Cotton Crop: Various Aspects and Transition from Past, Present and Future

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Abstract:

Cotton is a fibre crop and the oldest among the commercial crops of global significance. It belongs to Gossypium genus of family Malvaceae. It is warm season crop and grown worldwide with narrow temperature range. The plant is unique because it's a perennial plant with an indeterminate growth habit and has perhaps the most complex structure of any major field crop. Due to its complex growth habit is extremely sensitivity to adverse environmental conditions. Better understanding of cotton physiology and its response towards changing environment is significant for the commercial production of the crop. Origin crop can be traced back to the Indus Valley civilization in the Indian subcontinent and it is grown until now. It has pushed back the position of United States of America to third in 2006 and China to second in 2014 and surpassed every nation to be at the first position to as per USDA reports. Again to ensure its production efficacy in the coming year's one has to understand the intricacies of effect of changing climate on the cotton crop. Location-specific best management practices have to be provided to enhance its productivity in the coming years.

Keywords: *Cotton, origin, climate change, adaptability*

I. INTRODUCTION

The history of cotton is as old as human civilization itself. From the period of domestication of the cotton plant by several old civilizations till present times, this particular plant and its by products have given many things to the humankind. One of the most important contributions is the fabric which is received from it. The transition of the usage of cotton and its products can vary from purely functional decorative use of it to the shift in the manufacture of textile from a highly individualized and specialized cottage craft to a mechanized and large-scale operation. This outcome of the creative genius of many persons from all walks of life has contributed to the evolution of the particular material. These changes are closely interlaced with events in other spheres of human history. The cotton plant and the various factors starting from its birth till the harvest of the crop, it undergoes various stages. Moreover, several other physiological as well as climatic factors are deeply involved in the full fledged growth of this particular crop. Therefore, the cotton plant which comes under the category of cash crops, demands us to examine its economic value as well.

There has been discovery of evidences of cotton under various aspects of the civilization. It is traced that how a single plant and its usage and the products is deeply connected in our day to day lives of every individual. An attempt is made to highlight the perks and the importance of cotton which is not only an essential part of the society but also the economy and the natural environment it is grown. For last many centuries and several different time period it has served various services and also different purposes to the mankind. And on the other hand, mankind have exploited this particular crop in various ways. A sincere emphasis is put to draw a nexus between historical, economical, physiological aspects of the cotton plant, as a crop. This overall understanding is important so that it will help in managing a view about the future where, steps could be taken to protect the crop and enhance its production.

Cotton fabric has been found in the excavations of Mohenjodaro and pre- Inca cultures in America. In 1929, archaeologists recovered fragments of cotton textiles in Mohenjodaro dating between 3250-2750 B.C. This indicates the use of it to a very old period and most probably , one of the ealiest evidence. In the context of the Indian subcontinent , the by products of the cotton plant and its history of usage dates backs to the ancient period and many more other examples are found. In another instance, the Vedic scriptures , composed between 1500-1200 B.C. also allude to cotton spinning and weaving (Hagge, P. D. ,2013; p.586)

Continuing the culture of cotton production and its uses, under the Mughal Empire, which ruled in the Indian subcontinent from the early 16th century to the early 18th century, Indian cotton production increased, in terms of both raw cotton and cotton textiles. The Mughals introduced agrarian reforms such as a new revenue system that was biased in favour of higher value cash crops such as cotton and indigo, providing state incentives to grow cash crops, in addition to rising market demand. (John . F. Richards, 1995;Pg, 190) .

The largest manufacturing industry in the Mughal Empire was cotton textile manufacturing, which included the production of piece goods, calicos, and muslins, available unbleached and in a variety of colours. The cotton textile industry was responsible for a large part of the empire's international trade.((John . F. Richards, ,1995; Pg. 191).

India had a 25% share of the global textile trade in the early 18th century. Indian cotton textiles were the most important manufactured goods in world trade in the 18th century, consumed across the world from the Americas to Japan. The most important center of cotton production was the Bengal Subah province, particularly around its capital city of Dhaka. Bengal accounted for more than 50% of textiles imported by the Dutch from Asia, Bengali cotton textiles were exported in large quantities to Europe, Indonesia, and Japan, and Bengali muslin textiles from Dhaka were sold in Central Asia, where they were known as "daka" textiles. (John . F. Richards, 1995; Pg. 202.)

The worm gear roller cotton gin, which was invented in India during the early Delhi Sultanate era of the 13th–14th centuries, came into use in the Mughal Empire sometime around the 16th century, and is still used in India through to the present day(Habib, I. 2011.; Pg 53) . Another innovation, the incorporation of the crank handle in the cotton gin, first appeared in India some time during the late Delhi Sultanate or the early Mughal Empire. The production of cotton, which may have largely been spun in the villages and then taken to towns in the form of yarn to be woven into cloth textiles, was advanced by the diffusion of the spinning wheel across India shortly before the Mughal era, lowering the costs of yarn and helping to increase demand for cotton. The diffusion of the spinning wheel, and the incorporation of the worm gear and crank handle into the roller cotton gin, led to greatly expanded Indian cotton textile production during the Mughal era (Habib, I. 2011.; Pg. 53-54).

The cotton industry has been highly dominated by India in the 18th century and was taken over by the British. India's cotton industry struggled in the late 19th century because of unmechanized production and American dominance of raw cotton export. India, ceasing to be a major exporter of cotton goods, became the largest importer of British cotton textiles. During 20th Century , when India's independence struggle began , _Mahatma Gandhi believed that cotton was closely tied to Indian self-determination. In the 1920s he launched the Khadi Movement, a massive boycott of British cotton goods. He urged Indians to use simple homespun cotton textiles, khadi Cotton became an important symbol in Indian independence. During World War II, shortages created a high demand for khadi, and 16 million yards of cloth were produced in nine months. The British Raj declared khadi subversive; damaging to the British imperial rule. Confiscation, burning of stocks, and jailing of workers resulted, which intensified resistance. In the second half of the 20th century, a downturn in the European cotton industry led to a resurgence of the Indian cotton industry. India began to mechanize and was able to compete in the world market (Logan, F. A., 1958). Cotton has also played a very important role in the freedom struggle of the country. One single crop has seen many faces of transition in the ongoing centuries.

The economy of an agro based country like India is predominantly based upon the agriculture sector. This includes the production of edible crops for food security and commercial crop as well for economic empowerment. Cotton is world's most important fibre crop and second most important oil seed crop (Freeland Jr T. B., et al., 2006). It is a source of fibre, oil for human consumption, protein meal for livestock feed and potentially a fuel for diverse industries. The waste after ginning can also be used as fertilizer and cellulose as paper and cardboard (Freeland Jr T. B., et al., 2006). It is grown worldwide with India as highest producer accounting for 26% of the total world's cotton production and largest area under production as 38% to 41% as its share (International Cotton Advisory Committee report, March 2017). Due to its economic importance it is our priority to provide it with best management practices to increase its production. For the year 2016-17 projected area is 105 lakh hectares for the of production of 351 bales for the yield of 568 kgs per hectare (Cotton Advisory Board, 2017). In India, cotton is grown in three discrete agro-ecological zones: The Northern zone (Punjab, Haryana and Rajasthan), the Central zone (Gujarat, Maharashtra and Madhya Pradesh) and the Southern zone (Andhra Pradesh, Tamil Nadu and Karnataka) Orissa and others. Perhaps no other crop has garnered as much controversy in the history of Indian agriculture as has Bt-cotton been both before as well as after its introduction. Bt-cotton is a genotype developed by the techniques of genetic engineering also referred to as transgenic. It contains endotoxin which is protein inducing gene from soil bacterium Bacillus thuringiensis. The introduction of this transgenic has been done to provide the growers with a new tool for managing bollworms. But the rising controversy is due to its failure to fight against other pests and ultra-expensiveness for the growers in general.

To ensure proper seed germination and crop emergence adequate soil temperature and moisture conditions are required at the time of planting (Oosterhuis D., 2001). Crop production is directly influenced by temperature, photoperiod, total radiation, and precipitation. stated that Processes

leading to squaring, flowering and boll formation and maturation are temperature-dependent (Mauney J. R., 1986). Minimum of 15ºC is required for germination, 21ºC-27ºC for vegetative growth, and 27ºC-32ºC during the fruiting period (Freeland Jr T. B., et al., 2006). Cool nights are beneficial during fruiting period but extremes in temperature can result in delayed growth and aborted fruiting sites. Cotton needs between 550 mm and 950 mm for water not to be a limiting factor for the yield evenly distributed during the cropping season (Doorenbos et al., 1984). Precipitation or humid weather conditions during later stages of cotton growth can promote the pests or insects attack and disease such as boll rot (Boyd et al., 2004). Water stress can manifest reductions in photosynthetic activity and increases in leaf senescence (Gerik, T. J. et al., 1996), stunned plant with reduced leaf (Pettigrew W. T., 2004b). Drought stress can cause severe shedding of small squares, resulting in decrease in flowering reduce fibre length (Pettigrew W. T., 2004a). Hence, we can say that a combination of warm and dry weather conditions along with abundant sunshine and sufficient moisture during the bolls opening till the harvest will maximize yield and quality potential (Freeland Jr T. B., et al., 2006). For attaining its potential productivity it requires long frost-free days, warm season with mean annual temperature of over 16°C, plenty of sunshine, and a moderate rainfall usually from 450 to 750 mm. Cotton can be successfully grown on all soils (sandy loam, clay loam, loam, alluvial soils, black cotton soils, red sandy loams to loams and lateritic soils) except the sandy, saline and waterlogged soils. Cotton is semi-tolerant to salinity and sensitive to water logging and thus prefers well- drained soils. Cotton requires a soil with excellent water-holding capacity, aeration and good drainage, since excessive moisture and water logging are detrimental to production. Monocropping of cotton and heavy dependence on chemical fertilizers should be avoided in order to maintain stability of cotton production.
Characteristic of agricultural drought is different from other types of droughts. Thus, there is the need to analyze agricultural drought events based on continuous weather data upon seasonal basis. And any realistic definition of drought must be region and application specific (Raymond, 2010).

Cotton is grown as an annual crop, but has a xerophytic, woody perennial nature (Hearn A. B., 1980). Among the major field crops Cotton possibly has the most complex structure. Also it is very sensitive towards adverse environmental conditions (Oosterhuis D.M., 1990). The stages of growth and development in cotton plant are coinciding and overlapping upon each other. So its precise demarcation is not possible as in case of other crops like wheat and rice. The growth stages consist of both vegetative and reproductive phases. After sowing, the vegetative phase starts which includes seedling, emergence, and formation of leaf. Further the reproductive stage starts with the formation of squares, followed by flowers and then ball. The nutritional hypothesis in combination with hormonal influences playing a significant role on the changes in growth patterns during the cotton ontogeny, with a negative correlation between vegetative and reproductive growth (Guinn, 1986). However vegetative and reproductive growth could continue indefinitely under favourable conditions. But due to limitations on the resource supply by the reproductive organs the vegetative growth cease at the time which is called 'cut-out' (Hearn et al., 1994).

After planting, seedlings can emerge within 5 to 7 days under favorable conditions. Vegetative growth and development takes around 40-45 days after emergence. This includes development of root, stem and leaves system. After the vegetative growth, reproductive growth starts. It actually starts with the appearance of first floral-bud on the lowest fruiting branch after 30-35 days of emergence, depending upon prevailing environmental conditions. This is followed by coming up of other floral-buds at regular intervals until flowering ceases. Flowering can cease after the ball formation starts or due to and stress. During the period of peak flowering, the vegetative growth is almost contemptibly small in amount. Some shedding of squares is probable to happen, even under the best management practices. The cotton plant may shed off 40% to 50% of all its squares, which is further benefitted during its ball formation and maturity. Extensive shedding may occur due to stress which can upset the vegetative and reproductive balance of the plant and affect its yields. The plants response to "cutout" as shedding of squares is to consume the produced carbohydrates in maturing the balls. Yields can also be reduced if cutout occurs too early. Squares also may shed off either because of insect damaging the plant or due to the poor growing conditions. Both flowering and seed formation keeps occurring in the same plant at different branches. During this phase fertilization of the flowers occurs. The cotton blossom is a perfect flower. It contains both female parts and the male parts in the same flower. These fertilized flower finally results into seed. This process of first flower to the first seed formation generally takes 18-24 days. After fertilization has occurred the flower drops and a small ball is formed. It generally starts after 65 days of sowing. It takes 30 to 35 days for its formation phase. In a plant, at the same time the square is formed, the flower is blooming and the balls. Not every ball that is formed makes it up till maturity. Initially, the process of ball development is slow during its formation. Later, the growth rate enhances and reaches steady phase of growth. Balls that set late in the season often take longer time duration to mature than that set early and in the middle of the fruiting season. Balls that set in time have enough time to develop, mature and open to produce quality lint, with good yield. Balls that appeared late are generally smaller, not mature properly and may not open. Thus the quality of lint and yield is generally low. After ball formation, four to five weeks are required for ball maturation. First ball generally begins to open 100 to 110 days after cotton sowing. During this phase thickening of fiber occurs by the deposition of consecutive layers of cellulose in the inner walls. In this phase of ball maturation fiber elongation can be impacted by numerous factors. Length and the quality of the fiber is largely controlled by the genetic code. But, length could also be influenced by the environment. Stress during this period can cause fibers to be shorter than normal. Finally after maturity the crop is harvested for the final product. In general the number of pickings are four (120, 140, 155 and 165 days after sowing) and vary according to the availability of labor. After the balls are matured, they are ready to be harvested.

Historical climatic information can be utilized to understand its intricacies and take advantage and divert ill effects of weather. Future climate change scenarios can also be assessed based modeling to mitigate its ill effects. Although with changing climate weather almost remains similar to the average. The intensity and frequency of intermittent rainfalls with longer periods of dry spells in between and extreme hot and cold days are threatening for the crop productivity across the globe (Liebig, M.A. et al, 2012).With this still evolving climate change scenarios, our soil, water and other natural resources are deteriorating (Gurdak, J.J. et al 2012). Elevated temperature and carbon dioxide affects the biological processes like respiration, photosynthesis, plant growth, reproduction, water use etc (Murthy, 2002). In cotton it affects plant fitness and flowering related events by regulating of flowering time (Jagadish S.K., et al., 2016). Under irrigated conditions, cotton yields increased significantly with changing climate driven by low to moderate emission levels of RCP 2.6, 4.5, and 6.0 in years 2050 and 2080, but under the highest emission scenario of RCP 8.5, the cotton yield increased in 2050 but declined significantly in year 2080. But under rainfed conditions, the yield declined in both 2050 and 2080 under all four RCP scenarios. However, the yield still increased when enough rainfall was received to meet the water requirements of the crop, in about 25% of the cases (Saseendran S. A. et al., 2016).

The simulations show that change in meteorological parameters can influence the crop productivity which is the resultant of climate change. This would lead to reduced cotton yields in the future scenarios without the effect of CO_2 fertilisation. With the effects of CO_2 fertilisation, it ameliorates the effect of rising temperature and decreased water availability to increase the yields. Also, it is found necessary to increase irrigation amounts by almost 50 % to sustain the productivity and maintain the adequate soil moisture levels (Williams et al., 2015).

So to ensure better productivity and reduced environmental risks various management practices could be followed that to helps in mitigation. This includes selection of adapted cultivars, designing and following suitable packages and practices, effective pest management, proper fertility management etc. Research based recommendations and government agencies taking initiative to disseminate information to assist cotton growers in making good management decisions to avoid or minimize risk. These sources may include environmental and climatological monitoring and forecasting services, policy makers etc. Guaranteed risk is also required for the growers to bring confidence among them while choosing this crop. This could come with various guidelines and conditions which has to be easily accessible.

But before that, to avoid making erroneous projections of yield and associated risks and design the blue print for the policies and investments physiological response of plants to climate change needs to be thoroughly understood. This has been antecedently done by field experiments, but now conjoined with modeling studies which is both cost and time effective. Crop simulation models are designed as such to intimate the behaviour of plant system. They are the mathematical equations depicting relationships between crop growth, development, yields, technology, and climate (Raymond, 2010).Thus can play a vital role in agricultural management and decision making process. Various risks are posed upon the agriculturists for the potential productivity of the crop. As defined by 'The United States Department of Agriculture’s Risk Management Agency' there are five primary categories of risks: production, marketing, finance, legal, and human risk (Harwood et al. 1999). Seasonal climate variability is major disaster in terms of potential productivity of the crop, which can also associated with market risks.

So this location-specific differences due to climate change and their impacts on agriculture necessitate the excogitation and proposing advanced mitigation and adaptation strategies for sustainability of productivity over long-term. Thus, agro-management practices based on long-term experiments, that captures all possible location specific climate variability has to be considered for robust climate-smart solutions. And as an adaptation measure for future climate change as per simulation studies, planting cotton six weeks earlier than the normal (historical average) planting date, in general, was found to boost irrigated cotton yields and compensate for the lost yields. But, this early planting strategy only partially compensated for the rainfed cotton yield losses. However, providing the crop with supplemental irrigations compensated for all the yield losses (Saseendran S. A. et al., 2016). Most suited adaptation for such climate changing scenarios is Best management practices (BMPs) with sound farming activities or practices that are natural and environment friendly. With other advantage such as prevention from pesticides, nutrients and other materials enrichment from polluting our water, air and soil.

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