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New Approaches in the Research for Increasing the Productivity of the Cotton Crop in 21st Century under the Global Warming Situation in India

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Abstract

The cotton is the most important crop and its productivity is likely to be affected in India by the climate change, due to the global warming processes in ensuing decades which has a negative impact on the agriculture, health of mankind and economy of the country. To mitigate the negative impact of the global warming it is suggested to have the current research approach for increasing the yield of the varieties and hybrids along with the new approaches involving the change of the architecture of the plants with determinate growth habit with the lesser number of small sized leaves and efficient utilizer of increasing level of CO₂ in the environment, water, fertilizers and ability to withstand the increasing level of the temperature, surface Ozone, drought, flooding and salinity. The degree of pollution at dyeing center and adjoining niches may be reduced by developing varieties and hybrids with high degree of polymerization of fibers. The mankind may be protected from the increasing degree of UV radiation by providing the fabrics made out of the naturally coloured cotton fibers.

Keywords: Cotton, yield, global warming, future strategy

1. Introduction

The environmental changes induced by the global warming due to accumulation of the CO₂, methane, nitrous oxide in the atmosphere, use of chemical fertilizers and rise in sea levels, and increase in the surface ozone level on the earth sphere affect the gene action, growth and development of all plant species including the cotton and biospecies associated with them. Under this situation using the current cotton varieties and hybrids do not give the expected yield to the farmers and to meet the demand of the user agencies. New approaches in the cotton research and development as detailed in this paper are warranted to provide the people with the healthy fabrics under the fast changing climatic situation in India.

The introduction of Cambodia cotton *Gossypium hirsutum* (Sethi, 1960) during the period of British rule though helped to augment the production of cotton in India through several high yielding varieties went against the research activities on the native species *Gossypium*

arboreum and *G. herbaceum*. The native species of cotton is tolerant to several abiotic and biotic stresses as against the hirsute varieties and forced them to remain in the germplasm. However some work has been done on the Desi cotton in India and evolved some varieties.

But the farmers were after the hirsute cotton as they are

bushy with large sized bolls and these characters retards them to harvest better yield rather forced them to become addict to the use of fertilizers and chemical pesticides. But over dependence on the chemicals have caused several ecological, economical and health hazards in the cropped and adjoining areas (Colborn et al., 1993). It has been well established that the chemical based cotton agriculture may not be profitable with the current varieties and hybrids under changing situation due to the global warming. Newer efforts are needed for improving the native species of cotton *G. arboreum* and *G. herbaceum*. The native species of cotton needs some changes in their architecture, size of bolls and quality of fibers. The native cotton *G. arboreum* and *G. herbaceum* may survive the global warming and can support the textile industries by providing their chromosomes which are doubled and used for both the pure line selection and inter-intra species hybridization for evolving new varieties and hybrids. The process of mutation breeding with aid of chemicals or irradiation may also yield the expected changes in the native cotton. The genes related to boll size, long staple length and good strength with high degree of polymerization of fibers are sliced either from the hirsute or other species of cotton and transfer into the native one. In recent years the Desi cotton with the bolls having five loculi with the increased length of fibers has been identified from Central Institute



for Cotton Research, Nagpur and this may serve as base for further research to develop high yielding quality varieties and hybrids that will go well with the different agro-climatic zones of India to overcome the effects of the global warming, and to meet the requirement of the cotton by the mankind. The Government and private research organizations including multinational corporates should come forward in a big way for initiating research on the *G. arboreum* and *G. herbaceum* to help not only India but also other parts of the world to meet the consequences of changing climate.

The green revolution and subsequent efforts to increase the yield of various crops including the cotton have forced the farmers to cultivate one particular crop for improving their farm economy which eliminated the poly crop system from the cropped habitats. The monocropping system has brought in several bio-disasters by adversely affecting the soils, environment and provided the nutrient levels for insect pests as against the poly crop system which provides inconsistent nutrient levels for insect pests.

The poly cropping system was successfully done by our fore fathers which enabled them to maintain the fertility of soils, health of human beings with less pollution and bio stresses in the cropped areas. The recent study also shows that the diversity of crops (Wetzel et al., 2016) and the existing *Jhum* poly crop system in Assam (Basu, 2016) and *Akkadi* system in Karnataka (Umesh et al., 2012) reduce the insect damage. The diverse crops in the polycrop system by constantly evolving the different secondary phenolic volatile chemicals (Nishida, 2014) mask and reduce the visitation of bio intruders including the insect pests. The secondary volatile compounds that emit from the cotton crop (Robert et al., 2008) serve as attractants to insect pests which can be synthesized and used as environment friendly technique for trapping the visiting insect pests in the cotton cropped areas.

The monocrop system by attracting a large number of species of insects damaged the crop seriously which paved the way for over reliance on the pesticides. The frequent application of insecticides besides eliminating the natural balance in the cotton system induced several physiological and biochemical changes (Sundaramurthy, 1994) in the plant system and caused resistance in insects against chemicals and ecological succession of other species of insects. These natural phenomena can be mitigated by developing the appropriate varieties and hybrids that suite the poly cropping system as the current varieties and hybrids may not fit well for developing such system. A medium duration short structured inter specific hybrid has already been developed and released for cultivation (Sundaramurthy, 1996c) which may go well with such system under the present scenario of the global warming. The materials that have been developed subsequently at Central Institute for Cotton Research and Agricultural Universities may be explored for their suitability for developing such cropping system.

Among different crops the cotton is known for its unique

character of growing indeterminately with large number of leaves which have been evolved originally from *sub-okra* type (Andres et al., 2016). Increasing the growing period of the crop inviting insect pests and provides some false hope of making bumper harvest. The scientists may appreciate that this character is a compensatory mechanism to meet the probable loss likely to occur due to environmental, physiological causes and insect's damage. It was accepted in earlier years but it is not well suited in 21st century as everything around the plant has changed now due to the warming process. The indeterminate growth habit and large number of leaves of the cotton crop is responsible for the loss of many valuables around the living beings and this trait forces the farmers to apply more fertilizers, more water and pesticides without knowing their implication and its impacts on the soils, environment, and neighboring ecosystem. But the phenomenon of over dependency on the chemical has not given the expected results in different agro systems in India.

The varieties and hybrids that are currently cultivated are not efficient utilisers of the fertilizers and water and leave considerable amount of the fertilizers in the soils and this is main cause for degradation of fertility of soil. The unutilized left over fertilizers from the soils is taken by run off of the rain water and rivers to adjoining niches and cause eutrophication phenomenon. It has been conclusively proved that the phosphorus that is present in the fertilizers and weedicides is responsible for the bloom of algae in the river and other water ways (Chislock, 2013). The phenomenon of eutrophication may be lessened by restricting the unwanted growth of the plants by developing the varieties and hybrids with the alteration of the structure of the root system, the number and size of leaves of the plants to facilitate them to be water and fertilizer efficient one as has been done with the other crops (Heppell, 2015; Streda, 2012; Srinivasan et al., 2016). The efforts are under way to manipulate the genetic code to reshape the cotton (Figure 1) leaves from the normal to okra type for enabling the pesticide spray to disperse evenly across the plant to produce higher rates of flowering which mature early in cotton (Andres et al., 2016) and yield more.



Figure 1: The normal leaf (left) and "okra" shape (right) of cotton. (Andres et al, 2016)

The short duration dwarf or semi dwarf emits comparatively lesser amount of the secondary substances from the leaves and harbor less number of insect pests resulting in less environmental pollution with the pesticides under this system. The compact determinate growth habit of cotton may be obtained by modifying the florigen as has been done in other crops (Soyk et al., 2016). The fact is that the dwarf materials are being grown in other countries in the world and similar approach is needed in India as these will go in a long way to help the mankind and lessen the ecological and environmental deficiencies including the phenomenon of eutrophication arise due to over doing with the chemicals. A dwarf inter specific hybrid Sruthi (Sundaramurthy, 1996c) has been developed at Central Institute for Cotton Research, Coimbatore some 20 years back and materials like this may go well with the poly crop system in delta area and other irrigated regions. But there are no takers as they are not bushy and attractive to the farmer's addicted psychology of using the tall growing variety and hybrids with mass of broad leaves. Recently a hirsute variety Indica (Figure 2) has been developed (Sundaramurthy, 2003) which differs from other varieties having short internodes with the capability of the boll

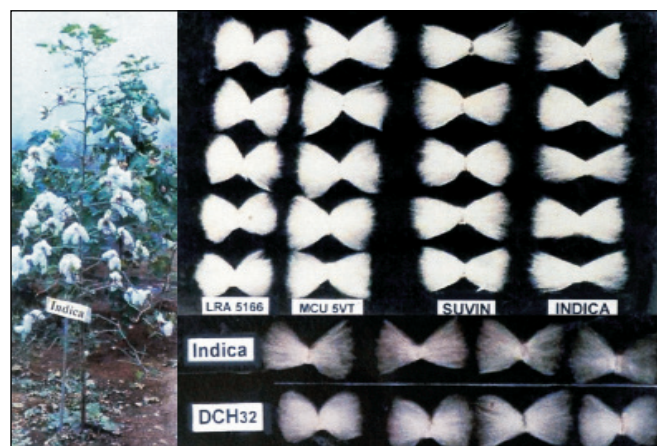


Figure 2: Indica Compared with the other popular cotton varieties and a hybrid DCH32 (Sundaramurthy, V.T., 2003)

bearing branches to grow further as the fruiting parts fall due to physiological changes or insect attack and make the plant canopy open one as against the conventional one where in the main stem keeps on growing under this situation. Several dwarf and semi dwarf materials are available with Agricultural Universities and other cotton research establishments in India and they may augment the yield with the less strains provided the farmers are to change their mentality of using tall growing bushy materials. Most of our crops are season bound and this is the reason for not cultivating them if the rain is not striking at proper time. If they are not season bound they may be sown at any time in the year for making some harvest. Such crops may change the biocycle of insect pests in the cotton system and support the farmers and textile industries.

The widespread and over use of nitrogen fertilizer enables

a few plant species to thrive, while the majority of plant species that live in symbiotic relationships with microbes and other species of animals including highly specialized insects which are dwindling due to changes on the earth sphere. The processes of global warming, increase of the surface ozone level, intense

competition for land and pressures to reduce chemical fertilizer and pesticide use which have negative effects on the productivity of the cotton crop in ensuing decades which compelled the scientists to come with the use of the microbiome living with in and outside of the crop plants to increase the yield through improving the fertility of soils with less dependency on the chemical fertilizers. Interestingly the seed treatment with the specific endophytic bacteria isolated from the tissues of cotton plant has helped the plants to thrive under stress condition (Vessey, 2003, MIT, 2016). The seeds coating with the microbial formulation Acceleron B-300 SAT, and a fungus, increase the yields of the crops and also cut down the use of fertilizer and CO₂ emissions It has also been used to check the pathogenic organism in cotton by internally colonizing the biological control agent, *Pseudomonas fluorescens* with a known endophytic bacterium, *Enterobacter asburiae* (Quadt-Hallmann et al., 1997). The Indian farmers were used to apply cattle manure and plough the fields before the advent of industrial agriculture which is nothing but the use of native microbiome which has ecologically viable activity. But this vital activity is on decline in India due to modernization of living and other reasons. Adding beneficial microbes to crops could be an effective but less controversial alternative to genetic engineering.

The modern chemical agriculture is no longer helps the mankind under the processes of global warming and demands reestablishing the old mixed farming and mixed cropping systems that have evolved with the age of old Indian culture. The mixed farming besides supporting the farming communities serves as good source of organic manure for enriching the soil fertility. The fear of the evolution of methane from the mixed farming system is eliminated by feeding the cattle either with the 'Burpless' Grass (Anonymous, 2008) or using the novel methane inhibitor 3-nitrooxypropanol as feed mix (Alexander et al., 2015). The scientists in India can explore the availability of such native specific endophytic microorganisms and micro biome in our cotton system at different ecological niches for which the Government and Industries should come forward to establish the microbiological research units in different crop research institutes in the country for identification of native endophytic micro biome and to develop suitable delivery system (Musson et al., 1995) into the plant system for increasing the yield. This will enable to reduce the dependency on the chemical fertilizers and prevent further erosion of soil fertility from the current level of 30% in India. The recent innovation of bionic leaf from the Harvard University may eliminates the external application of the chemical fertilizers as this technology

involves the uses of engineered microbes, sunlight, water and air to make the base materials in the soil where crops are grown for uptake and biosynthesis of the nutrients to support the plant growth and thereby enrich the soil fertility with no adverse impacts on the environment. This approach will benefit the farmers in countries like India or sub-Saharan Africa. (Anonymous, 2017)

The strongest evidence of global warming can be seen in the rising air temperatures in nearly all parts of the world (Hansen et al., 2010). Increase of temperature may affect the growth and development including the quality parameters of the cotton and this phenomenon warrants the development of temperature tolerant varieties and hybrids with the acceptable quality by the industry. The accumulation of carbon- di-oxide on the earth sphere may be good for the crop plants to utilize in the photosynthetic process and yield. The modern crop cultivar produces more leaves than what is required for optimal yield under today's and future level of CO₂. It has been recently shown that reducing leaf area would give higher yields (Srinivasan et al., 2016). Whether all available varieties and hybrids including the modified one utilize more CO₂ is not known to science. But some species and strains of cotton may be in the germplasm that uptake more CO₂ and utilize efficiently in the processes of photosynthesis and yield more. If such materials are identified it will be a great boon to man and economy of a nation. The scientists of Central Institute for Cotton Research, Coimbatore had done a pioneering work on the effect of carbon- di-oxide on the cotton crops (Khader et al., 1996) and a leaf feeding insect in India (Sundaramurthy, 1996). The studies on the carbon- di -oxide need to be pursued further for identifying the varieties and hybrids of cotton with reduced leaf area that are efficient utilizer of carbon-di-oxide and yielding more with the requisite quality of cotton to feed the textile industry.

The other serious change of increasing the surface Ozone level due to increase in the levels of photo- oxidants and its precursors, the volatile organic compounds in the environment is going around the world and this phenomenon has greatest impact on the agriculture and productivity of the crops (Aunan et al., 2000). It has been proved that the increased level of surface ozone negatively affects the productivity of the agricultural crops including the cotton crop. The varieties and hybrids those are tolerant to ozone similar to Soya Bean in USA (Chernikova et al., 2000) will help the Indian farming system and textile industries under this situation. Such crop varieties and hybrids may invite less number of insect pests due to the masking effects of ozone on the plants secondary volatile substances that are constantly evolving from the crops to guide the insect visitation to the cropped area.

Man has succeeded in harvesting the basic unit of the life process the DNA (Joos et al., 1983) from the soil bacterium and inserted into the plant system for protection against the insect pests (Vaeck et al., 1987) and eliminated partly the use of

insecticides. But this newer technology besides causing several ecological, economical, social and health problems go against a number of useful species of insects including honey bee and other pollinators and soil microbes (Sundaramurthy, 2010). It is well known fact that the removal of a single gene from living organisms will cause multiple effects such as disruption of coordinated molecular and cellular functions that evolved over millions of years and genes that are functioning normally begin to become abnormal (Hollingsworth et al., 2003). Such changes are responsible for getting allergens in the modified foods, new sugars in sugarcane, new carbohydrate in potato and absence of certain amino acids in maize (Sundaramurthy, 2010). The modified one in India had given fairly good results at the time of introduction but they were failed subsequently because of poor expression of the inserted alien genes due to several reasons including the change of abiotic factors in those days. More over such crops are with the changed leaf anatomy and wider stomata (Sundaramurthy, 2015) enabled the plants to uptake more water and transpire more resulting an imbalance in the soil moisture content as compared to the conventional one. Such materials should never be grown in the rain fed situations and also where water is a scar commodity. The increased temperature and other unknown abiotic stresses affect the expression of genes, change the physiology and biochemical metabolisms particularly nitrogenous compounds in such plants (Chen et al., 2008) and these phenomena are responsible for getting the insects that have different feeding habit to the cropped areas as has been noticed recently in India. The out breaks of the mealy bugs and white flies in Central and Northern parts of the country are the good evidences for such ecological succession of insect pests in the cotton system due to the deranged metabolism in the plants (Sundaramurthy, 1994). Therefore there is a need to develop varieties and hybrids that do not undergo any such biochemical changes due to the modification of gene in the plant system. It is also well known fact that the honey bees, a major pollinators of agricultural crops are declining due to several reasons including the modification of crops. India is blessed with several agricultural and horticultural crops to meet the food demand for 1.3 billion people there is a need to study the effects of such crops and means to prevent the occurrence of hazards to honeybees in the cotton system.

The modified materials are being cultivated in about 98% of the total cotton cultivated area in this country. The recent studies show that the seed cotton is well contaminated with the DNA of alien genes and is cleaned from the lint in USA before using (Barnhardt, 2013). This enables to prevent the horizontal gene transfer of such genes (Giraldo et al., 2013) and protect the other species of the plants in the nature as they do not have the species specificity and protect the other species of the plants in the nature. A degradation and erosion of the commonly owned genetic resources available today for agricultural development (Garcia, and Altieri, 2005). A similar efforts need to be expended in highly diversified country like

India for protecting one of the most important biodiversities on the earth sphere from easy contamination of alien genes. Since the cotton crop also provides food and oil to the mankind care should be exercised that these do not carry the fraction of DNA of the alien gene.

The uncertainty of rain and its pattern, increase of salinity and flooding due to the global warming necessitate development of varieties/hybrids tolerant to these adversities as has been done with rice in Kerala, Tamilnadu and in USA in recent years (Bailey-Serres et al., 2010; Singh et al., 2016; Ramakrishnan, 2016). The varieties and hybrids that do not undergo any serious biochemical changes like braking up of the complex substances into a simpler one due to the post sowing. Drought may also help for the sustenance of cotton in our sphere under these changing situations. We have been bothering only to get higher yields with the higher quality of fibers in cotton and forgetting several other vital things that go against our living and environment. The fibers from the present day varieties and hybrids are polluting much at the point of dyeing. The execs dyes that flow through the water bodies from the dyeing centers pollute our agricultural fields and make them unfit for cultivation of the crop plants. The scientists are capable of tackling this problem by developing suitable varieties/hybrids with the high degree of polymerization of fibers to result in lesser level of dye getting into the wash-off that runs into the water ways to reach the agricultural fields and to damage the eco niches our life line. Any variety coming for approval should have the value of degree of polymerization along with the other quality parameters of the fiber in future.

It has been well established fact that the abundance of invertebrates including the insects are on the decline (Dirzo et al., 2014) from the global index of 1.0 in seventies to less than 0.5 in 2010 amounting to 35% perhaps due to global warming coupled with the mono culture and chemical based agriculture. The insect pests that are associated with the crop plants in this era may change in the cotton system. The robust bodied insects with comparatively long period of the life cycle may vanish and tiny one with little biomass and short life cycle period may emerge and associate with the cotton to damage seriously in coming decades (Figure 3) as evidenced recently. The occurrence of a leaf perforator *Bucculatrix loxoptila* Meyrick, (Lepidoptera:Bucculatricidae) a micro Lepidopteran insect measuring 5 mm long feeding on the lower surface of the leaf in a farm in the Western Ghats region (Sundaramurthy, 2016) that was first noticed 24 years before (Uthamasamy and Mahendran, 1994). The modern genetic modification or depending only on insecticides may not go well with this group of insects under the global warming situation and they need to be tackled in the natural way by adopting the IPM/IRM technologies (Sundaramurthy and Basu, 1985, Sundaramurthy, and Gahukar, 1998; Sundaramurthy, 2002; Kranthi et al., 2005). The requisite labour force for carrying out the IPM/IRM may be drawn from MNREGA during the crop season.

Many crop lands will soon be subjected to less or heavy rainfall

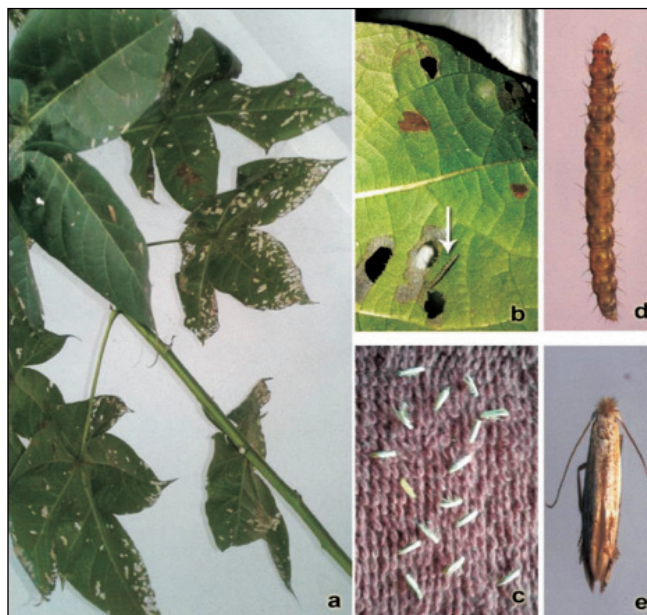


Figure 3: The cotton leaves damaged (a) by the larva (b) indicated by the arrow and adults of *Bucculatrix loxoptila* (c) appeared on cotton in a farm in 2015 at the Western Ghat eco niche. The magnified views of the larva (d) and adult (e).

and higher temperatures due to the phenomenon of the global warming and the present varieties and hybrids including the modified one will also suffer. However some species may survive such situation both in the desert as well as in cultivated areas. A vigil on the occurrence of such plants in the cultivated areas including the germplasm and surrounding niches around the Thar Desert may serve as source for getting some plants which are tolerant to global warming processes. Such plants may be used in the breeding program for getting new varieties to meet the situation. The Scientists at Central Institute for Cotton Research, Coimbatore had already studied the impact of flooding on the physiological and biochemical changes in certain genotype of cotton (Khader et al., 1996) and this may serve as a base for developing varieties and hybrids that are tolerant to inundation of water and salinity.

The level of emittance of UV rays will go up under the global warming situation and affects the health of the crops, animals and human beings (Diffey, 1991). The cotton fabrics may alone help us to live under this situation as long as the synthetic fibers with the in built quality of cotton fibers are available. Efforts are under way to develop such synthetic fibers in countries like USA. Man may succeed in such efforts and leave the cotton fields for cultivation of food and other crops in 21st century to meet the demand of the growing population. The nature has given us the environment friendly white cotton for protecting our skin and also health. Interestingly it has also provided the cotton with different hues (Sundaramurthy et al., 1994; Khadi et al., 1996; Kranthi, 2014) and they never came out of the germplasm. Time has come for the naturally coloured cotton to rule the globe. It is a well known fact that

the global warming enables the UV rays to strike more on the earth sphere which warrants the use of the fabrics that resist the penetration of UV rays into our body surface. The recently published study shows that the naturally coloured cotton has very good capability of resisting the penetration of UV rays (Venkatakrishnan et al., 2015) into the skin of human beings and provides good hopes for man to live happily under the global warming situation with the coloured cotton fabrics. The naturally coloured cotton will also aid in eliminating the pollution with dyes so as to protect the environment and agricultural fields. Since the available coloured cotton materials are coarse and poor in quality and need to be improved further by following the appropriate breeding techniques. The nature and chemistry of the colour of the naturally coloured fiber if known, it may pave the way for the synthesis and use in the place of modern chemicals for protecting from the UV rays.

The donors like World Bank, ICAC, Asian Development Bank, FAO and Government, National and International Philanthropic organizations should come forward to help for launching these research projects to meet the situation arising out of the global warming phenomenon. These technologies being environmentally friendly go against various abiotic stresses and enable to boost the productivity of the cotton and contribute significantly to the health of mankind, other living beings and national economy and social structure of the country in 21st century.

2. Conclusion

Besides the current research approach for increasing the yield, there is a need to change the plant architecture with determinate growth, optimum number of small sized leaves for enabling the pesticides to cover the entire crop. The plants that efficiently utilize increasing level of CO₂ in the environment, water, fertilizers, and ability to withstand the increasing level of the temperature are warranted. The degree of pollution at dyeing center and adjoining niches can be reduced by developing cotton plants with high degree of polymerization of fibers. The mankind may be protected from the increasing degree of UV radiation by providing the fabrics made out of the naturally coloured cotton fibers.

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