Chapter 3
Managing Planting Time for Cotton Production

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Abstract Since cotton is responsive to its surrounding environments, an appropriate planting time is very important to realize its optimum yield potential. The temperature is an important environmental factor for which planting time varies across the world. It may be from few days to weeks, called as planting window. It must be optimized according to yield target, forthcoming weed, pest, disease, and abiotic stress problems. The planting time is considered optimum if it permits the completion of the crop vegetative and reproductive growth stages in an efficient way. There is an optimum planting time and further delay drastically reduced seed cotton yield. It determines the duration of various phenological stages such as appearance of first square, flower, and boll split on 50% population and total crop duration. Generally, early planting results in higher yield by extending growth period, and late planting reduces yield because of shortened season. The planting time has a major role for fiber and seed quality optimization to ensure good-quality yarn and better seed germination. The planting time is strictly monitored and legally implemented in certain regions of the world to prevent disease and pests. The climate change is threatening cotton production throughout the world, and adjustment of planting dates may play an effective role as an adaptation strategy to match fruiting phase to favorable climate.

Keywords Planting window · Yield · Seed · Lint quality · Climate change

Abbreviations

BB	Bacterial blight
CCRI	Central Cotton Research Institute
CIM	Cotton Institute Multan
CLCuD	Cotton leaf curl virus disease

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ENSO	El Niño-Southern Oscillation
NIAB	Nuclear Institute for Agriculture and Biology
RLS	*Ramularia* leaf spot

3.1 Introduction

The cotton crop possesses indeterminate growth habits which take advantage of duration of growing season (Ali et al. 2011, 2013a, b, 2014a, b). The growth and development of cotton are highly influenced by prevailing weather variables at various growth stages (Ahmad et al. 2014, 2017, 2018; Abbas and Ahmad 2018; Ahmad and Raza 2014). Planting at various dates creates variable weather conditions which affect the growth and yield. The planting time is optimized in such a way that the developmental stage may coincide with desirable environmental conditions (Amin et al. 2017, 2018; Tariq et al. 2017, 2018). The optimum planting time ensures uniform stand establishment, growth, and improved seed cotton yield (Khan et al. 2004; Rahman et al. 2018; Usman et al. 2009). The decision of best planting time is based on soil temperature; availability of canal or rainwater; incidence of diseases, pests, and weeds; and harvesting time of crops in rotation with cotton. The early planting prolongs the growth season which translates into higher yield. It is preferred in regions where low heat units are accumulated. In this way, the crop will be mature before the onset of the fall. The late planting is often left with no chance of successful replanting in case of germination failure. The selection of planting date is even more important than irrigation for obtaining higher yield (Hallikeri et al. 2009). The cotton yield is highly influenced by planting time due to its relevance with heat unit accumulation. Therefore, the planting time varies across cotton-growing countries which have been summarized in Table 3.1.

The advent and duration of various phenological stages were also affected by prevailing temperature which depends upon the planting time. The planting time affects the growing degree days' accumulation for completion of various stages. The

Table 3.1 Time of planting of various cotton-growing countries

Regions	Time of planting
USA	March, April
Greece	April
Central Asia	April
China	April
Middle East and Egypt	May
South Asia	June
Argentina	September, October, November
Australia	September, October, November
Brazil	October, November

Source: US Department of Agriculture [Major World Crop Areas and Climatic Profiles] days taken to start emergence, 50% emergence, and mean emergence time were gradually decreased with delay in planting from 14th February till 15th May (Shah et al. 2017). The days taken to square, flower, and first boll split were reduced with delay in sowing (Sohair et al. 2015; Shah et al. 2017; Iqbal et al. 2018). The cotton seed quality is highly influenced by time of planting and picking. It was revealed that emergence of seed harvested from early sowing was delayed (Kamran et al. 2017).

The significantly higher seed cotton, seed index, and dry matter yield from early planting have been witnessed in literature (Arshad et al. 2007; Ali et al. 2009; Huang 2016). However, oil contents were improved with delay in sowing (Mohamed et al. 2016). The fiber traits like fiber length, uniformity, and spinning consistency index showed non-significant relationship with planting time. However, micronaire, fiber strength, and fiber elongation were decreased, and short fiber contents were increased with the delay in sowing (Killi and Bolek 2014).

The early sown crop can better withstand with weeds than late sown. The lower weed competition, density, dry matter, and yield losses were reported in early sown crop (Webster et al. 2009; Tauseef et al. 2012; Hariharasudhan et al. 2017). The planting time has been used for disease and insect management. The early planting has been suggested for tarnished plant bug management in Mississippi (MS) Delta (O'Berry et al. 2008) and cotton leaf curl disease management in Pakistan (Iqbal and Khan 2010). On the other hand, the early planting has been banned in Pakistan to tackle the problem of pink bollworm infestation.

3.2 Goals of Planting Time Optimization

3.2.1 High Yield and Better Lint Quality

Optimum planting provides proper growing season to best utilize the natural sources for higher yield. The planting time determines the crop growth season, duration of phenophase, and dry matter partitioning to various plant organs (Ali et al. 2009). The yield increases of about 10% in Mississippi Delta, USA (Pettigrew and Adamczyk 2006); 60.1% in Dera Ismail Khan, Pakistan (Usman et al. 2016); and 51.4% at Sakha Agriculture Research Experimental Station, Egypt (Sohair et al. 2015), have been reported by adjusting planting time. Although boll weight and ginning out turn vary under the influence of planting time, the number of bolls is more affected. The low yield in delayed planting in comparison with early planting is the result of short reproductive period, heat stress during early development, and sub-optimal temperature, photo period, and solar radiations during reproductive stages (Rahman et al. 2016).

The fiber length, strength, micronaire values, and uniformity index are some of the key attributes of fiber quality. In general, cultivar selection and growing environment matter the fiber quality, while the impact of crop management remains inconsistent. The ginning out turn, fiber length, strength, fiber elongation, uniformity index, and micronaire values decreased with late sowing (Ali et al. 2009; Awan et al. 2011; Sohair et al. 2015; Usman et al. 2016). The lower micronaire values in late sown conditions suggested that late sowing of genotypes with high micronaire value may offer an opportunity for reducing its value. However, in certain environments, the mid planting produced higher ginning out turn and superior fibers over early and delayed planting (Awan et al. 2011; Shah et al. 2017).

3.2.2 *Insect, Disease, and Weed Management*

The selection of planting time is an important tool for the management of insects, diseases, and weeds. The early planting was suggested for the management of tarnished plant bug in MS Delta (O'Berry et al. 2008). Likewise, the early sowing is being discouraged in Pakistan for the management of pink bollworm. The diseases' infestation level also varies in response to planting time. The early planted cotton during the third week of December in Brazilian conditions was more infested with *Ramularia* leaf spot disease than the crop planted during the third week of January (Ascari et al. 2016). Similarly, early cotton planting is a better management strategy to minimize the cotton leaf curl virus incidence in Pakistan (Iqbal and Khan 2010). The bacterial blight is the most common disease of cotton in Sudan which flourishes in warm humid weather. The results of experiment conducted by Mohammed et al. (2003) suggested late planting is safer for the disease incidence in comparison with early planting. For such diseases, particular planting window is defined and implemented on large scale by the government agencies.

The weeds' competitive ability varied with planting time. Generally, the weeds compete less in early sown crops than late sown crop. The lowest weed density and dry matter were recorded in first August planting as compared to 15th August, first September, and 15th September planting (Hariharasudhan et al. 2017). The damp and moist weather in the month of July favors growth and development of narrow leaves weeds. The problem is more severe for late sown crop with poor plant canopy development at very early stage (Tauseef et al. 2012). The competitive ability of Benghal dayflower was assessed in Georgia cotton, sown at various times. Its presence resulted in yield loss of about 21–30% in May-planted crop, while 40–60% more yield losses were recorded in June planting (Webster et al. 2009).

3.2.3 *Heat and Drought Stress Management*

Adjusting planting time is helpful to offset the effects of bad weather events, particularly heat and drought. In the areas where planting window is wider, the farmers may prefer different planting time to avoid unpredicted weather events. It may reduce the bad effects of the drought events, pest attack, boll rot and other seedling disease, etc. Mitigating heat stress through planting time adjustment may be less important for irrigated than rainfed cotton (Luo et al. 2016). Shifting planting time may avoid the period of high evaporation demand to efficiently use available water. The concept of climate zones thus has been used to decide planting time according to soil water availability and to match subsequent crop growth with optimum climatic conditions (da Silva et al. 2007).

3.2.4 Seed Quality

The seed quality determines the success of planting particularly in stressful environment. The planting time affects the seed quality mainly when boll opening coincides with rainy season. The seed quality reduced with delay in sowing from 25th April to 10th June. The second (25th May) and third sowing dates (10th June) produced 1.74 and 3.35%, 3.90% and 14.99%, 3.40% and 8.76%, and 1.75% and 5.00% less seed weight, embryo weight, embryo oil, and protein contents, respectively. The differences in seed quality between planting time are due to variations in daily mean, maximum and minimum temperature, and solar radiations. The oil and protein accumulation is faster in early sown crop than late sown crops, mainly from temperature effect (Wei et al. 2017). The delayed sowing mostly pushes the crop to cold environment and poor light penetration which reduces the sucrose translocation from leaves to developing boll (Liu et al. 2013).

3.3 Factors Affecting Choice of Planting Time

3.3.1 Soil Temperature and Precipitation

The soil temperature is an important environmental factor which affects the date of planting. The cotton planting is not recommended if the soil temperature is below 16 °C (Luo et al. 2016). It must be consistent about three consecutive days because short changes in temperature may be misleading. Such variations in required temperature make the cotton planting time different which has been listed in Table 3.1. The lower temperature delays the germination process and produces poor stand. Conventionally, the calendar dates are used to define regional planting windows based on long-term farming experience. The weather projections may be used to estimate the approximate date with the right temperature to make all the necessary arrangements for planting. The occurrence of rainfall during sowing determines the planting time of rainfed cotton. The knowledge of future weather conditions is required to coincide peak irrigation requirement with rainy season. The planting time should be adjusted in such a way that boll opening coincides with less rainy season to avoid seed and fiber quality deterioration from boll rot disease.

3.3.2 Genotypes

The prevailing weather conditions at critical growth have a strong impact on the yield formation process. There are two means to adjust particular growth stages with specific environment which include shifting planting time and selection of genotypes. The potential yield of cultivar can be harvested only if planted at optimum time. The continuous experimentation is being carried out to find out the optimum planting time for different cotton varieties in local environment. In fact, different genotypes have been identified for specific planting windows, and yield decline occurs in case of delayed planting. The crop duration is reduced in case of late planting for which short-duration genotypes should be preferred, while long-duration genotypes are suitable for early planting to harvest maximum yield benefits. The earliness character also plays an important role for deciding planting time in areas where boll opening may coincide with rainy season. Therefore, decision of planting time is based according to genotypes in hand for cultivation.

3.3.3 Cropping Sequence

The cropping sequence affects the planting time by making land fallow. Harvesting of previous crop and cultivation of successive crop determines the planting time. In some cropping sequence, a lot of time span is available between harvesting and planting, and planting window is wider for such sequence. However, the harvesting and planting time overlap in certain cropping sequence, e.g., wheat-cotton and planting window become narrow. The cotton crops sown in wheat-cotton, sunflower-cotton, and maize-cotton sequence in Pakistan often get late (Ahmad et al. 2017; Tariq et al. 2018). Hence, cropping season moves with planting time. In cropping systems, where planting time overlaps the harvesting of the preceding crop, the relay cropping technology is preferred for timely planting.

3.3.4 Availability of Inputs and Labor

The labor availability is an important factor to decide the planting and picking time. If two crops mature simultaneously at local level, there should be delayed or early sowing of one of the crops to avoid labor at crises at maturity. For example, the maturity time of cotton and peanut matches in South Georgia where early planting time of short maturity varieties may be used for early picking to overcome the labor crises.

3.3.5 Diseases and Pests

The disease incidence requires specific environmental conditions in addition to host availability and likely to prevail at particular time. The farmers are usually well familiar with the disease appearance time and critical sensitive growth stages. In this regard, shifting planting dates aims to avoid host availability or enable host plant to better tolerate the diseases. Such examples include *Ramularia* leaf spot (RLS) in Brazil, cotton leaf curl virus disease (CLCuD) in Pakistan, bacterial blight (BB) in Sudan, and *Fusarium* wilt in Australia (Ascari et al. 2016; Iqbal and Khan 2010; Mohammed et al. 2003; Allen 2005). The early sowing is preferred in areas which are very prone to CLCuD incidence. It enables the crop to attain enough vigor to tolerate the disease problem.

3.3.6 Technological Advancement

Planting time also varies with the advancement in production technology. For example, planting time in China has been advanced about 7–10 days by plastic film mulching (Dai and Dong 2014; CRI 2013). Similarly, the area under early planting was significantly increased in Pakistan with the arrival of transgenic (*Bacillus thuringiensis* (Bt)) cotton cultivars. This technology provides the built-in protection against selected bollworms which were a major threat for conventional cultivars under early planting system. The mechanical picking is gaining popularity which would require the development of compact cotton cultivation. The planting time is a very important tool to keep the crop compact to make it harvestable through mechanical picker. The results of experiments conducted at Yellow River valley, China, indicate that late planting should be preferred over seasonal planting for mechanical picking (Wang et al. 2016).

3.4 Planting Time Vital for Cultivar Selection

The cotton cultivars are responsive to environmental conditions in terms of phenological development like time for initiation of squaring, flowering, and boll maturation (Singh et al. 2007). The cotton cultivar NIAB-112 was regarded as an early maturing cultivar because it completes phenological development earlier about 6–8 days in comparison with AA-802 and IR-3701, the long-duration cultivar. The boll opening of 21st June planting was reduced by 18 days over 10th March planting which drastically affected the boll development in the last planting and produced poor yield (Rahman et al. 2016). Therefore, different cultivars are sown at their proper time to coincide growth stages with optimum weather conditions. The genotype yield and growth response are modified by various planting dates, and such association indicates that genotypes had differential weather requirement. The response of CIM-602 was different than CIM-598, CIM-599, and Ali-Akber 703 because CIM-602 produced the highest bolls and seed cotton yield with 04th May planting, while 19th April was the optimum planting time for the rest of the genotypes (Usman et al. 2016). The short-duration cultivar will perform better for late planting. The early planting of long-duration cultivars is required in areas where the risk of end season frost is present. However, early maturing varieties can be sown in normal sowing time to avoid the peak fruiting period with frost.

3.5 Shifting Planting Time for Climate Change

The climate change is a continuous process and has become the major challenge for cotton production. The year-to-year variations among various planting date experiments are due to results of climate impacts. The impact of climate change is not the same in various regions but depends on prevailing temperature. For instance, the yield increase of 782.6 kg ha^{-1} was expected in Northwest China with 1 °C rise in diurnal temperature range from peak bloom to maturity, whereas a mean temperature increase of 1 °C during whole growing season may result a yield increase of 4765.9 kg ha^{-1}. The sunshine hour's value from budding to anthesis is important for leaf area index. The yield may be improved by 0.0121 kg ha^{-1} per sunshine hour from budding to anthesis (Huang 2016), while it has a negative relation with yield in hot countries because a yield decline of 110 kg ha^{-1} is estimated with every increase in ambient temperature above optimal value (Singh et al. 2007). Hence, better understanding of climate change impact is necessary to adjust planting time. The shedding of fruiting structure is accelerated with rise in temperature (Tariq et al. 2017, 2018). The global warming in addition to yield reduction would accelerate the occurrence of phenological events, thus reducing the duration of phenophases. Generally, sowing occurs earlier with increasing temperature trends during planting season. The cotton sowing has been advanced by 5.35 and 0.24 days decade^{-1} in Pakistan and North China Plain from 1980 to 2015 and 1981 to 2012, respectively (Ahmad et al. 2017; Wang et al. 2017). In such circumstances, the regional sowing time should be critically reviewed and revised to take the full advantage of heat sources and other climatic attributes. Various environmental conditions are imposed at different growth stages through planting time adjustment. The shifting planting time is being taken as adaptation strategies to minimize the impact of various weather vagaries. The ENSO (El Niño-Southern Oscillation) influences the cotton production in Georgia, USA. One of the suggested key management to minimize the impact of ENSO is shifting planting time (Paz et al. 2012). The analysis of 33-year yield data revealed that planting time should be 20 days back than 10th May under Faisalabad, Pakistan, environment to minimize the impact of adverse weather on yield (Rahman et al. 2017). The results of multiyear sowing time trials indicated the year-to-year yield variability (Pettigrew and Dowd 2011; Pettigrew and Meredith 2009), suggesting the role of climatic variability for planting time decision. The short-term field experiments of about 2–4 years do not produce reliable results for deciding planting windows for long-term climate variability. About three decade field experimentation would be required to account variations in climatic variables (Anapalli et al. 2016). Indeed, the approach is very expensive and time-consuming; however, the crop modelling approach enables us to explore the climatic variable impacts on a long-term basis from short period field experiments.

3.6 Planting Time Adjustment for Cotton Leaf Curl Disease Management

The cotton leaf curl disease is the most important disease of the cotton in Pakistan, India, and Africa which is characterized by upward leaf curling, vein thickening, leaf enation, and stunted plant growth. It appeared as a minor disease in Pakistan during 1967; however, it became a serious disease during the early 1990s. It caused huge yield losses of about one million bales by reducing productivity from 9.05 to 8.04 million bales during 1992–1993 (Mahmood et al. 2003). Various disease management approaches including development of resistant strains were tested. But no single approach provided desirable results on a long-term basis, and integrated strategy was outlined for its management. The disease appearance depends upon environment where day and night temperature difference and level of relative humidity are very important. The incidence is favored by small differences in day and night temperature and higher levels of relative humidity. Therefore, the presence of younger plants along with such favorable environment promotes the disease infestation. The planting time may be adjusted to provide enough growth season prior to disease arrival. Three-year field experiments (2015–2017) were conducted at Central Cotton Research Institute (CCRI), Multan, Pakistan, to monitor the disease incidence on transgenic and non-transgenic genotypes at 15-day interval for various planting times. The transgenic genotypes were planted on 01st March till 15th May, and non-transgenic genotypes were planted from 15th April till 15th June. The results revealed that March planting of transgenic genotypes avails about 105-day

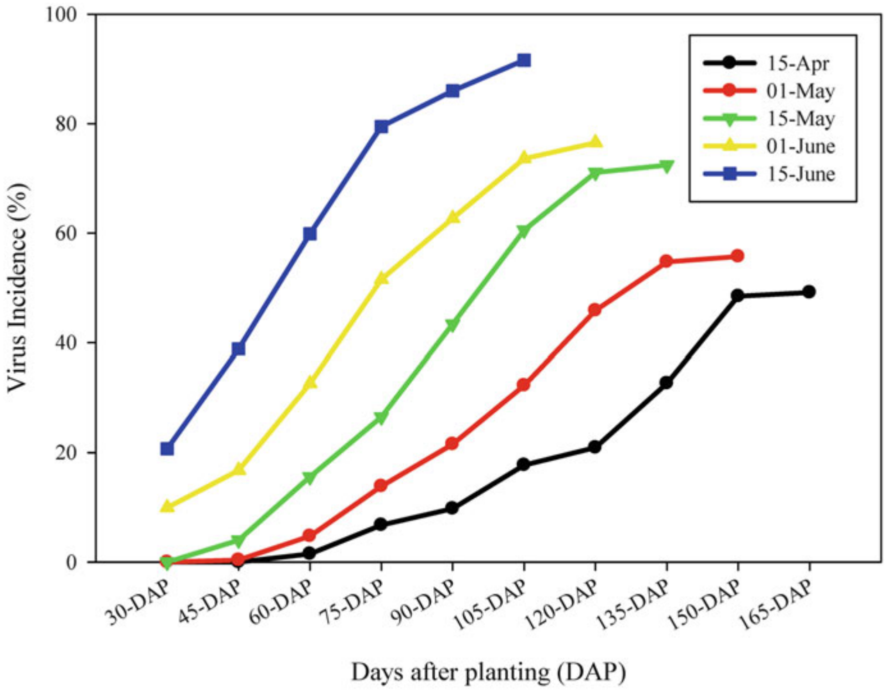

Fig. 3.1 Cotton leaf curl incidence (%) trend on transgenic genotypes across various planting time

virus-free period. The length of disease-free period gradually decreased with delay in sowing, and disease infestation appears at very early growth stages (Fig. 3.1). The March planting showed virus incidence below 50% at 180 days, while 100% disease incidence was observed at 105 days for May planting. The disease progression rate remains low for early planting and high for late planting. Therefore, March planting is a safer planting window to minimize the risk of disease infestation. The same trend appears for non-transgenic cotton where disease appears at 60 days after planting for April planting, while June planting is infested with disease at very early stages (Fig. 3.2). The impact of disease on yield reduction is more if the crop is infested during early growth season. In case of late planting, the virus-tolerant genotypes should be preferred to secure yield from reducing the virus infestation level.

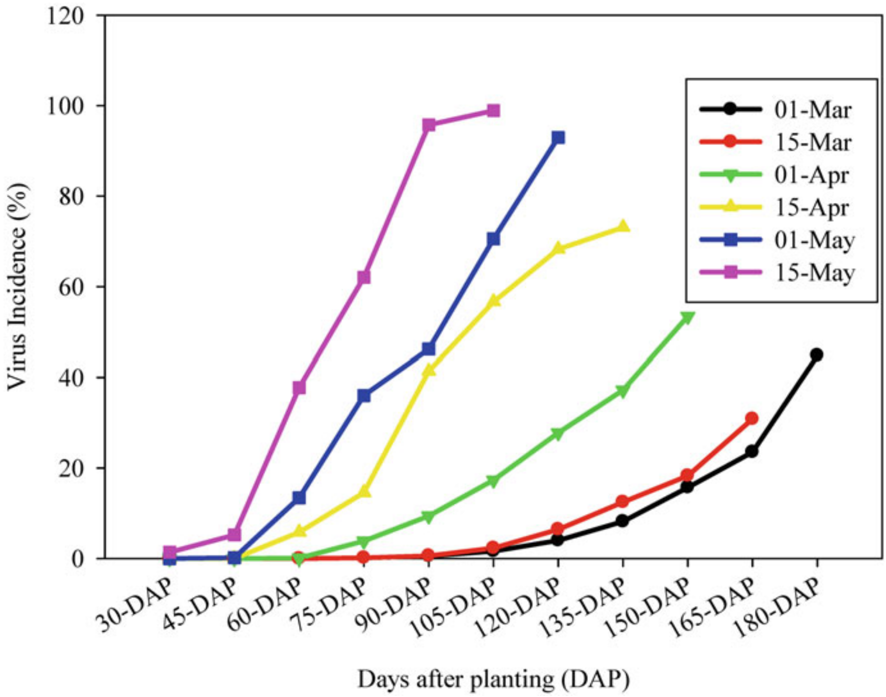

Fig. 3.2 Cotton leaf curl incidence (%) trend on non-transgenic genotypes across various planting time

3.7 Conclusion

Because shifting planting times alters the crop growth season, the impact of climatic conditions would vary at various planting time. Such variations have a deep impact on yield formation process. The planting time decides yield potential because of its relation with crop phenology and seasonal crop duration. The decision regarding selection of planting time is even more important than cultivar selection in cotton. The selection of planting time is objective oriented which may be adjusted for higher yield; better fiber quality; management tool for weeds, diseases, and insects; and drought and heat stress. The impact of planting time is significant for yield and yield components and remains variable for fiber quality in various environments.

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