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OPTIMIZATION OF THE SOWING TIME FOR Bt COTTON PRODUCTION IN PUNJAB, PAKISTAN

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A rapid climatic change has threatened the productivity of many field crops across globe including Pakistan. Suitable sowing time is imperative for yield enhancement and sustainability under unpredictable climatic conditions. Bt cotton is cash crop of farmers in central and south Punjab, Pakistan. However, there exists the problem of sub and supra optimum temperature in cotton growing regions of Pakistan which negatively impacts the seed-cotton yield. Thus, there is dire need to optimize the sowing time of cotton in central and south Punjab. This 2-year study (2013 and 2014) was conducted to evaluate the best sowing time of different Bt cotton cultivars under different climatic conditions of Punjab. The experiment consisted of three Bt. cotton cultivars (viz. BH-184, CIM-598, MNH-886) which were sown at five sowing dates (viz. March 01, March 15, April 01, April 15, May 01, May 15) at three experimental sites (viz. Faisalabad, Multan, Bahawalpur) with three replications. The results indicated that Bt cotton sown on 15th April produced the highest seed yield (3044 kg ha^{-1}) and showed the better fiber quality than all other sowing dates owing to increase in yield related traits (number of sympodial branches, bolls per plant and 100-seed weight); while crop sown on 1st March didn't performed well. MNH-886 produces highest seed cotton yield (3044 kg ha^{-1}) at Multan. There was a positive correlation of growth and yield related traits with seed cotton yield. In conclusion, sowing of Bt cotton on 15th April is the best option to harvest higher seed cotton yield under arid to semi–arid conditions of Punjab, Pakistan.

Keywords: *Gossypium hirsutum*, crop sowing, climatic zones, phenological development, temperature stress

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is a leading fiber and cash crop being grown commercially for agriculture and industrial purpose in the temperate and tropical region of the world. Cotton is also a main source of raw material to the textile industry. It has a critical role in agricultural economy of Pakistan and is the most important source of foreign exchange earnings. It is a dual-purpose crop because it provides fiber as well as edible oil (Government of Pakistan, 2016).

An appropriate sowing time, crop protection measures, nutrient management and plant density are the main drivers of harvesting maximum potential of cultivar and they are influenced by soil moisture, light, humidity and wind movement. Therefore, cultivar selection and sowing date are key components for better cotton production. Any delay in sowing time significantly affects boll shedding intensity and ultimately the seed cotton yield (Tahira *et al*., 2007). Reduction in yield commonly occurs due to late sowing because it delays maturity and shortens the fruiting period (Bange *et al*., 2004, 2008; Shah *et al*., 2017). Appropriate time of sowing provides maximum growing period which enable plants to intercept more solar radiation and accumulate the biomass (Arshad *et al*., 2007) while delayed sowing is exposed to super optimal temperature at crop stand establishment stage and sub optimal at reproductive stage (Akhter *et al*., 2002). Late sowing usually results in yield reduction due to short reproductive phase as compared to early sowing. Early sown cotton (April) produces more seed cotton yield due to higher boll retention while it could also reduce late season cold stress during reproductive phase by shifting it towards completion of its life cycle earlier (Akhter *et al*., 2002). Arshad *et al*. (2007) reported that sowing time plays pivotal role in yield potential because it varies from cultivar to cultivar in different climatic zones. Early sowing of a genotype of cotton gives higher yield and narrows down the gap between genotype potential yield and actual yield (Wrather *et al*., 2008; Ali *et al*., 2018).

Higher productivity can be achieved by sowing suitable cultivars at appropriate time, because it is thermo-sensitive crop so cultivar selection at different sowing time is of prime significance. Early sowing not only promotes plant growth but also reduces the negative impact of biotic and abiotic factors on plant growth. High yield of cotton could not be realized previously due to many problems such as sowing dates, cultivar, weed infestation, insect pest and disease problems, water shortage, excess salinity, low germination of seed, conventional sowing methods, poor soil management practices, pre-mature flowering and boll shedding, too early or too late sowing and improper use of varieties in different agro-

ecological zones. Cotton sowing time is also one of the most important critical aspects which leads towards phenological development and conversion of assimilate and biomass to economic yield (Ali *et al*., 2009). Early sowing (February and March) results in cold temperature (<12°C) stress which hamper stand establishment and delays all the developmental and phenological stages (Constable and Bange, 2006), results in poor biomass accumulation and ultimately lower the seed cotton yield (Pettigrew, 2008; Conaty *et al*., 2012).

The objective of the study was to the select suitable sowing date for higher production and to avoid the heat and cold stress under uncertain environment. So, it was hypothesized that optimum sowing date may help in enhancing the productivity of Bt cotton under the diverse climatic conditions.

MATERIALS AND METHODS

***Experimental sites*:** Two field experiments (repeated over time) at three locations viz, Agronomic Research Farms, University of Agriculture. Faisalabad (31.26 °N, 73.06 °E), Regional Agriculture Research Station (RARI) Bahawalpur (29.20 °N, 71.47 °E) and Central Cotton Research Institute (CCRI.) Multan (30.12 °N, 71.26 °E) were conducted to optimize the sowing time for Bt cotton production in Punjab during 2013 and 2014.

***Weather*:** Summary of weather variables recoded during 2013 and 2014 for each location is presented in Figure 1. Bahawalpur site was relatively hotter than the Multan and Faisalabad sites during both cropping seasons. Mean temperatures were higher by approximately 1-2°C at the Bahawalpur whereas Multan was also slightly warmer than Faisalabad by 0.5-1°C. High rainfall was recorded during monsoon (July to August) season and was variable at all the three sites during both growing seasons. In this regard, Bahawalpur had lower precipitation 116 mm than Multan (191 mm) and Faisalabad (215 mm) in 2013. Comparable rainfall values recorded in 2014 were 110 mm, 188 mm and 422 mm at all three sites, respectively. In general, all sites have more rainfall during 2013 as compared to 2014 except Faisalabad. Radiation levels were also different at each site during both the seasons.

***Design and treatments*:** The experiment was conducted in randomized block design in split plot arrangement with three replications. The experiment consisted of three Bt cotton cultivars (viz. BH-184, CIM-598, MNH-886) which were sown at five sowing dates (viz. March 01, March 15, April 01, April 15, May 01, May 15) at three experimental sites (viz. Faisalabad, Multan, Bahawalpur) with three replications. The sowing dates were kept in main plot and the Bt. cotton cultivars were kept in sub-plot. The crop was sown on ridges with P×P and R×R of 20 cm and 70 cm respectively. All other agronomic procedures remained similar for all treatments.

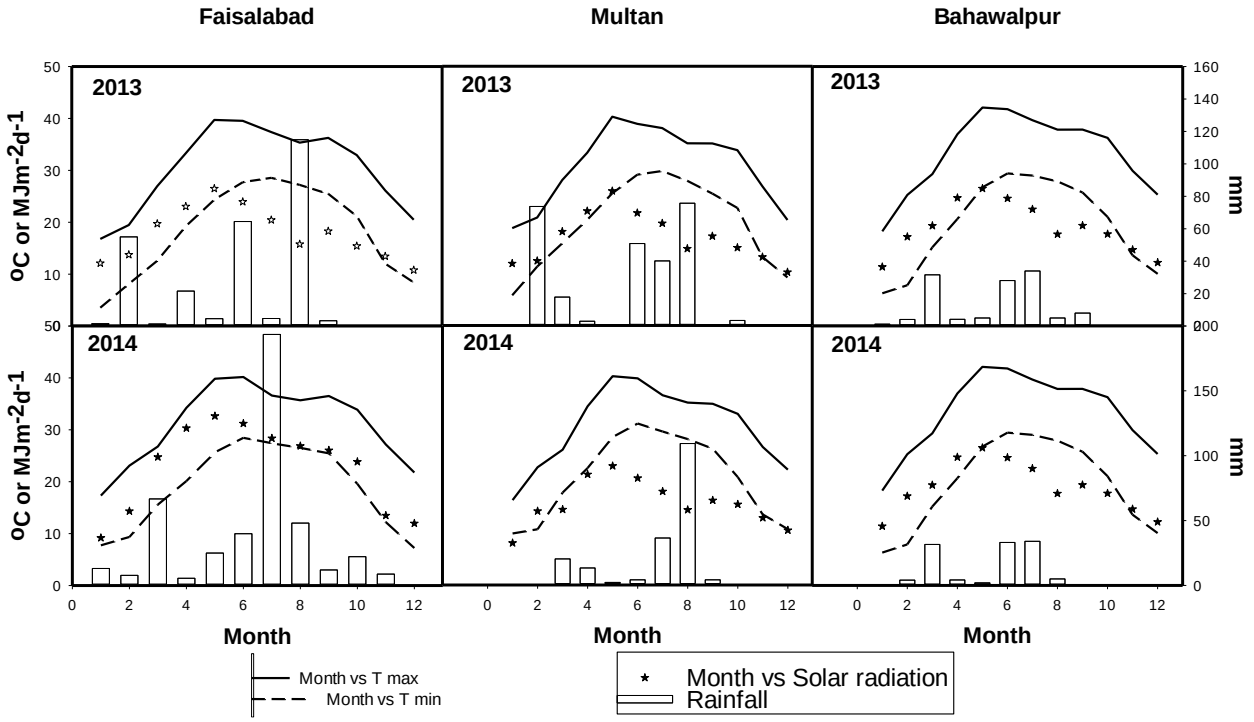

Figure 1. Monthly total rainfall, average minimum and maximum temperature and solar radiation for the experimental sites during 2013 and 2014.

***Growth traits*:** Three randomly selected plants were harvested at ground levels with interval of 20 days after establishment of crop from each plot during both the growing seasons. Fresh weight of each fraction (leaf, stem, squares, flowers and boll opened and un-opened) was recorded using sensitive electronic balance. These samples were sun dried for 48 hours and then oven dried weight was determined at 65°C. From these measurements, total dry matter (TDM) was calculated at each harvest. Similarly, leaf area meter (JVC Model TK-S310EG) was used to measure the leaf area of an appropriate sub-sample of green leaves. Leaf area index (LAI) was calculated as the ratio of leaf area to land area (Watson, 1952).

***Morphological and yield traits*:** The sympodial branches and the number of bolls were counted separately in the ten tagged plants and average value was recorded. Three samples each of 100 seeds were taken at random, weighed on an electric balance and then averaged. Seed cotton from each picking was weighed and recorded. After final picking, average yield was taken. Before ginning, seed cotton samples were dried in the sun, dust and inert matter were removed from samples, then single roller electric ginner was used for ginning of these samples. After weighing the obtained lint from each sample, its ginning outturn (GOT %) was calculated by using following formula.

(GOT %) = Weight of the lint/ Weight of seed-cotton × 100

***Statistical analysis*:** Fisher's analysis of variance technique was used to analyze the data related to growth and seed cotton yield. Then the significance of treatments' means was verified using Tukey's honest significance difference (HSD) test at 5% probability level (Steel *et al*., 1997). During statistical analysis, the experimental location was also considered as factor and the data was analyzed in a three factorial randomized block design.

RESULTS

Sowing dates had a significant effect on seed cotton yield, growth and its related traits (Table 1). In case of sympodial branches and total bolls plant^{-1}, the maximum number was observed when the crop was sown on April 15 at all three locations. However, a decreasing trend was observed when crop was sown late or earlier than April 15 (Table 1). Sowing dates had also a significant on 100-seed cotton weight, seed cotton yield and ginning out turn (GOT). The crop sown on 15th of April produced maximum 100-seed cotton weight, seed cotton yield and ginning out turn (GOT) for all cultivars at all three locations when crop was sown on 15th of April. However, the crop performed poor for these parameters when sown late or earlier than April 15 (Table 1). In case of growth related traits, the maximum leaf area index and total dry matter accumulation was produced by the crop sown on 15th of April (Fig. 1 & 2).

Correlation analysis indicated a strong positive link of growth like total dry matter and leaf area index with seed cotton of

Table 1. Response of sowing dates on the yield and yield related traits of Bt cotton.

Treatments	Sympodial branches plant^{-1}		Total bolls plant^{-1}		100-Cotton seed weight (g)		Seed cotton yield (Kg ha^{-1})		GOT (%)	
Sowing dates	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
A= Location										
Faisalabad	21c	24c	26c	31c	6.06	6.41	2049c	2149c	36.71c	37.98b
Multan	26a	32a	34a	42a	6.27	6.59	2268a	2376a	38.65a	38.73a
Bahawalpur	24b	28b	30b	36b	6.24	6.55	2149b	2283b	37.75b	38.90a
HSD 5%	1.32	1.32	1.66	1.66	0.15	0.15	49.02	54.37	0.38	0.4
Significance	**	**	**	**	ns	ns	**	**	**	**
B= Sowing Dates										
1st March	13e	18e	19e	25e	5.66d	5.97d	1341f	1441f	35.90e	36.74e
15th March	18d	22d	25d	31d	5.78d	6.10d	1577e	1677e	36.74d	37.58d
1st April	23c	27c	30c	36c	6.15c	6.46c	2152d	2269d	37.96c	38.79c
15th April	33a	38a	41a	49a	6.83a	7.18a	2910a	3044a	39.44a	40.28a
1st May	29b	33b	37b	42b	6.48b	6.83b	2666b	2783b	38.64b	39.47b
15th May	24c	28c	29c	35c	6.25bc	6.57c	2285c	2401c	37.52c	38.36c
HSD 5%	2.28	2.28	2.87	2.87	0.26	0.26	84.64	103.68	0.66	0.64
Significance	**	**	**	**	**	**	**	**	**	**
C=Cultivars										
BH-184	21b	25b	27b	33b	6.05b	6.37b	2053c	2167c	37.14b	37.46c
CIM-598	24a	28a	31a	37a	6.24a	6.57a	2177b	2291b	37.90a	39.40a
MNH-886	25a	29a	32a	38a	6.28a	6.61a	2236a	2349a	38.06a	38.75b
HSD 5%	1.32	1.32	1.66	1.66	0.15	0.15	49.02	54.37	0.38	0.4
Significance	**	**	**	**	**	**	**	**	**	**

Bt. cotton sown under different sowing dates (Table 2). Moreover, seed cotton was also positively correlated with yield contributing characters like sympodial branches plant^{-1}, total bolls plant^{-1}, and 100-seed cotton weight of Bt. cotton sown under various sowing dates (Table 2).

DISCUSSION

For Bt cotton growers, sowing time is the most important point of concern because it is directly related with production potential of the crop. Results of this study indicated that Bt.

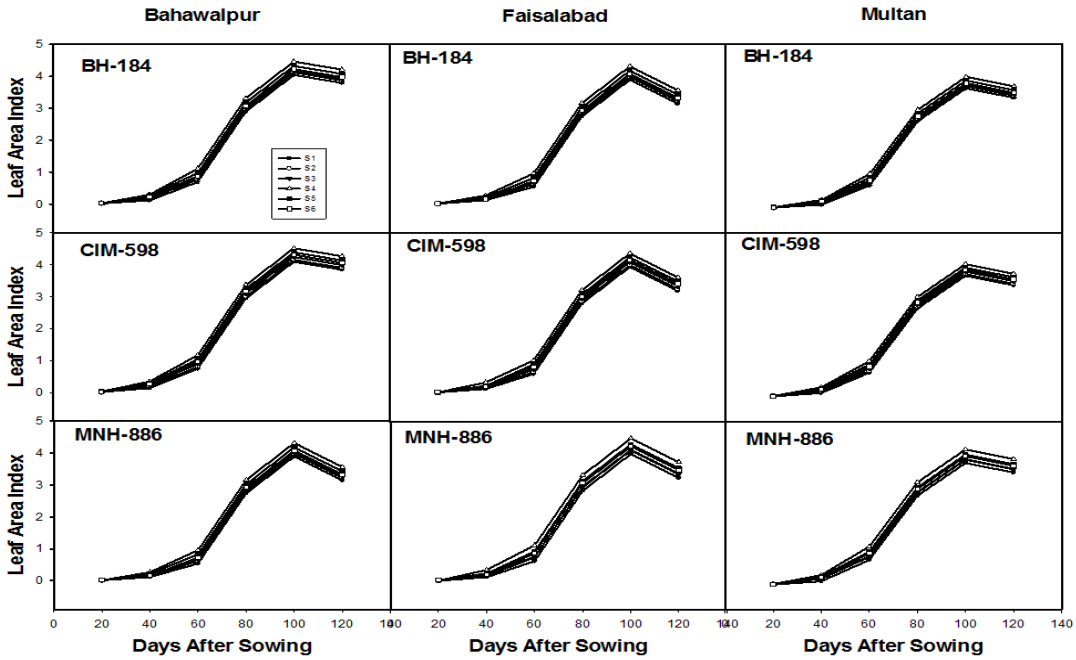

Figure 2. Change in pooled leaf area index of three cultivars with time under six sowing dates at Bahawalpur, Faisalabad and Multan.

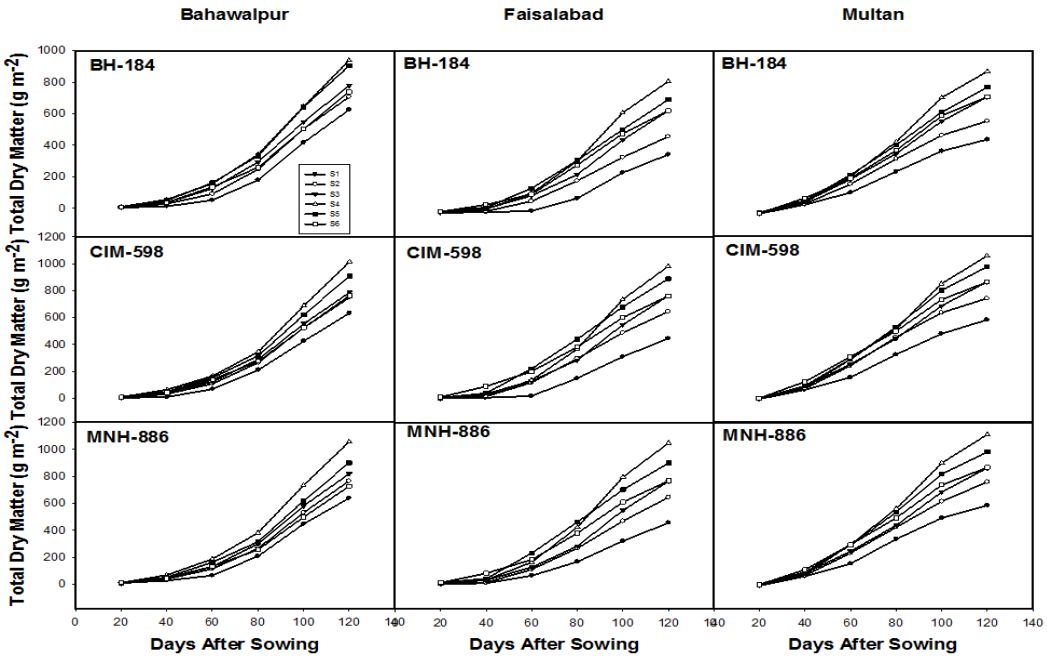

Figure 3. Change in pooled total dry matter of three cultivars with time under six sowing dates at Bahawalpur, Faisalabad and Multan.

cotton sown on April 15 produced higher yield than too early and late sown crop (Table 1). Early sowing (compared with conventional planting during late April and May) of cotton in Pakistan had the advantage of promising ecological conditions before the start of monsoon and high temperature during flowering and fruit development (Ali *et al*., 2009).

Table 2. Correlation coefficients of different yield and growth parameters with seed cotton of Bt cotton sown under different sowing dates for pooled data.

Variables	Seed cotton Yield (kg ha^{-1})
Sympodial branches plant^{-1}	0.98**
Total bolls plant^{-1}	0.96**
100-seed cotton weight	0.95*
Total dry matter accumulation	0.94*

** = Significant at $p \leq 0.01$and * = Significant at $p \leq 0.05$

Temperature has significant impact on emergence and early stand establishment of crops (Hussain *et al*., 2012). Prevalence of low temperature might be the key towards poor and delayed emergence and stand establishment in early sown crop i.e. March 1st and 15th as it has been reported earlier in many studies (Hussain *et al*., 2012; Singh *et al*., 1997). On the other hand, the crop sown on May 1st and May 15th had quick and uniform emergence due to the prevalence of high temperature at that time but was less than the crop planted on April 1st to April 15 which might be due to high temperature-induced loss of seed viability. So, the temperature seemed the driving motive to modulate the emergence and early stand establishment of Bt cotton sown on varying dates (Siddiqui *et al*., 2004). Early sown crop completed its vegetative phase during the months of April and May when prevailing mean temperature was low.

Cotton development between planting and squaring stops below base temperature 12°C. Similarly, high temperature adversely affect the growth and development. Bt. cotton sown on April 15 yielded better than too early and late sown crop due to substantial increase in yield related traits like sympodial branches, bolls per plant, and 100-seed weight (Table 2). There was a strong positive correlation of all these traits with seed cotton yield (Table 2).

Late sown crop (May 1st and May 15th) had poor seed cotton yield owing to less number of sympodial branches and bolls per plant (Table 1). Late sown crop had fewer days than the crop sown on April 15, hence had less time to boll formation and opening leading to less number of bolls of small size. Moreover, in late sown crop, boll formation and opening took place during the hot weather of July and August; so high temperature in these months accelerated boll shedding. Actually, temperature beyond 30/20°C (day/night temperature regime) may result in decrease in boll retention due to enhanced abortion of squares and young bolls (Reddy *et al*., 1999). Therefore, mid-season plantation may increase yield (Pettigrew, 2002). In this study, although the crop sown too early (March 1st and 15th) had more time to complete its various phenophases but low temperature during early growth cycle retarded crop growth which resulted less seed cotton yield than the crop sown on April 15 (Table 1). High temperature negatively effects the photosynthesis process of the crop which directly effects the sympodial branches of the crop. Crop growth is also retarded due to less availability of photosynthates. The findings of Bibi *et al*. (2003) also supported our concept that, above 35°C, leaf extension rate was reduced significantly in upland cotton. As per findings of Saleem *et al*. (2014) less opened bolls and seed cotton yield were produced in late sowing than earlier sowing because late sown crop has to face temperature stress during flowering stage. Reduction in total bolls per plant may be a reason of less seed cotton yield during 2013 than 2014. Moreover, high rainfall near the boll formation stage produced fewer bolls to contribute in seed cotton yield.

Mid-season sowing provided better environmental conditions, which allowed the plant to gain more sympodial branches and number of bolls; hence resulting in more seed cotton yield than delayed sowing (Bozbek *et al*., 2006; Bange *et al*., 2008; Wrather *et al*., 2008). Reproductive stage of cotton plant just starts after the initiation of first square and continue with the development of new fruiting branches resulting in production of fruiting sites (Deho *et al*., 2012). But in late sown crop, boll maturation period is shorter than early sowing (Bednarz *et al*., 2005). Similarly, flowering interval also perform a key role because early flowering is translated in better yield (Pettigrew, 2002; Ali *et al*., 2009) as was observed in this study.

Although the yield related characters are genetically linked but the impact of growing conditions like time of sowing, cultivars and prevailing weather etc. also have significant impact as observed in this study (Ali *et al*., 2009; Awan *et al*., 2011; Deho *et al*., 2012;).

***Conclusion*:** Early sown Bt cotton i.e. March 1st and 15th had poor and delayed emergence, and erratic crop stand. Sowing of Bt cotton on April 15 (mid-season planting) is the best option to get good crop stand tied with higher seed cotton and lint yield under arid to semi–arid conditions of Punjab, Pakistan.

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