International Journal of Agricultural Sciences
Volume **14** | Issue 2 | June, 2018 | 431-441 ■ e ISSN-0976-5670
DOI:10.15740/HAS/IJAS/14.2/431-441
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A REVIEW

Impact of climate change and their mitigation for better sugarcane production

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Abstract : Sugarcane is a climate sensitive crop; its spatial distribution on the globe is restricted as per the suitability of various climatic parameters. The climate change is now accelerated due to natural, as well as enormous human activities disturbing the composition of atmosphere. The predications of various climatic models for probable rise in temperature, rainfall, sea level show an alarming condition in forthcoming decades. As the sugarcane is very sensitive to climatic parameters therefore, a significant effect on its production and sugar yield is expected in future. Sugarcane is one of the precious crops of the world and its end products *i.e.* sugar and ethanol has a continuous growing demand. Hence, the studies on good production of sugarcane in changing climate has become front line area of research and is a major concern of sugarcane scientist. An advance agronomic practice seems to be the effective measures for obtaining high production of sugarcane with good quality juice.

Key Words : Sugarcane, Climate change, Agronomy, Soil

View Point Article : Kumar, Ajeet, Choudhary, Ashwini and Kumar, Mukul (2018). Impact of climate change and their mitigation for better sugarcane production. *Internat. J. agric. Sci.*, **14** (2) : 431-441, **DOI:10.15740/HAS/IJAS/14.2/431-441.**

Article History : Received : 31.01.2018**; Accepted :** 27.05.2018

INTRODUCTION

Sugarcane is called as 'wonder cane' owing to its versatile utility and capability to meet the demands of the burgeoning population. It is utilized in manufacturing of sugar, bio-fuels, spirit and generation of electricity. In addition, this provides raw materials for papers, fertilizers, amendments, chemicals, and distilleries. Thus, sugarcane provides livelihood for the peasant. Sugarcane is a tropical plant (Humbert, 1968) globally grown from 37°N to 31°S (Reddy, 2004). Its cultivation has been extended over the sub tropics between the latitude of 30° N and 35° S. It thrives well at 20°C temperature and required about 8 - 18 months for maturity (Nazir, 2000). Sugarcane produces multiple stems from lateral shoots. A mature stalk is composed of fibre (11–16%), soluble sugars (12–16%), non-sugars (2–3%), and water (63–73%). Sugarcane has fibrous stalk of 2-6 m tall, it is perennial grass of the genus *Saccharum* of family Poaceae (Clark *et al.*, 1995). Sugarcane is a C_4 plant (efficient photo-synthesizers), which convert 1% of incident solar energy into biomass. The plant has four growth phases. The

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first phase (germination phase) covers a period of planting upto germination of buds which lasts for 4-5 weeks. The optimum temperature for sprouting is 20^0C to 30^0C. The second phase (tillering phase; lasts for 120 days) is highly sensitive to local climate, soil, water and nutrient. Temperature around 30^0 C and solar radiation play a major role for good growth. Tillering is influenced by water availability, spacing, manuring, and weed control etc. The third phase (main growth phase) is a period of actual cane formation and elongation (take 270-300 days) and it requires warm and humid conditions (80% humidity), which is best for leaf production. The fourth phase (maturity and ripening) prevails for about 90 days. Here, rapid accumulation of sugar and conversion of simple sugar to cane sugar takes place. This crop is grown in several countries, of which, Brazil, India, China, Thailand, Pakistan, Mexico, Columbia, Australia, Philippines and USA are the top ten countries in production (FAO, 2005). Area wise, Brazil is the highest, *i.e*. 5.63 million ha, whereas, India's contribution is 4.0 million ha (FAOSTAT, 2005). In production, Brazil still remains on the top with 33% of global sugar production followed India (23%), and China (7%) (FNP, 2009). In India, sugarcane occupies about 4.0 million hectare area and is produced in most of the states. The yield of sugarcane per hectare is highest in Tamil Nadu, followed by West Bengal, Karnataka and Maharashtra (ICRISAT, 2009). The average cane yield in India is about 70.0 tonnes per hectare while the sugar recovery is around 10.0 per cent (IISR, 2011). Sugarcane depends heavily on the amount and duration of precipitation, humidity, moisture, temperature and soil condition (Gawander, 2007). In recent years, variations in the earth's orbital characteristics, atmospheric carbon dioxide variations, volcanic eruptions and variations in solar output (Masih, 2010); and the rapid industrialization resulted in increased emission of CO_2, global warming and green house effect (Segalstad, 1996) have influenced the climatic set-up globally as well locally. Therefore, it is essential to study the effect of climatic change on various aspects of sugarcane production.

Requirement of climate for sugarcane production:

Climate plays an important role in cultivation of sugarcane, since, the plant stands for 12-18 months, hence, goes through all possible limits of weather, which have a role in growth, sugar yield, quality and juice content etc. In India, two distinct regions categorized for sugarcane cultivation, *i.e*. tropical and sub-tropical. The northern subtropical region experiences extreme summer temperatures as well as severe cold in winter, whereas, the tropical region, the temperature, shoots upto 47^0C in comparatively prolonged summer season. Sugarcane thrives well in temperature between 20-40^0C, long period of sunlight (12-14 hours), high humidity (above 70%) and high rainfall even upto 1500 mm. If assured irrigation is available, it can also be grown in areas where rainfall is low upto 500 mm. sugarcane withstands temperature variations of winter (6-8^0 C) and summer (40-42^0 C). Optimum climates required for cane development are as follows (Binbol *et al*., 2006).

Rainfall:

An average of 1200 mm evenly distributed rainfall is optimum for higher yield. The rains during the vegetative growth encourages rapid elongation and internodes formation (ICAR, 2000).

Temperature:

An optimum temperature for germination of stem cuttings is 32-38°C. Temperatures above 38^0C reduce the rate of photosynthesis and increase respiration. During ripening period, a low temperature in the range of 12-14^0 C reduces vegetative growth rate while enhancing enrichment of sucrose in the cane (Fageria *et al*., 2010). A minimum temperature of 20^0 C is congenial during active growth phase. Temperatures both below 5^0 C and above 35^0 C are not suitable as lowest temperature may be harmful for young leaves and buds whereas the high temperature, causes rolling irrespective of water supply. Further rise in temperature enhances red rot disease. The adverse effect of high temperature is marked by reversion of sucrose into fructose and glucose. Enhanced photorespiration may reduce accumulation of sugar (Gawander, 2007).

Sunlight:

On an average 7-9 hours of bright sunlight is optimum for high production of cane and good yield of sugar (Fageria *et al.*, 2010). Increase in leaf area index is rapid during 3^{rd} to 5^{th} month, coinciding the formative phase and attained its peak values during early grand growth phase. The upper six leaves of the sugarcane canopy intercept 70% of the radiation. Therefore, care to be taken for proper spacing during plantation. The areas with short growing period benefited more from closer spacing to intercept higher amount of solar radiation and thus get higher yields however, with long growing season, wider spacing is suggested to avoid mutual shading and mortality of shoots. The growth of plant result from conservation of solar energy into plants fibres and sugar. The amount of carbon gain per day from photosynthesis is dependent on latitude and clouds covers.

Relative humidity and wind:

Upto 80-85% humidity and warm weather favours the rapid growth of the plant as well as cane length with good yield. In ripening phase, a moderate humidity with limited water supply is favorable. The high wind velocity may be harmful in initial stage of growth. The long duration high velocity wind will result in loss of moisture. The ripening season needs clear sky without precipitation, warm days and dry weather conditions.

Impact of climate change on sugarcane production:

All agricultural activities are the most sensitive and vulnerable to climate change (IPCC, 2005). IPCC (2007) reports that the climate change is real and the process is going on, which is directly concerned with the crop production. It is estimated that climate change have extreme events and slow onset impacts, such as changes in precipitation and temperature (Nelson *et al*., 2010). Climate change has negative impacts upon agricultural production, food security and economic development; especially in developing countries (Hannah *et al*., 2005). Sugarcane is strongly influenced by the impacts of climate change and local weather and seasonal variations. The climate affects activities of micro-organisms which directly or indirectly suited for better yield. Rosegrant *et al*. (2008) identified potential effects of climate change on the agricultural which are as follows: Seasonal changes in rainfall and temperature could impact agro-climatic conditions, which alters growing seasons, planting and harvesting calendars, water availability, pest, weed and disease populations, Transpiration; photosynthesis and biomass production is altered, Land suitability is altered, Increased CO_2 levels lead to a positive growth response under controlled conditions, also known as the "carbon fertilization effect". The global warming is result of an increase in the concentration of "greenhouse" gases, (CO_2, CH_4 and N_2O), which affects the climate (Nikolaos *et al*., 2011). The fossil fuel combustion is the main reason for the increase of CO_2, while agriculture for CH_4 and N_2O (Cerri *et al*., 2007). The increase in their concentrations retained the radiations emitted by the earth's surface and causing imbalance to the earth's thermal system. IPCC (2007) reported that the average global temperature has increased by 0.74±0.18°C in the last century and is projected to increase by another 1.1°C-6.0°C in this century; may be 6.0°C increase by the end of this century (Rahmstorf *et al*., 2007). The mean annual temperature is likely to increase ~ 4°C over India by the end of 21st century. The daily maximum and minimum temperatures may be intense. The role of temperature in cane development continues upto last stage. Temperature directly linked with the growth, photosynthesis and other biochemical processes including bud development; Cool night temperatures and sunny days slow down growth rates and carbon consumption, while photosynthesis may continue (Gawander, 2007). Photosynthetic efficiency of sugarcane increases in a linear manner with temperature in the range of 8^0C to 34^0C. Gbetibouo and Hassan (2005) employed a Ricardian model to measure the impact of climate change on sugarcane, and their study reveals that the production is very sensitive to even marginal changes in temperature. Gouvea *et al*. (2009) made the estimates of sugarcane yield, based on future climatic scenarios and interpreted that increasingly higher temperatures will cause an increase of the productivity. A climatic prediction made for 2050 shows that the increases in rainfall during good years may offset the impacts of warmer temperatures, with little change in sugarcane production. However, a warmer and possibly drier climate could lead to more intense droughts during El Nino years in which the sugarcane will be heavily affected (World Bank, 2004). The availability of water is more or less a dependable factor on climate. An increase in temperature will enhance the evaporation which leads more demand of water, and it should be properly mulched. Kimball *et al*. (2002) interpreted that elevated CO_2 and temperatures will effect plant growth and water balance. In India, monsoon is most active with a share of about 70% annual rain fall in the duration of July to September. The number of raining days may be non uniform and spatial pattern may also differ. The intensity of rain fall on a raining day is likely to be higher in future (Kumar *et al*., 2011). The sugarcane producing coastal belt is also vulnerable to climate change; low lying areas will be submerged when the sea level rises and coastal erosion and inundation will be high.

Soil and nutrient management under changed climatic condition :

All types of soils like alluvial soil, black soil and red soil are suitable for cultivation of sugarcane. Soils, provides essential nutrients and water to the crop. The physical and chemical properties of the soil have an impact on the plant growth (Hartemink, 1998). Well drained loamy soil with pH of 6.5-7.5 and adequate nutrients is ideal for sugarcane production. However, sugarcane can tolerate the pH range from 5.0-8.5. The plant has a capacity for deep roots upto 5 m; hence, it has appreciable dry tolerance (Huang, 2000). The soils of the area varies considerably, therefore, the agronomic practices varies from area to area. Soil is one of the main factors which influence the production potential according to its chemical composition particularly nitrogen and potassium which play a major role in physiology, growth and development (Rice *et al*., 2002). A bulk density of 1.4 mg /m^3 and porosity around 50% occupied by both air and water in equal proportions are favorable for root growth. Soil bulk density in the sugarcane field varies considerably as the crop is usually grown on low ridges, where tractors passing over the inter rows making it compact thus, the soil strength gets increased but the porosity is reduced, resulting in low water intake capacity of top soil (Srivastava, 1984). The crusting of soil occurs when the soil surface dries out after rainfall or irrigation. Physical disaggregation of soil particles occurs in response to the impact of raindrops, causing compaction of the surface layer which limits water penetration into the soil. Soil crusting is a precursor to soil loss through erosion and improving water intake rates (Meyer *et al*., 1996). In acid soil, high alumina level damages the root system; as a result, the roots tend to be shortened and swollen, having a stubby appearance, which can be ameliorated by lime and dolomite applications. The soil salinity is also a common problem in areas having low rain fall. Occasionally, poor quality irrigation water may be source of salts (Meyer *et al*., 1996). The maintenance of soil fertility for the crop by adding organic manures press mud, vermicompost, green manure, compost, dung and fertilizers which improves the physical, chemical and biological properties of the soil. Nitrogen is an essential for all plants. Its deficiency in the soil is represented on sugarcane by thinner and shorter stalk, paleness of foliage, leaves turn black and die, leaf blade turn light green to yellow, and thin roots, which influences the quality and quantity of juice. Phosphorus in low quantity reduces tillering, less elongation of stalk, and purple colorations of leaf, slender leaves and delay in canopy development. It is essential for cell division responsible for plant growth and also for root development. Potassium helps in carbon assimilation and photosynthesis, in addition to providing resistance to sugarcane against pests and diseases. Deficiency symptoms are yellow-orange coloration of leaf borders and tips, slender stalk. It is the most abundant cation in cell sap. It is fundamental to the synthesis and translocation of sucrose from the leaves to the storage tissues. It also plays a role in controlling the hydration and osmotic concentration within the stomata guard cells (Ng Kee Kwong, 2002). Sugarcane requires sulphur in relatively large amount which is used for plant structure and growth. The natural sources of sulphur are rainfall and irrigation. Calcium is essential for cane growth and for cell wall development. Magnesium is essential for plant photosynthesis as it is the main constituent of chlorophyll. Sodium required in very small amount for the maintenance of plant water balance. The micronutrients which are taken up by cane are regulators of plant growth (Wood *et al*., 2003). The traditional methods like mixing of fertilizer with soil, its application in the furrows followed by little irrigation are still widely used. It is also important to retain the nutrient in the field by avoiding the runoff and erosion by soil and water conservation.

Agronomic measures for enhancing production potential :

Sugarcane cultivation starts with field preparation followed by seed selection, planting patterns, tillering, irrigation, manuring, weed and insect controls, irrigation management etc. These practices required certain specifications at different phases.

Field preparation and planting materials :

The sugarcane field should be free from residue of the previous crop. A cross and deep ploughing by disc harrows, tyned harrows or rotavator for 2-3 times, with sufficient organic manure provides good condition for crop growth. Soil should be friable and proper aeration, followed by leveling of land for uniform distribution of water required for better crop stand. Organic manure may be added by last ploughing to improve soil fertility (ICRISAT, 2009). The improved varieties should be selected for high yield with respect to change in local setup of climate and soil. The cane setts, settlings and bud chips are planting material to raise the crop. The three budded setts of a healthy and disease free cane are used. Treatment with chemicals ($KMnO_4$, $MgSO_4$, ammonium sulphate and acetylene) are good for better germination and bud sprouting. The prevention from fungal and insects attack can be made by treatments of aretan and benzene. The settlings are cane setts having roots, which raised in the nursery and used in transplanting. The bud chip which is excised auxiliary buds of cane stalk are also used as planting materials. It reduces the mass and improves the quality of seed cane. The bud chips are less bulky, easily transportable and more economical seed material. The bud chip technology holds great promise in rapid multiplication of cane varieties (Jain *et al*., 2010). This method, have multifaceted advantages. A study carried out for improvement of sprouting by growth-promoting chemicals *viz*., ethephon and calcium chloride helps in enhancing bud sprouting, root growth and plant vigor by altering the biochemical attributes under field conditions. Treated bud chips recorded higher bud sprouting, shoot height, root number, fresh weight of leaves, and plant vigor index (Jain *et al*., 2011). An ideal seed can be obtained from crop of 7-8 months.

Planting pattern :

Planting pattern has a direct bearing on the productivity and yield. The common planting patterns are flat beds, ridges and furrows, trench method and Rayungan method. The flat method (simple and cheep) is adopted for low rain fall area. Shallow furrows of 8-10 cm depth at the distance of 70-90 cm are made on flat seed bed. The 3-budded setts are planted end to end in these furrows, and covered by soil. Moisture should be adequate at this time. The furrow planting is common in northern and southern India, having moderate rain fall and heavy soil with low drainage. FYM, potassium and phosphatic fertilizers may be added as per the recommended dose of fertilizers. The trench method is followed in coastal areas where strong winds prevail in the rainy season. This prevents the crop from lodging. It is also known as 'Java method' as common in Java. Trenches of 20-25 cm depth are dug at the distance of 75-90 cm. Soil should be added by through mixing of fertilizers rich in sodium, potash and phosphate. End to end pattern of fungicide treated cane setts should be planted. Trenches are filled with the soil after planting. In Rayungan method, the seed stalk is topped off about two months before planting which results in the development of lateral shoots. Trenches having 30 cm depth and 90 cm lateral intervals are made and prepared by mixing of manure. Further digging and softening of soil upto the depth of about 15 cm is carried out and filled with same soil and fertilizer. Shaft of about 40-45 cm with 2-3 nodes are planted. There are other methods of plantation like distance planting, bud transplantation, sprouting method, planting of uppermost nodes etc. which are more or less modifications of above mentioned methods suitable for specific region or climatic and soil conditions (IISR, 2008). Garside and Bell (2009) demonstrated that high density planting did not produce more sugar yield. In general, tiller survival, cane weight and yield are higher in wide row planting resulting to high produce of millable canes as well as longer duration and high-yielding nature of the same (Kapur *et al*., 2011).

Advanced irrigation management :

Sugarcane is a high water requirement crop. Reduction in the stalks elongation and leaves are the primary symptoms of water stress, whereas, the last phase of crop shows decrease in sucrose accumulation. In the changed climatic conditions, the rain fall is very erratic, unpredictable and uneven. Its stipulated duration is also shifting in some of the regions. In central India, 2-3 seasons of good rain fall is normally followed by a draught or low rainfall period. Since, the demand of water is high for sugarcane. Moreover, it becomes necessary for the judicious use of water. In India, the present demand of irrigation water is between 543-557 billion cubic meter (BMC) as estimated by NCIWARD (1999) which may go to 826-852 BMC in the year 2065. However, it is expected that demand for water is likely to exceed the availability much before 2050 (Jain, 2011). The drip irrigation saves the water, reduces labor cost, save electricity and is suitable for almost all land; is highly adopted technique, largely preferred in central India because of low rainfall and high depth of water table. Besides, free movement of pests and diseases are automatically prohibited. The northern India, where the water table is comparatively low, may need comparatively less number of irrigations. Water requirement is more in the areas having hot and dry winds.

Effective weed management :

The sugarcane is a long standing crop: therefore, it is affected by the different weeds in changing climatic conditions. The common weeds are *Cynodon doctylon, Cyperus rotundus, Echinochloa* spp, *Saccharum* sp. (narrow leaved); *Chenopodium album, Solanum nigrum, Convolvulus arvensis, Trianthema* sp. *Digera arvensis, Anagallis arvensis, Fumania* sp. (broad leaved) and *Sorghum halepense, Panicum* spp, *Dactylocterium aegyptium* (grasses) which reduces the sugar yield by 25-90% as competing for moisture and nutrients. The initial 4-6 months of growing phase needs more care, otherwise will have an adverse affect on tillers, and development of millable cane (Chattha *et al*., 2007). The injudicious use of selective herbicide will encourage a resistant type of weed to flourish. The herbicides are specific for pre-emergence and post-emergence varieties (Odero and Dusky, 2010). Some herbicides are Atrazine-controls annual grass and broadleaf weeds; 2,4-D-spiny amaranth, ragweed and morning glory; ametryn - annual grass and broadleaf weed seedlings, especially effective against Alexander grass; metribuzin-controls annual grass and broadleaf weeds; pendimethalin; halosulfuron-controls purple and yellow nut sedge and some broadleaf species, applied to any stage of sugarcane. Apart from these, glyphosate is a broad-spectrum herbicide which is only effective on actively growing plants (Duke and Powles, 2008). Paraquat has an excellent control on annual weeds. Integrated weed management at proper time provides the maximum productivity and yield.

Remedies for insect and pest attack :

Sugarcane is very much susceptible to the insect attack due to enormous growth of the pests in comparatively short time. In India, more than 200 species of insects are known, however, a few are most devastating, which are as follows:

Pyrilla perpusilla:

It is most destructive foliage sucking pest, causes heavy loss in cane yield and sugar recovery. It appears in August-September after heavy rainfall. Chemical spray is the only remedy. Planting in paired row provides space for supervision and to control measures (Paul, 2007).

Termites:

These are the underground insects (*Coptotermes heimi, Odonotermes assmuthi, O. obesus, O. wallonensis, Microtermes obesi and Trinervitermes biformis)* mostly active under draught conditions (April-June and October). In initial phase, it enters in cut ends of the seed and damage the soft tissue, leading to low bud germination. Termites killed by spraying pesticides on stalks in furrow (Cheavegatti-Gianotto *et al*., 2011).

Borers:

These are the insects which bore young shoots, canes and roots. This cause a loss of stalk weight and sucrose yield. The borer's tunneling into the stalk allows points of entry for secondary invaders. Weakened stalks are more subject to breaking and lodging (Cherry *et al*., 2011). The shoot borers (*Chilo infescatellus*) attacks during April-June by entering through the holes in the stalk, and producing dead hearts. The internode borer (*Chilo saccharifagus*) is major pests of peninsular India (Gupta, 1957) and is active after the internode formation, (Ananthanarayana and Balasubramanian, 1980). Due to infection, the reduction in intermodal length, girth and cane yield (David *et al*., 1979) occurs. It also deteriorates juice quality and reduces sucrose content (David and Ranganathan, 1960). The top shoot borer (*Scirpophaga excerptalis*) attacks the youngest part of the plant, and destroys the growing point, stalks die, and sucrose content adversely affected (Sallam, 2006). It attacks during March-October. The larvae penetrate along the midrib of the leaf. Larvae feed on tender leaves turn dark. Collection of moth and egg and their destruction are useful. The root borer (*Emmalocera depresella*) disconnects the conducting tissues of the root and finally plant die. It also paves way for Ratoon stunning disease. Plants infested with *E. depressella* suffer dead hearts. It infests sugarcane at all stages of their development (Singh *et al*., 1996).

Blak bug:

The insects *Blissus gibbus* and *Macropes excavate* is most destructive for the ratoon, in North India. The nymphs and adult accumulate in the whorl of the cane shoot and suck the sap, finally the shoot turns pale yellow with brown patches and sickly appearance. An increase in nitrogen content of infested leaves and decrease in chlorophyll content hampers the growth (Yadav, 2003). Nymphs appear in March-April (peak period of infection) and from June to October. Burning of trash and leaves, controlled the pest population. Nitrogen deficiency has been reported to invite black bug infestation in ratoon crop (Jaipal, 2000). Foliar fertilization of infested crop with 2.5 % urea at formative phase has reduced the nymph population.

Scale insect:

It is post monsoon pest normally appears in 5-6 months old crop after formation of internodes (Rao, 1970). The symptom is the presence of circular, grayish-black scale, covers on stems and leaf midribs (Agarwal *et al*., 1959). Infested leaves show drying of the tip and pale green to yellow coloration. It thrives well between 24°C to 34°C and at high humidity. The flood irrigation strongly favors survival of the pest (CPC, 2012). Rao *et al*. (1991) found that a long dry period immediately after the rains favored rapid build-up of *M. glomerata* populations. Wind enhances the dispersal of the scale (Tripathi and Omkar Shukla, 1985).

Mealy bug (Sacchariоccus sacchari):

These are found on the stalks in cluster, under leaf sheaths and spreads up and down to the other internodes and buds. The damage caused by sucking the cell sap. It plays a role in virus transmission and the growth of sooty-mould fungus due to large amount of honeydew secreted by the insect (Eid *et al*., 2011). The pest grows in drought conditions, and shows a sickly appearance. Severe infestation causes drying up of the leaves. Spray of insecticides and destruction of affected leaves are the control measures.

White fly (Aleurolobus barodensis, Neomaskellia bergii):

The pest population reaches to maximum level under water logged and nitrogen deficient areas (Mann *et al*., 2006). It becomes active with the onset of monsoon. The period of maximum attack is September-October. Both adult and the nymph suck the sap from the leaves and turning them yellow. Due to their attack, cane juice becomes more watery. Sucrose reduction and less recovery of sugar are other adverse affects.

White grub (Hilotrichia sp.) *:*

It is a major problem in tropical India. It feeds on the root and also damages the underground part of the stem of sugarcane. The visible symptom appears in September, with chlorosis, followed by stunted growth, dense browning, lodging, and death in heavily infested crop. Damage usually severe in ratoon around the edges of field (Srikant and Singaravelu, 2011). It thrives well in moist sandy soil. Flooding for 24 hr during pest activity reduces grub population. Crop rotation with paddy and sunflower, minimize the pest population. Biological control is self sustaining measures, in which a fungus *Beauveria brongniarthi* is effective to control the white grub by penetrating the body wall of larva and multiply within, thus finally killed the insect.

Strategies for disease management :

There are about 50 diseases of sugarcane reported that caused by fungal, bacterial, viral and phytoplasm (Vishwanathan and Padnabhan, 2008). Fungal diseases include Red rot, Smut, Wilt, Eye spot, Yellow spot, Brown spot, Pine apple, Banded scletioal and Pokkah boeng, whereas Ratoon stunting, Leaf scald and Red stripe are mainly caused by bacteria. *Sugarcane Streak Mosaic Virus* (SCSMV) and *Sugarcane Mosaic Virus* (SCMV) are two common viruses affecting the crop (Damayanti *et al*., 2010). Viral and mycoplasmal diseases are Mosaic, Grassy shoot and Leaf yellow of sugarcane. The symptom of important diseases are as follow:

Red rot of sugarcane:

It is caused by *Colletotrichum falcatum*. The growth of fungus is affected by temperature, pH, nutrition and environmental conditions. Initially, the infected tissues show dull red coloration with whitish patches across the stalk. In resistant varieties, the infection is largely confined to the internodes. In the early stages, it is difficult to recognize the disease in the field, as the plant does not show external symptom. At a later stage, some discoloration of rind becomes apparent, when internal tissues have been damaged and are fully rotten. At the field level, it may be observed as the death of few plants (Duttamajumdar, 2008). Infected leaf shows red marks on upper surface of the lamina and midrib. Due to this disease, yield reduces with low juice quantity. The management includes selection of healthy setts, burning of trash and other residue in field, rotation with paddy, onion, garlic, linseed and green manure etc.

Sett rot or pine apple disease:

It is caused by *Ceratocystis paradoxa*, It is both sett borne and soil borne. In the primary phase of infection the internal tissue of the setts turns red and black, due to production of fungal spores. Nodes act as partial barriers for the spread of rottening. The disease retards bud germination, shoot development and early shoot vigor. (Raid, 1990). The disease is much prone in low lying areas and soils having ill drainage. It may be controlled by treating the setts by fungicide before plantation (Vijaya *et al*., 2007).

Wilt disease :

A fungal disease caused by *Cephalosporium sacchari*, spreads through setts and adversely affects the germination, which ultimately affects the root development and cane formation. The symptoms visible after 4-5 months of plantation during monsoon and post monsoon. The affected tissue show reddish brown coloration in patches. The leaves turn yellow and dry up. The disease is controlled by selecting disease free seed setts treated with fungicide (Gupta and Tripathi, 2011).

Gummosis or gumming disease (Xanthomonas vasculorum):

The symptoms are white leaf stripes with necrotic zones at leaf margins, vascular reddening and cavity formation in invaded stems, production of side shoots, rapid wilting and death of plants. The development and spread of disease includes xylem-invading pathogen, transmitted in cuttings as mechanically and by wind-blown rain (Birch, 2011). The control is selection of disease free setts and cultivation of resistant varieties.

Sugarcane smut:

It is caused by *Ustilago scitaminea*, and spread by windblown spores, infested seed-cane and infested soil (Nzioki *et al*., 2010). The diagnostic feature is the emergence of a whip from the top of the cane plant which turns gray to black, curved and pencil-thick growth. The control measures are hot water treatment of seed canes, roughing out diseased plants, planting resistant cultivars, and use of fungicides (Agnhotri, 1983).

Biotechnological approaches :

Biotechnological strategies improve a number of plant traits which may be important for adoption under changed climatic conditions including early vigor, water-use efficiency, nitrogen-use efficiency, water logging tolerance, frost resistance, heat tolerance, pest and disease resistance, and reduced dependence on low temperatures to trigger flowering or seed germination (Tiwari *et al.*, 2010). The genetically modified sugarcane would really be the answer to cope with the challenges of climate changes.

Conclusion :

Various climatic factors and agronomical measures required for better growth of sugarcane are specific in local set-up. The change in climate is a matter of serious concern to sugarcane cultivators. A review of various scientific literatures on climate change and agronomic measures strongly suggests for the adaptation of modern techniques being developed at regional level in most of the sugarcane producing areas. In the initial phase, both land preparation, planting material and seed treatments following different technique need a careful planning. The selection of planting material is being suggested for those varieties which can sustain local climatic conditions as well as resist for pests and diseases. Sugarcane is a long standing crop and experiences severe changes in climate, biotic and abiotic factors, therefore, a regular care of soil and nutrient management, pest control, disease management and adequate irrigation are required. It is advised to the farmers to take suggestions from the experts of research centers to enhance the quality and production of the cane on their field.

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