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Full Length Article

Reproductive Development and Seed Cotton Yield of *Gossypium hirsutum* as affected by Genotype and Planting Time

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Abstract

This experiment was conducted to assess the effect of planting time on development of floral parts and seed cotton yield for two years. It was comprised of four planting times at four levels (i.e., 1 April, 1 May, 1 June and 1 July) and three cotton genotypes (IUB-222, IUB-13 and IUB-63). Data were collected for square development, time for first flower and boll open, boll retention, boll size, seed index, monopodial and sympodial branches including seed cotton yield. Statistical analysis revealed significant ($P \geq 0.05$) genotypic and planting time differences for all studied traits and interaction of the two factors was also found significant ($P \geq 0.05$) for all traits. The results revealed that early sown crop required more days for reproductive development but had less boll retention due to exposure to high temperature during its reproductive phase. Early sown crop had also maximum seed cotton yield. Among the genotypes, IUB-13 proved best for early sowing whereas no significant genotypic effect observed for yield in the late sown crop. Correlation analysis revealed negative correlation of boll retention with other yield related traits neutralized their effect on the final yield. Therefore, care should be taken in selecting such traits for high seed cotton yield. © 2018 Friends Science Publishers

Keywords: Cotton; Sowing time; Seed cotton yield; High temperature; Correlation analysis

Introduction

Cotton *(Gossypium hirsutum* L.) is a major cash crop of the world which not only provide raw material to the cloth industry but also contribute to the food security and feed of dairy animals due to its seed oil and oil seed cake respectively. Climate change is a hot current issue and it is projected to significantly affect the crop production due to heat and drought.

Despite of the fact that cotton is a crop of tropical and sub-tropical regions, it is sensitive to heat stress during reproductive and fruiting phase (Iqbal *et al.*, 2017). Akey factor for this may be the sensitivity of pollens to heat (Song *et al.*, 2014, 2015) which cause pollen death and results is flower and boll abortion. Heat stress at the time of pollen formation (two weeks prior to flower opening) has been reported to have extreme impact on pollen viability (Meyer, 1969) as high temperature effects. High temperature during reproductive phase of cotton results in smaller bolls and lowers yields (Iqbal *et al.,* 2017; Mahdy *et al.,* 2017). Position of flowers on branches determines viability of pollens as top flowers reported to have more pollens than lower branches flowers (Burke and Wanjura, 2001) that might be due to the lower canopy temperature than air temperature. Compared to the maximum temperature, increase in daily minimum temperature reported to have more effect on reproductive growth (Singh *et al.,* 2007) that leads to lowers seed cotton yield.

Depending on the region and cultivar optimum temperature for the crop growth and development varies (Burke and Wanjura, 2010). Harsh effects of heat started to appear even when temperature raised over 29°C but some genotypes can even tolerate more than 35°C (Brown, 2008) which shows the potential of deveoping heat tolerant cultivars. Heat tolerance is a complex mechanism where different physiological and biochemical processes are involved to keep the normal plant growth and development even at higher temperatures. Higher temperature (≥ 35°C) usually shrinks the quantum efficiency of the photosynthetic system (Snider *et al.,* 2010) and decline the level of chlorophyll contents, escalate the photorespiration and cell membrane thermostability (Kamal *et al.,* 2017; Schauberger *et al.,* 2017) reduces CO_2 availability and deactivate the ribulose-1,5-bisphosphate carboxylase production (Carmo-Silva *et al.,* 2012; Sekmen *et al.,* 2014) due to the reason photosynthetic activity reduces and ultimately development of bolls affected.

In wheat-cotton cropping system of Pakistan, cotton is normally sown in May–June. But with commercialization of *Bt* cultivars, farmers preferred to grow cotton early i.e., in March–April to gain maximum productivity and profit (Shah *et al.,* 2017a). Reproductive phase of early sown cotton starts in June and due to sensitivity of reproductive stage to heat stress (Sage *et al.,* 2015; Iqbal *et al.,* 2017; Khan *et al.,* 2017), flower and boll formation is badly affected which resulted in lower seed cotton yield relative to long growth period. This problem can be overcome by using genotypes tolerant to heat stress during reproductive phase. Therefore, it is crucial to identify yield related traits stable with temperature variations to develop heat tolerant genotype for maximum yield and profit with early sown cotton.

Keeping in view the above mentioned facts and problems, present study was conducted to depict the effect of different planting times on genotypic response of cotton in terms of reproductive growth, yield and seed traits.

Materials and Methods

Experimental Site and Plant Material

The research was accomplished at experimental area, Department of Plant Breeding and Genetics, UCA & ES, The Islamia University of Bahawalpur, Pakistan (located at 29° 24' 0" North, 71° 41' 0" East and 116 m asl) for two successive years i.e., 2014 and 2015. The climate of the area falls in sub-tropical semi-arid with cool winters and hot summers and a long term mean rainfall of 280 mm. Physio-chemical properties of soil and climatic data are presented in Table 1 and 2, respectively.

Experimental Details

Three cotton genotypes viz. IUB-222, IUB-13 and IUB-63 were sown on April 01, May 01, June 01 and July 01 for two consecutive years i.e., 2014 and 2015 in same plots with similar crop husbandry. The experiment was arranged in a randomized complete block design with factorial arrangement and replicated four times with net plot size of 5 m × 3 m.

Crop Husbandry

Field was irrigated before sowing and after attaining suitable moisture for cultivation, seed bed was prepared by cultivating the field two times followed by planking. Sowing was made on ridges prepared with tractor mounted ridger to maintain a row to row distance of 75 cm. Cotton seed was sown by hand by keeping plant to plant distance 20 cm at respective dates mentioned above. Crop nutrients, nitrogen (N) and phosphorus (P) were applied at 250 and 200 kg ha^{-1}, respectively in the form of di-ammonium phosphate and urea. Whole P and $1/3^{rd}$ N was applied at the time of seed bed preparation while remaining N in equal splits with 1^{st} and 2^{nd} irrigations. Plant protection measures were kept same in all treatments by using recommended pesticides (*imidacloprid* for sucking insects and *roundup* for weeds) and cultural practices. Recommended irrigations were applied each with an interval of two weeks to avoid moisture stress. Crop was harvested (final picking) in last week of October during both years.

Data Collection

In each treatment 10 plants were randomly selected and tagged for data collection. Data were collected for days taken to square initiation (days counted from date of planting), days taken to first flower open (days counted from date of planting), days taken to first boll open (days counted from date of planting). Boll retention (retention percentage) was calculated as ratio of total number of bolls opened to total number of fruiting points, number of monopodial branches, number of sympodial branches, seed index and boll weight was measured from the randomly selected twenty bolls and average was calculated. For seed cotton yield two central rows from each plot were harvest to measure seed cotton yield and then data were converted to seed cotton yield per hectare. All data measurements were as described elsewhere (Iqbal *et al.,* 2017; Shah *et al.,* 2017b).

Statistical Analysis

Data collected for all traits, were subjected to analysis of variance considering factorial design (Steel *et al.,* 1997) with statistical software MSTAT-C followed by Tukey's test to compare the means of different treatment. As the year effect was non-significant, so data of two years were pooled and analyzed for comparison. Simple linear correlation analyses were carried out among phenological and yield related traits using software sigma plot.

Results

All studied phonological traits, yield and yield related traits were significantly ($P \leq 0.05$) influenced by planting time, genotypes and their interaction. The interaction of genotypes and planting date was significant for days taken to imitation of squares, days taken to first flower open, days taken to first boll open, boll retention, boll size and seed cotton yield (Table 3).

For days taken to initiation of squares, first flower open and first boll open, maximum days were taken by genotype IUB-222 followed by IUB-13 and IUB-63 respectively across all sowing dates. IUB-13 and IUB-63 took maximum days to initiation of squares, when sown on 1^{st} April and took minimum days when sown on 30

Table 1: Physio-chemical analyses of experimental soil in 2014 and 2015 before sowing

Parameter	Unit	Value		Status
		2013-14	2014-15	
Physical parameters				
Sand	%	64.9	64.7	
Silt	%	19.3	19.8	
Clay	%	15.8	15.5	
Bulk density	Mg m^{-3}	1.29	1.29	
Texture class		Sandy Loam	Sandy Loam	
Chemical parameters of soil				
pH		8.1	8.0	
EC	µS/cm	1.98	1.85	
Total Nitrogen	mg kg^{-1}	472	456	Very low
Available Phosphorus	mg kg^{-1}	6.40	6.71	low
Available Potassium	mg kg^{-1}	131	126	Adequate

Table 2: Monthly temperature and rainfall data of experimental duration as obtained in 2014 and 2015

Month	Mean monthly maximum temperature (°C)		Mean monthly maximum temperature (°C)		Rainfall (mm)	
	2014	2015	2014	2015	2014	2015
April	34.2	34.8	21.5	22.1	18	16
May	40.5	41.0	26.1	26.8	51	10
June	41.3	40.8	30.2	30.5	79	17
July	40.2	41.3	30.4	29.8	46	80
August	37.6	38.2	26.8	26.1	23	54
September	34.2	34.8	27.4	26.9	24	17
October	33.1	32.6	24.5	23.8	01	10

Table 3: Significance of mean squares of different traits of cotton as affected by genotypes and sowing dates

Source of variation	Days taken to initiation of squares (days)	Days taken to first flower (days)	Days taken to first boll (days)	Boll retention (%)	Boll size (g)	Seed Index (g)	Number of monopodial branches per plant	Number of sympodial branches per plant	Seed cotton yield (kg ha^{-1})
Sowing date	117.5**	83.0**	50.1**	217.9**	0.2**	8.9**	0.04**	71.5**	858543.0**
Genotype	13.5**	306.1**	687.2**	1226. 3**	2.8**	52.5**	3.4**	28.8**	406238.0**
Interaction	3.1*	30.5**	12.4*	7.0*	0.003**	0.02^{ns}	0.04^{ns}	2.4^{ns}	27880.0**

*significant at 5% probability level; ** significant to 1% probability level; ns not significant

June. Whereas IUB-222 showed no significant difference for initiation of squares for sowing dates. IUB-222 showed no statistical difference for days taken to first flower open among different sowing dates whereas IUB-13 and IUB-63 took significantly more days at first sowing date (1st April) than other dates. IUB-222 took statistically same days to first boll open on all sowing dates, whereas IUB-13 and IUB-63 took minimum days for crop sown on 1st May and 30th June (Table 4).

The genotype IUB-63 showed maximum boll retention followed by IUB-13 and IUB-222 respectively, across all sowing dates. All genotypes showed maximum boll retention when sown on 30 June and minimum boll retention for 1st April and 1st May sowings. Overall boll size and seed index was maximum for IUB-222 across all sowing dates. All the genotypes showed maximum boll size and seed index for first sowing date (1st April) and minimum values were observed for last sowing date (30th June). Overall maximum monopodial branches were observed in IUB-222 followed by IUB-13 and IUB-63 across all sowing dates. Maximum sympodial branches were shown by IUB-13 and IUB-63 with no statistical difference across all sowing dates. Furthermore, all genotypes showed maximum sympodial branches for first sowing date (1st April) followed by next sowing dates respectively. Maximum seed cotton yield was observed in IUB-13 followed by other two genotypes. Furthermore, all genotypes showed maximum seed cotton yield at first sowing date (1st April) followed by next sowing dates respectively (Table 4).

Correlation analyses (Table 5) showed that initiation of squares had significant correlation with days taken to first boll open (0.74), number of monopodial branches (0.62) and seed cotton yield (0.72). Days taken to first flower open has significant positive correlation with all traits except number of sympodial branches and seed cotton yield. Boll retention has significant negative correlation with all traits except number of sympodial branches and seed cotton yield. Seed cotton yield has significant positive correlation only with days to initiation of squares (0.72) and number of sympodial branches (0.70).

Discussion

Optimizing sowing time of any crop is crucial as it depicts the fitness of crops in a cropping system. Significant

Table 4: Effect of different sowing dates on phenological and yield related traits of different cotton genotypes

Sowing dates	Genotypes	Days taken to initiation of squares (days)	Days taken to first flower (days)	Days taken to first boll open (days)	Boll retention (%)	Boll size (g)	Seed Index (g)	Number of monopodial branches per plant	Number of sympodial branches per plant	Seed cotton yield (kg ha^{-1})
Interaction of Genotype × Sowing dates										
1-Apr	IUB-222	30.1a	59.0ab	106.7a	43.6f	4.2a	11.5a	2.5ab	45.5ab	6360bc
1-May	IUB-222	24.9b	60.2a	106.2a	42.3f	4.0ab	9.9ab	2.8a	42.7bc	6089cd
30-Jun	IUB-222	25.1b	58.6ab	106.4a	44.5f	3.9abc	9.5bc	2.7a	39.6c	5891de
30-Jun	IUB-222	25.0b	58.5ab	108.6a	52.1e	3.8bc	9.5bc	2.8a	39.2c	5771de
1-Apr	IUB-13	30.7a	58.1ab	104.2ab	55.0de	4.0ab	10.1ab	1.8bc	48.4a	6740a
1-May	IUB-13	23.5bc	52.5bcd	96.3cd	56.4cde	3.8bc	8.4bc	1.6c	46.3ab	6305b
30-Jun	IUB-13	23.4bc	51.5bcd	95.2de	61.8bc	3.7bc	8.1cd	1.9bc	42.0bc	6223c
30-Jun	IUB-13	22.9c	53.4abc	98.4bc	68.3a	3.6c	8.0cd	1.9bc	41.7bc	6092cd
1-Apr	IUB-63	31.0a	58.3ab	95.2de	60.9bcd	3.2d	7.5de	1.7c	47.8ab	6494b
1-May	IUB-63	22.1c	46.1cd	90.0e	61.5bc	3.1d	5.9e	1.8bc	43.6bc	6183cd
30-Jun	IUB-63	21.8c	45.2d	89.2e	66.9ab	3.0d	5.3e	1.7c	42.4bc	5772de
30-Jun	IUB-63	21.7c	46.3cd	93.1de	70.6a	2.9d	5.2e	1.8bc	43.1bc	5612e
Genotypes										
	IUB-222	26.275a	59.075a	106.975a	45.625c	3.975a	10.1a	2.7a	41.75b	6027.7b
	IUB-13	25.125b	53.875b	98.525b	60.375b	3.775a	8.65b	1.8b	44.6a	6340.4a
	IUB-63	24.15c	48.975c	91.875c	64.975a	3.05b	5.975c	1.75b	44.225a	6015.2b
Sowing dates										
1-Apr		30.6a	58.5a	102.0a	53.2c	3.6b	9.5	1.8b	47.2a	6514.7a
1-May		23.5b	52.9b	97.5b	53.4c	4.3a	8.7	2.7a	44.2b	6192.3b
30-Jun		23.4b	52.7b	96.9b	57.7b	4.2a	8.3	2.8a	41.3b	5962.0bc
30-Jun		23.2b	51.7b	100.3ab	63.6a	4.1a	8.2	2.8a	41.3b	5825.0c

Means sharing same letter in each column do not have any significant ($P \leq 0.05$) difference (means are compared with Tukey's test)

Table 5: Correlation analyses of phenological and yield related traits of cotton

	Days taken to first flower (days)	Days taken to first boll open (days)	Boll retention (%)	Boll size (g)	Seed Index (g)	Number of monopodial branches per plant	Number of sympodial branches per plant	Seed cotton yield (kg ha^{-1})
Days taken to initiation of squares (days)	0.737**	0.504^{ns}	-0.437^{ns}	0.486^{ns}	0.018^{ns}	0.144^{ns}	0.622*	0.721**
Days taken to first flower (days)		0.887**	-0.818**	0.801**	0.570*	0.650*	0.104^{ns}	0.505^{ns}
Days taken to first boll open (days)			-0.883**	0.857**	0.816**	0.832**	-0.177^{ns}	0.229^{ns}
Boll retention (%)				-0.924**	-0.658*	-0.782**	0.099^{ns}	0.349^{ns}
Boll size (g)					0.715**	0.601*	0.027^{ns}	0.501^{ns}
Seed Index (g)						0.742**	-0.534^{ns}	-0.110^{ns}
Number of monopodial branches							-0.56*	-0.164^{ns}
Number of sympodial branches								0.703**

* significant at 5% probability level; ** significant to 1% probability level; ns not significant

interaction of genotypes and sowing dates portrayed feasibility of different genotypes at different sowing dates (Usman and Anayatullah, 2016). Cotton is mostly grown in wheat-cotton-wheat, sunflower-cotton-sunflower, fodder-cotton-fodder cropping system where planting time of cotton varies from March to June and due to variation in genotypic response to environment (Iqbal *et al.*, 2017), all genotypes do not produce well across different sowing dates. Therefore, it is very important to investigate the effect of sowing time on the growth and seed cotton yield.

Development of reproductive trait is very important as seed cotton developed on reproductive parts and failure of which results in reduction of seed cotton yield. Time taken to development of reproductive parts depicts early or late maturity (Shakeel *et al.*, 2011; Munir *et al.*, 2015). Phenological traits like days taken to initiation of square, first flower open and first boll open were highly influenced by planting time. Early sown crop took more days to initiate buds, flower and open boll because temperature was low during early stages in April and May relative to other planting time (Table 2) so development of reproductive parts took more time as crop took more days to accumulate required degree days (Huang, 2016; Khan *et al.*, 2017; Shah *et al.*, 2017a). Across all sowing dates, genotype IUB-63 took minimum days for development of reproductive parts depicted with early maturing. As cotton has indeterminate growth habit, therefore if early sown, this genotype will have maximum production period till harvesting.

Early sown cotton has major problem of boll shedding due to high temperature during early reproductive phase (Usman and Anayatullah, 2016; Iqbal *et al.*, 2017). In April and May sowing dates, boll formation started in hot month of June and July, where temperature was more (40–41°C maximum and 30°C minimum) and there were more buds, flower and bud shedding relative to late planting where boll formation started in relative cooler months of August and September (34–38°C maximum and 26–27°C minimum). Along with boll shedding, temperature higher than 35°C also reduces the quantum efficiency of photosynthetic system which results in less accumulation of assimilates (Snider *et al.,* 2010). It is reported that high temperature during reproductive phase induces production of pectinase, hydrolase, ethylene, abscisic acid and pollen mortality which cause flower and immature boll shedding (Echer *et al.*, 2014; Loka and Oosterhuis, 2016; Tariq *et al.*, 2017; Ullah *et al.*, 2017). In case of boll weight and seed index, these were increased with early sowing, as with early sowing it took more time to open, which in return provide it to store more photosynthates and resulted in more boll weight (Reddy *et al.*, 1999; Lokhande and Reddy, 2014; Wu *et al.,* 2014). Similar case was with monopodial and sympodial branches which were more in early sown crop due to having more time to develop. Seed cotton yield was more in early sown crop due to more time crop received for growth and development. Although the crop has less boll retention, but early sown crop has much more time for growth and development (Khan *et al.,* 2017; Ul-Allah *et al.,* 2017) which increased the final seed cotton yield.

Among genotypes, IUB-222 was observed to be influenced maximum by the planting time. Traits of IUB-63 remained comparatively stable in all planting times and boll retention was also maximum in this genotypes, therefore this genotypes proved tolerant to high temperature faced by the early sown cotton. But its yield was less due to less boll size than other genotypes. This genotype may be used in breeding programs to introgress heat tolerant traits to other high yield but heat sensitive genotypes. The genotype IUB-13 had better boll retention compared to IUB-222 and better boll size compared to IUB-63 across all sowing dates, therefore seed cotton yield of this genotype was highest at all sowing dates.

Interesting results were observed from correlation analysis. Most of the yield related traits e.g., days taken to first boll open, boll size, boll retention and seed index showed non-significant association with final seed cotton yield which is contrary to previous findings (Worley *et al.,* 1974; Bange *et al.,* 2008; Yang *et al.,* 2011). Reason of non-significant association with seed cotton yield, in present study, may be the antagonist effect of yield related traits among themselves and genetic difference in the genotypes used for this study. For example, first boll open, boll size and seed index are desired traits for high seed cotton yield (Bange *et al.,* 2008, Yang *et al.,* 2011; Ul-Allah *et al.,* 2017) due to their negative correlation with boll retention had neutralized the effect on the final yield. Care should be taken in selection of such traits for developing high yielding cultivars (Ul-Allah *et al.,* 2017) suitable for different sowing times.

Conclusion

Development of reproductive parts and yield traits were affected by the different planting times due to different temperature received during development. Genotypes IUB-13 proved best for early sowing. At late sowing all genotypes were equally good. The genotype IUB-63 showed maximum boll retention in all planting times, but showed less yield due to relative smaller boll size. This genotype may be used in further breeding programs to improve boll retention in the genotypes with more boll weight coupled with high boll shedding in high temperature regimes. As some yield related traits showed negative correlation among themselves, so such traits should be selected carefully for development of high yielding cultivars.

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