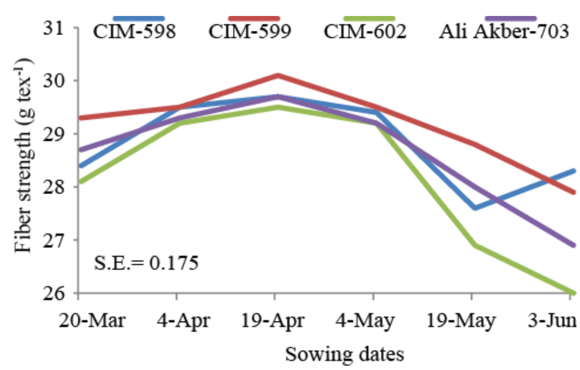

Fig. 8c. Interactive effects of sowing dates and genotypes on fiber strength during 2012-2013.

Micronaire: Micronaire indicates an indirect measure of cotton fiber gravimetric fineness (mass per unit length), and was significantly influenced by sowing dates, genotypes and their interactions (Table 3). Sowing dates effects revealed that late sowing (June 3) resulted in higher maicronaire value indicating lower fineness of the fiber while April 19 sowing produced lower micronaire value indicating more fineness of the fiber (Table 5). Among genotypes, CIM-599 had lower micronaire value compared to all other genotypes. Interaction effects revealed that CIM-599 sown on April 19 had the lower micronare value indicating more fineness of the fibers compared to all other combinations having higher micronaire values (low fineness of the fiber) (Fig. 9a, b & c). Deho *et al*. (2012) reported that micronaire value was lower (more fine fiber) in April sowing compared to May sowing having higher micronaire value. McAlister & Rogers (2005) reported three types of micronaire values for marketing purposes, a premium (micronaire value of 3.7 to 4.2) with regard to price, normal (3.5, 3.6, & 4.3 through 4.9), and price discount range (3.4 and below and 5.0 & above are considered to have lesser value). Micronaire values in this study for April 19 × CIM-599 interactions were in the premium range.

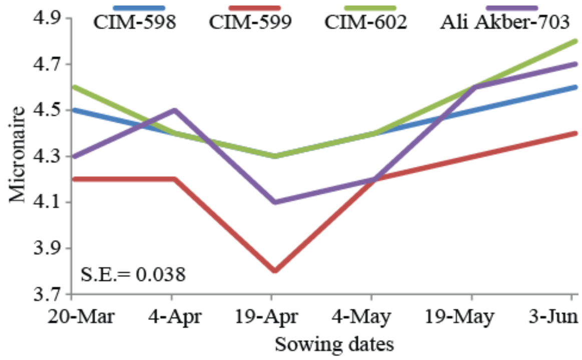

Fig. 9a. Interactive effects of sowing dates and genotypes on micronaire during 2012.

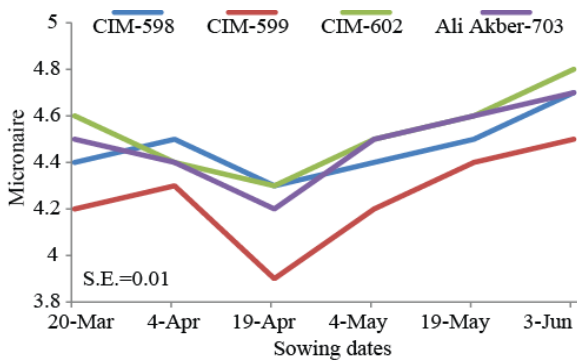

Fig. 9b. Interactive effects of sowing dates and genotypes on micronaire during 2013.

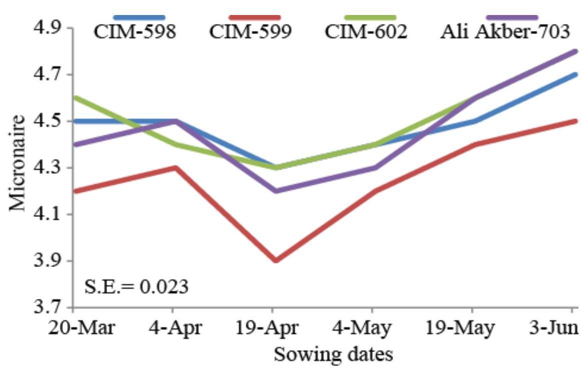

Fig. 9c. Interactive effects of sowing dates and genotypes on micronaire during 2012-2013.

Uniformity (%): Fiber uniformity is a measure of the fiber length distribution in a sample. A low uniformity index value indicates that there are more short fibers (<12.7 mm in length) in a sample than one with a high fiber uniformity for cotton of the same upper half mean length. Fiber uniformity was significantly affected by sowing dates, genotypes, and sowing dates × genotypes interactions, however, interaction effects were not significant in first growing season (Table 3). April 19 to May 4 showed higher fiber uniformity compared to earlier or later sowing dates (Table 5). CIM-599 had higher fiber uniformity than other genotypes. However, CIM-602 and Ali Akbar-703 produced similar fibers uniformity. Interaction effects revealed that CIM-599 produced higher uniformity percentage when sown on April 19 (Fig. 10a & b). El-Zik *et al*. (2000) reported that late sowing in the season adversely affected uniformity ratio. Similarly, Baloch *et al*. (2001) also communicated analogous results that late sowing of cotton resulted in lower uniformity ratio of cotton. Our results indicate that fiber uniformity is affected both by sowing date as well as genotypic material; however, the later one seems to have more impact on fiber uniformity. Zia-ul-Hassan *et al*. (2014) & Bednarz *et al*. (2005) reported that uniformity was a genetically controlled character which could be improved by selection.

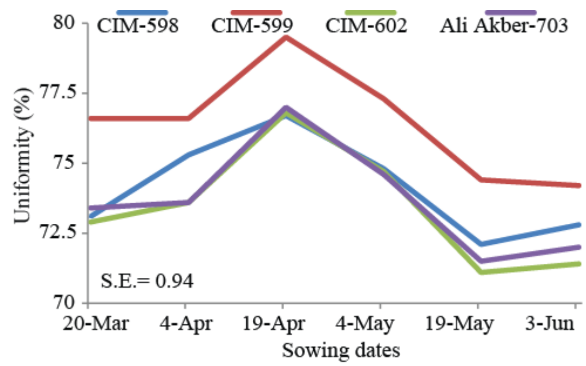

Fig. 10a. Interactive effects of sowing dates and genotypes on uniformity during 2013.

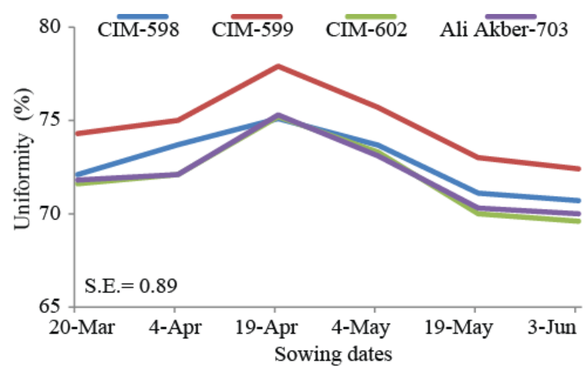

Fig. 10b. Interactive effects of sowing dates and genotypes on uniformity during 2012-2013.

Conclusions

This study comprised of six sowing dates (March 20, April 4, April 19, May 4, May 19, & June 3) and four genotypes (CIM-598, CIM-599, CIM-602, & Ali Akber-703). It was observed that yield and quality traits were different for different genotypes. However, CIM-599 performed better regarding cotton yield and quality traits when sown on April 19. Late planting delayed crop maturity and caused flowering and boll formation at cold temperature stress that resulted in lower cotton yield. Similarly, early planting could not produce more seed cotton yield for the reproductive stage of the crop came in the warmest month of the year that resulted in more vegetative growth rather than seed cotton yield. April 19 sowing was the optimum sowing date at which all other genotypes also performed better regarding lint yield and quality. Therefore, it is generally recommended to grow cotton on April 19 irrespective of the genotypes, however, genotype, CIM-599 had a comparatively higher potential to optimize cotton yield and quality in D.I. Khan region of Khyber Pakhtunkhwa, Pakistan. Sowing genotype at an appropriate time can improve its yield potential. This work provides a foundation for more in-depth research on testing April 19 as optimum sowing date for cotton varieties. CIM-599 and April 19 sowing need to be tested on some other locations for broader recommendations.

References

Ahmad, M. and M.F. Razi. 2011. Cotton sowing in doldrums. http://www.pakistan.com.

Ali, H., M.N. Afzal and D. Muhammad. 2009. Effect of sowing dates and plant spacing on growth and dry matter partitioning in cotton (*Gossypium hirsutum* L.). *Pak. J. Bot*., 41(5): 2145-2155.

Arain, M.H., M.J. Baloach, C.K. Kalwar and A.A Memon. 2001. Performance of newly developed cotton strains under different sowing dates. *Pak. J. Bio. Sci*., 1(3-4): 1-2.

Arshad, M., A. Wajid, M. Maqsood, K. Hussain, M. Aslam and M. Ibrahim. 2007. Response of growth, yield and quality of different cotton cultivars to sowing dates. *Pak. J. Agri. Sci*., 44(2): 208-212.

Arshad, M., N. Illahi, M. Afzal, R. Ali and M. Hanif. 2001. Effect of planting dates on fiber characters of three upland cotton varieties. *Pak. J. Biol. Sci*., 4(4): 313-315.

Azhar, F.M., A.I. Khan and I. Mahmood. 1999. Path coefficient analysis of some advanced generation progenies of *Gossypium hirsutum* L. *Int. J. Agri. Biol*., 1(3): 85-87.

Baloch, E. 1997. Environmental adaptation analysis of several upland cotton varieties. *Pak. J. Sci. Ind. Res*., 41: 91-94.

Baloch, M., S.H. Ghaloo and A.A. Rajper. 2001. Are cotton fiber characters under influence of planting dates? *Life Sci. Int. J*., 1(1): 1-5.

Bange, M., E. Brown, J. Caton and R. Roche. 2004. Sowing time, variety and temperature effects on crop growth and development in the Hillston region. 11th Australian cotton conference proceedings. Gold cost convention and Exhibition centre, Broadbeach Queensland.

Bange, M.P., S.J. Caton and S.P. Milroy. 2008. Managing yields of high fruit retention in transgenic cotton (*Gossypium hirsutum* L.) using sowing date. *Aust. J. Agric. Res*., 59: 733-741.

Batool, S., N.U. Khan, K. Makhdoom, Z. Bibi, G. Hassan, K.B. Marwat, Farhatullah, F. Mohammad, Raziuddin and I.A. Khan. 2010. Heritability and genetic potential of upland cotton genotypes for morpho-yield traits. *Pak. J. Bot*., 42(2): 1057-1064.

Bauer, P.J., J.R. Frederich, J.M. Bradow, E.J. Sadler and D.E. Evans. 2000. Canopy photosynthesis and fiber properties of normal and late planted cotton. *Agron. J*., 92: 518-523.

Bednarz, C.W., W.D. Shurley, W.S. Anthony and R.L. Nichols. 2005. Yield, quality, and profitability of cotton produced at varying plant densities. *Agron. J*., 97: 235-240.

Bolonhezi, A.C., M.M. Justi, R.C. Oliveira and C. Bolonhezi. 2000. Narrow spacing for varieties of herbaceous cotton (*Gossypium hirsutum* L.), plant development and retention of reproductive structures. *Field Crop Res*., 53(5): 611-613.

Bradow, J.M. and P.J. Bauer. 1997. How variety and weather determine yarn properties and dye uptake. p. 560-565. In: *Proc. Beltwide Cotton Conf*., New Orleans, LA. 6-10 Jan. 1997. Natl. Cotton Counc. Am., Memphis, TN.

Bremner, J.M. and C.S. Mulvaney. 1982. Nitrogen-total. In: *Methods of Soil Analysis*. (Eds.): Page, A.L, R.H. Miller, D.R. Keeney. Part II. Chemical and Microbiological Properties. 2nd ed. American Society of Agronomy, Madison, WI, USA, pp. 595-682.

Campbell, B.T. and M.A. Jones. 2005. Assessment of genotype × environment interactions for yield and fiber quality in cotton performance trials. *Euphytica*, 144: 69-78.

Deho, Z.A., S. Laghari, S. Abro, S.D. Khanzada and Fakhuruddin. 2012. Effect of sowing dates and picking intervals at boll opening percent, yield and fiber quality of cotton cultivars. *Sci. Tech. Dev*., 31(3): 288-293.

Duckett, K.E., L. Cheng, T. Sapaletalova, M. Watson and H. Ghorashi. 1999. Color grading of cotton measurement (Part I). p. 645-650. In Proc. Beltwide Cotton Conf., Orlando, FL. 3-7 Jan. 1999. Natl. Cotton Counc. Am., Memphis, TN.

Ehsan, F., A. Ali, M.A. Nadeem, M. Tahir and A. Majeed. 2008. Comparative yield performance of new cultivars of cotton (*Gossypium hirsutum* L.). *Pak. J. Life Soc. Sci*., 6: 1-3.

El-Akkad, M.H., M.A.A. El-Dayem, A.F.H. El-Okkia and M.H. Fouad. 1980. Influence of planting date on flowering, boll setting, yield and earliness in Giza 69 cotton variety. *Agric. Res. Rev*., 58(9): 149-168.

Elayan, E.D., Sohair, A.M.A. Abdalla, Abdel-Gawad, S.D. Nadia and A.E.F. Wageda. 2015. Effect of delaying planting date on yield, fiber and yarn quality properties in some cultivars and promising crosses of Egyptian cotton. *American-Eurasian J. Agric. & Environ. Sci*., 15(5): 754-763.

El-Debaby, A.S., G.Y. Hammam and M.A. Nagib. 1995. Effect of planting date, N and P application levels on seed index, lint percentage, and technological characters of Giza 80 cotton cultivar. *Annals of Agric. Sci. Moshtohor*, 33(2): 455-464.

El-Zik, K.M., P.M. Taxton, T.F. Dusek and T.D. Brooks. 2000. Effect of planting date, moisture and heat units on cotton yield and fiber quality under dry conditions. *Procd. Beltwide Cotton Conf*., 1: 525-527.

Ewida, M.A.T., M.H. Fayed, A.M. Okaz and H.E.A. El-Gamal. 1985. Yield components and fiber quality of Egyptian and American cottons with different planting dates. *Annals of Agric. Sci. Moshtohor*, 23(2): 601-611.

Hodges, H.F., K.R. Reddy, J.M. McKinion and V.R. Reddy. 1993. Temperature effects on cotton. *Miss. St. Univ. Exp. Stn. Bull*., 990.

Hussain, M., A. Ahmad and S.I. Zamir. 2007. Evaluation of agro-qualitative characters of five cotton cultivars (*Gossypium hirsutum* L.) grown under Toba Tek Singh conditions. *Pak. J. Agri. Sci*., 44(4): 575-580.

Iqbal, J., S.A. Wajid, A. Ahmad and M. Arshad. 2012. Comparative studies on seed cotton yield in relation to nitrogen rates and sowing dates under diverse agro-environment of Punjab. *Pak. J. Agric. Sci*., 64(1): 59-63.

Jowah, P. 1994. Studies on insecticide applications on small-scale cotton farms. Thesis submitted for the degree of Doctor of Philosophy, University of Zimbabwe, Harare.

Karavina, C., R. Mandumbu, C. Parwada and T. Mungunyana. 2012. Variety and planting date effects on the incidence of bollworms and insect sucking pests of cotton (*Gossypium hirsutum* L.). *Res. J. Agric. Sci*., 3(3): 607-610.

Khan, F.U.Z., S.U. Rehman, M.A. Abid, W. Malik, C.M. Hanif, M. Bilal, G. Qanmber, A. Latif, J. Ashraf and U. Farhan. 2015. Exploitation of Germplasm for Plant Yield Improvement in Cotton (*Gossypium hirsutum* L). *J. Green Physiology Genetics & Genomics*, 1(1): 1-10.

Khan, W.S., M. Hanif and Z. Ahmad. 1980. Studies on the sowing date, quantum of irrigation and levels of fertilizers on the yield of American cotton in Sargodha. *The Pakistan Cottons*, 24: 75-85.

Khan, W.S., Z.A. Raja and A. Aziz. 1981. Studies on seed cotton yield for different sowing dates and spacings as affected by different years. *The Pakistan Cottons*, 25: 81-4.

McAlister, D.D. and C.D. Rogers. 2005. The effect of harvesting procedures on fiber and yarn quality of ultra-narrow-row cotton. ***J. Cotton Sci.,*** 9: 15-23.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon, and organic matter. In: *Methods of Soil Analysis*, (Eds.): A.L., R.H. Miller and D.R. Keeney. Part 2. Agronomy No 9, Madison, Wisconsin, USA. 539-579.

Pedigo, L.P. 2004. Entomology and pest management. Prentice Hall, Englewood Cliffs.

Poonia, B.L., R.P. Singh and N.K. Jain. 2002. Response of upland cotton (*Gossypium hirsutum*) cultivars to different dates of planting. *Indian **J.** Agri. Sci*., 72(3): 171-173.

Rahman, H.R., S.A. Malik, M. Saleem and F. Hussain. 2007. Evaluation of seed physical traits in relation to heat tolerance in upland cotton. *Pak. **J.** Bot.,* 39(2): 475-483.

Rauf, S. and H.A. Sadaqat. 2007. Effects of varied water regimes on root length, dry matter partitioning and endogenous plant growth regulators in sunflower (*Helianthus annuus* L.). ***J.** Plant Interact*, 2(1): 41-51.

Rauf, S., T.M. Khan, H.A. Sadaqat and A.I. Khan. 2004. Correlation and path coefficient analysis of yield components in cotton (*Gosspium hirsutum* L.). *Int. **J.** Agri. Biol*., 6(4): 686-688.

Reddy, K.R. 1992. Temperature effects on cotton fruit retention. *Agron. **J.***, 87: 820-826.

Reddy, K.R., H.F. Hodges and V.R. Reddy. 1990. Temperature effects on cotton fruit retention. *Agron. **J.***, 84(1): 26-30.

Richards, L.A. 1954. Diagnosis and Improvement of Saline and Alkali Soils. Agri. Handbook no. 60, U.S. Salinity Laboratory Staff. United states Department of Agriculture, U. S. Govt. Printing Press, Washington DC.

Sarwar, M., M.F. Saleem, M.A. Wahid, A. Shakeel and M.F. Bilal. 2012. Comparison of Bt and non-Bt cotton (*Gossypium hirsutum* L.) cultivars for earliness indicators at different sowing dates and nitrogen levels. ***J.** Agric. Res*., 50(3): 335-347.

Anonymous. 2009. Keys to soil of NWFP, FATA and Northern areas. National institute of research in soils and geomatics, Lahore, Pakistan, pp. 76.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures of statistics. McGraw-Hill, New York.

Tibugari, H., R. Mandumbu, P. Jowah and C. Karavina. 2012. Farmer knowledge, attitude and practice on cotton (*Gossypium hirsutum* L.) pest resistance management strategies in Zimbabwe. *Archives of Phytopathology and Plant Protection*, 1: 1-11.

Xian, G., M. Jun, G. Yuping, S. Mizhen1, Zhoujiajia, Y. Yanchao, Z. Tianzhen, S. Xuezhen and S. Xianliang. 2014. The relationship between fiber initiation and Lint percentage in cotton. *Pak. **J.** Bot*., 46(6): 2227-2238.

Yaseen, A.F.I.H. 1986. The relationship between yield and agronomic treatments for some Egyptian and American cotton varieties. Ph.D. Thesis. Fac. Agric. Ain Shams Univ., Egypt.

Yeates, S.J., G.A. Constable and T. McCumstie. 2010a. Irrigated cotton in the tropical dry season. II: Biomass accumulation, partitioning and RUE. *Field Crop Res*., 116(3): 290-299.

Yeates, S.J., M.F. Kahl, A.J. Dougall and W.J. Müller. 2013. The impact of variable, cold minimum temperatures on boll retention, boll growth and yield recovery of cotton. ***J.** Cotton Sci*., 17: 89-101.

Zeng, L., W.R.M. Jr., B.T. Campbell, J.K. Dever, J. Zhang, K.M. Glass, A.S. Jones, G.O. Myers and F.M. Bourland. 2014. Breeding and genetics. Genotype-by-environment interaction effects on lint yield of cotton cultivars across major regions in the U.S. cotton belt. ***J.** Cotton. Sci*., 18: 75-84.

Zia-ul-Hassan, K.A. Kubar, I. Rajpar, A.N. Shah, S.D. Tunio, J.A. Shah and A.A. Maitlo. 2014. Evaluating potassium-use-efficiency of five cotton genotypes of Pakistan. *Pak. **J.** Bot*., 46(4): 1237-1242.

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