Review paper

Effects of Climate Change on Field Crops in the Scenario of Food Security

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Abstract: The aim of this paper is to overview the effects of climate change on the growth of field crop and their productivity in the scenario of food security. This overview describes the effects of several environmental stresses such as temperature, salinity, drought and elevated CO2, which greatly influence the crop production through climatic variability. Global warming and climate change have severe impacts on agricultural crops, leading towards food security. High temperature cause pollen sterility, lower CO_2 assimilation, dehydration of tissues, reduction in pollen germination, pollen tube length, seed setting, grain size, silique, and seed production of crops. Low temperature affects germination rate, emergence percentage, stem length and root growth, chlorophyll contents, Fv/Fm ratio and yield in field crops. Cold stress causes solidification of membranes, loss of membrane functions and impaired with reproductive stage development leads to yield loss in plants. Drought stress has a significant influence on the stomatal exchange, photosynthesis, protein synthesis, vegetative growth, branches per plant, plant height, panicle initiation, flowering, pollen anthesis, pollination and accumulation of dry matter resulting in flower abortion, grain abscission and ultimately reduced seed yield and seed oil content. Salt stress affects germination, crop emergence, seedling growth, the rate of water uptake and significantly reduces the leaf number, leaf enlargement rate, root and shoot dry matter, root-shoot ratio, root growth rate, total dry matter in plants. Elevated concentrations of CO_2 results in increased growth rate, respiration, photosynthetic activity, biomass production, water use efficiency along with high yield and decreased in transpiration process. Identifying suitable screening indices and quantifiable traits would facilitate the crop improvement process under such environmental stresses and development of crop cultivars resilient to climate change. There is a dire need to combat the current scenario of climate change by identifying suitable genotypes and management practices to sustain the crop productivity.

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Introduction

Climate change has drastic effects on our ecosystem. Global food security threatened by climate change is one of the most important challenges in the 21st century to provide food for an increasing population in the stressed environment (Lal *et al*., 2005). Climatic erraticism is significantly swaying crop production even in high yielding agricultural regions every year. The increasing greenhouse gas discharge and global warming during climate change effects in the enlarged frequency and intensity of dangerous weather events. Climate change is estimated to have important penalties for global field crop production, especially in the developing countries due to relatively low adaptive capacity, high vulnerability to natural hazards, and poor forecasting systems and mitigating strategies (Zhao & Yang, 2015). A combination of long-term change in the global weather patterns, caused by natural processes and anthropogenic factors, may result in major environmental issues that have affected and will continuously affect agriculture. Atmospheric CO_2 concentration has increased by about 30% since the mid-18th century due to increases in combustion of fossil fuels, industrial processes, and deforestation (Houghton *et al.,* 2001). Global warming is directly associated with rise in atmospheric CO_2 and other greenhouse gases (GHG). Worldwide mean surface temperatures had amplified from 0.55 to 0.67°C in the last century and are projected to increase from 1.1 to 2.9°C (low emission) or 2.0 to5.4°C (high emission) by 2100 relative to 1980–1999, depending on GHG emission level, region, and geographic location (IPCC, 2014).

Climate inconsistency and climate change are projected to result in changes in sea levels, rainfall pattern, and the frequency of extreme high- and low-temperature events, floods, droughts, and other abiotic stresses (Dhillon and Wuehlisch, 2013) as well as tornados and hurricanes (Gawander, 2007). High temperatures and drought stress are the two major issues affecting agricultural production and economic impacts in many global regions. The challenges, faced by the agricultural sector under the climate change scenarios, are to provide food security for a growing global population, while shielding the environment and the functioning of its ecosystems (Rosenzweig, *et al.,* 2007). Plants face various biotic and abiotic stresses in the prevailing environment. Environmental stresses such as temperature, drought, salinity, cold and elevated CO_2 affect plant growth and development individually and in combination (Serrano *et al*., 1999). All these stresses result in significant loss of crop yield and quality.

Heat stress causes morphological, physiological and biochemical changes in plants which affect plant growth and development resulting in yield reduction. High temperature reduces plant biomass by decreasing the process of photosynthesis and increasing transpiration and stomatal conductance (Jones, 1992). High temperature reduces the photosynthesis process in plants by the deactivation of RuBisCO (Crafts-Brandner and Salvucci, 2000). Heat stress has harmful impacts on plant growth, metabolism, developmental processes, and production (Hasanuzzaman, 2013). Young *et al.* (2004) stated that high temperature during seed filling period causes severe yield losses through floral sterility and impaired seed filling. Temperature variability affects seed and grain yield of annual crops. Beck *et al.* (2007) reported that climate change has increased the intensity of heat stress which results in serious economic losses of agricultural and horticultural crops.

Cold stress is one of the major environmental factors which limit plant growth and productivity. Plants response varies to chilling (0-15 ºC) and freezing (< 0ºC) temperatures. Thakur & Nayyar (2013) reported that chilling stress < 20°C results in low-temperature effects on plant cellular molecules leading to solidification of cell membranes, slowing of metabolism and loss of membrane functions. Chilling stress effects include wilting (Bagnall *et al*., 1983), chlorosis (Yoshida *et al.,* 1996), reduced leaf expansion and growth (Sowinski *et al*., 2005; Rymen *et al*., 2007), impaired development of reproductive components leads to restricted seed and pod development (Kaur *et al*., 2008) which ultimately reduce the plant yield.

Drought is the most challenging threat for global food security that directly reduces the growth and development of crop plants by disturbing normal biochemical procedures and gene expression. Drought stress limits plant growth, development and ultimately seed yield in almost all the crops, thus it is one of the most severe intimidations to worldwide agriculture (Mustafa *et al.,* 2015). Due to shortage of water, food demand for increasing population is badly affected by drought stress (Somerville and Briscoe, 2001). The strength of the drought depends on the occurrence and division of rainfall, evaporation, and moisture storing capacity of the soil (Wery *et al*., 1994). Three mechanisms lower the crop yield through drought stress: 1) decrease canopy absorption 2) lowers radiation use efficiency 3) lowers harvest index (Earl and Davis, 2003). Drought stress causes elongation of cells in higher plants through less turgor pressure (Farooq *et al*., 2009). Drought lowers the photosynthesis rate through a reduction in leaf enlargement (Wahid and Rasul, 2005). Water deficiency in plants causes changes in photosynthetic pigment (Anjum *et al*., 2003) ultimately stopped the Calvin cycle which reduces the crop yield.

Salinity stress is one of the environmental stresses which badly affect plants. A rising level of salts in the soil is the drastic threat to food production because it is responsible for lowering the yield. On marginal lands soil management practices and water has helped in agricultural production in these areas. But these approaches also get problematic. Our field crops are very sensitive to the salt as compared to halophytes. High level of salinity causes ion disequilibrium and hyperosmotic stress it produces secondary effects on the crops. Some plants may get dormant during the salinity stress (Yokoi *et al*., 2016). Ion Imbalances, Osmotic stresses, and toxic effect of the ions on the metabolic processes are the important threats. Oxidative damages are also induced by the salinity stress.

Elevated CO_2 is an important factor in climate change. The level of CO_2 is increasing over the 150 years of past, which is predicted to reach 700 μmol mol^{-1} at the end of this century from the current level of 380 μmol mol^{-1} (Crowley, 2000; Houghton *et al*., 2001; Qaderi *et al*., 2006). Elevated CO_2 affects both crop quality and quantity and has positive effects on crop growth and productivity. Increased levels of CO_2 increase plant growth and biomass by increasing photosynthesis and water use efficiency and decreasing the transpiration process by reducing stomatal conductance (Long *et al*., 2004; Morison 1998; Qaderi *et al*., 2006). Plant species are directly influenced by increased level of atmospheric CO_2 which alters physical structure of plants and carbon: nitrogen balance. Ainsworth & Rogers (2007) stated that elevated CO_2 increases photosynthesis and photosynthate production in agricultural crops. McMaster *et al.* (1999), found a positive relationship between leaves appearance of wheat and CO_2. Franks & Beerling (2009) found a positive relationship between stomata size and elevated CO2 while a negative correlation exists between stomata density and elevated CO_2. Many other studies showed that disease development is accelerated due to elevated CO2 such as stem rust on wheat plants (Mitchell 1979), anthracnose pathogen on shrubby stylo (Chakraborty &

Datta, 2003), sheath blight on rice (Kobayashi *et al.* 2006).

Effects of Different Environmental Stresses on Field Crops

WHEAT

Wheat (*Triticum aestivum* L.) is the first most important and cereal crop for most of the world's populations. It is the main staple food of about two billion people (36% of the world population). Wheat provides 55% of the carbohydrates and 20% of the food calories to consumers (Breiman and Graur, 1995). It is the most important cereal crop in the world, which is grown under different climatic conditions.

Wheat has a relationship with the *Triticeae* in the grass family *Poaceae*. Wheat has further types as winter or spring, hard or soft, red or white (Briggle and Curtis 1987). Wheat is used for human consumption. Products of pasta are made by Durum wheat (Wiese 1987). It is also used for animal feed (Briggle and Curtis 1987).

Effect of high temperature stress

High temperature during the growth period reduces the grain yield (Wheeler *et al.,* 1996). In a field experiment, 40^0C temperature for ten days before and after anthesis decreased 50% kernels and 50% yield (Ferris et al., 1998). The optimum temperature for anthesis of wheat and for grain filling is $10\text{-}22^0$C. If temperature rises, grain yield reduces (McDonal *et al.*, 1983). If temperature rises during wheat anthesis, florets of wheat are aborted (Wardlaw and Wrigley 1994). If temperature rises during the reproductive growth cause sterility of pollen, dehydration of tissues, lower carbon dioxide assimilation, and photorespiration increased (Fischer, 1980). High temperature speeds up the growth rate but decreased the phenology (Wardlaw and Moncur, 1995). In Mexico, 10% wheat yield is less when 1^0C temperature rises. At night, if temperature is above 20^0C, spike fertility reduces with less grain number and grain size (Prasad *et al*., 2008). Prasad studied that $20\text{-}23^0$C temperature at night less the grain filling period by 3-6 days.

Photosynthesis

At high temperature, photosynthesis is a more critical physiological process (Wahid *et al.,* 2007). High temperature reduces photosynthesis and ultimately affects growth and grain yield of wheat (Al-khatib and Paulsen 1990). Photosynthesis is affected by the heat stress through a reduction in chlorophyll content (Xu *et al.,* 1995).

Leaf senescence

Leaf senescence means loss of green leaf part which is developed through the reproductive development of a crop (Nooden, 1988). At high temperature, synthesis of chlorophyll is closed which increased the leaf senescence (Tewari and Tripathy, 1998). By heat stress, the breakdown of thylakoid membrane is enhanced which also causes the leaf falling (Harding *et al.,* 1990).

Grain growth and development

Number of grains and grain weight are affected by high temperature (Ferris *et al.,* 1998). At spike development and anthesis starts, temperature above 20^0C less the grain number per spike (Saini and Aspinall, 1982). High temperature fasts the rate of spike development (Porter and Gawith, 1999) and spikelet number and number of grains per spike (Saini and Aspinall, 1982). More than 30^0C temperature during floret development causes sterility variation among wheat genotypes (Gibson and Paulsen, 1999). 30^0C temperature for three days, when applied to wheat plants, pollen mother cells remain half, resulting in reduction of grain yield (Saini and Aspinall, 1982) and this is not balanced by increase in grain weight. High temperature also disturbs the viability of anthers and pollen and cause less fertilization (Saini and Aspinall, 1982; Ferris *et al*., 1998). Dias *et al.,* (2008) studied that high temperature cause grain shrinkage when day/night temperature increased from $25\text{-}31^0$C.

Grain quality

Grain size and protein percentage in wheat determines the grain quality (Coles *et al.,* 1997). Elevated temperature during grain filling period severely affected the protein percentage of grain (Wardlaw *et al.,* 2002). Grain protein percentage is inversely linked to grain size (Guttieri *et al*., 2000). At high temperature, protein percentage increases but the functionality of protein decreases (Corbellini *et al*., 1997). If the high temperature is applied at an early period of grain filling, more increase in protein percentage in wheat occurs.

Effect of cold Stress

During different growth stages of wheat, low temperature affects the wheat and it is more critical to early stages of wheat (Khodabandeh, 2003). Many things affect the plant response to different stresses like duration and strength of stress, growth stage and time of stress exposure (Gupta and Sheoran, 1983). At 2^0C temperature, germination rate was low. At low temperature, root number was also lowered. The stem length is also less at 20C temperature. Low-temperature consists of chilling (below 20^0C) and above freezing temperature ($<0^0$C) which affects the plant growth and development in many ways. Yield reduction is caused by the low temperature. At low temperature, genetic potential of wheat is affected. Low temperature lowers the yield through a reduction in fertile tiller mortality and ear fertility.

Effect of drought stress

Drought stress is controlled by many genes which lower the crop yield. Wheat is an important crop where water stresses reduce the plant growth and yield. Wheat respond to drought stress depends on upon the developmental stage, severity and duration of stress (Beltrano and Marta, 2008). Drought stress at anthesis reduces pollination and less number of grains are formed (Ashraf, 1998). Optimum water level at or after anthesis increases the photosynthesis of wheat and it transmits the glucose into the grains which increase the grain yield (Zhang and Oweis, 1998). Drought stress at later stages of crop growth causes the less number of kernels/ear and kernel weight (Gupta *et al*., 2001). Water stress reduces the photosynthesis rate due to the closeness of stomata (Hsiao, 1973). Wheat crop production severely affected by abiotic stresses which reduced yield upto71%. Drought stress cause disturbance in biochemical processes and gene expression which influence crop growth and development. Drought stress has negative influence on chlorophyll contents (Mustafa *et al.,* 2013).

Effect of salinity stress

Salt stress affects the germination rate, germination percentage, and seedling growth in many ways. Germination percentage was less with high NaCl concentrations (Rubio-Casal *et al*., 2003). More salinity with the plant root zone has a drastic effect on plant growth. More salinity level reduced pigment percentage in leaves (Al-sobhi, O.A ;Al-Zaharani, 2006).It was studied that at less salinity (0.05-0.1mol/l NaCl) seedling growth was enhanced while more salinity (above 0.2 mol/l NaCl) decrease the growth. High level of salts causes oxidative stress which inhibits the germination. High level of salts causes a reduction in leaf number, leaf enlargement rate (El-Hendawy et al., 2005) root growth rate (Neumann, 1995b), root/shoot ratio and total dry matter yield (Pessarakli and Huber, 1991; El-Hendawy *et al*., 2005). Munns *et al*., (2006) studied that wheat cultivars with less sodium percentage cause more dry matter as compared to high sodium percentage.

Effect of Carbon dioxide concentration

Photosynthesis

Keeling *et al.,* (1979) studied the effect of elevated carbon dioxide on photosynthesis. Most of the studies are on the plants responses to below 0.12% carbon dioxide. At this level, high carbon dioxide increase photosynthesis, crop yield and high vegetative biomass (Ee, 2000).

Respiration

Respiration stops with short term increasing carbon dioxide in the chamber and ultimately stops. While when carbon dioxide increased in the atmosphere, the respiration rate enhances.

At 560 µ mol mol^{-1} CO_2, the respiration rate was 11% less on average than of controlled level of carbon dioxide. While at 700 micromoles mol^{-1} carbon dioxide, the respiration rate was less 25% on average (Kaiyan, Guangsheng, & Sanxue, 2013).

Root growth

Plant growth is affected by environmental conditions and increasing atmospheric carbon dioxide concentrations enhance growth and yield of most agricultural crops like wheat. Increasing carbon dioxide concentration increases growth, root/shoot ratio, root biomass, root length, root longevity, root mortality, root distribution, root branching, root quality. Increasing atmospheric CO_2 significantly increased the final plant biomass, aboveground biomass, leaf area and below ground biomass. Increased root growth contributes to root biomass and root dry weight under elevated atmospheric CO_2 regardless of species or study conditions Roots often exhibit the greatest relative dry weight gain among plant organs, even more than aboveground biomass or leaf area production. However, increased allocation of C to plant-root systems in response to CO2 levels may offset losses from increased activity of soil microorganisms. Increases in root mass may benefit mycorrhizal fungi and production of glomalin, a glycoprotein produced by endomycorrhizae contributing to soil aggregation.

Wheat (*Triticum aestivum*) shows increases in root dry weight under high carbon dioxide (Madhu & Hatfield, 2011).

Overall effects on different root parameters:

1) **Root biomass**: The increase in root growth was larger than shoot growth and root biomass increased as part of overall growth response to increased carbon dioxide.
2) **Root length:** Increased root length across species is the most common response observed. Root branching also increased with carbon dioxide enrichment.
3) **Root-shoot ratio**: Results vary among studies; however, 60% of studies show a positive response to R/S, 37% show a negative response, and 3% show no response.
4) **Root branching:** Increased root branching is commonly observed in most species and more evident in the upper soil profile.
5) **Root thickness, root quality, root diameter**: Increased root thickness and diameter are most commonly observed. Diameter changes are more difficult to quantify.
6) **Root mortality:** Increases in root mortality and turnover rates are observed across species with increased carbon dioxide (Madhu & Hatfield, 2011).

Impact of CO_2 concentration on grain yield and quality of wheat

At high carbon dioxide, grain yield increases by 10.4% and biomass production 11.8%. Thousands grain weight remain unchanged at high carbon dioxide but on grain quality, adverse effects were observed. Grain size is small due to high carbon dioxide which has lower market value. Kernel protein decrease to 7.4% at high carbon dioxide and protein and amino acid composition changed. Potassium, molybdenum and lead increased while magnesium, iron, cadmium and silicon decreased (Wieser & Ko, 2009). Elevated CO2 will promote growth and yield of the freely tillering line more than growth and yield of the restricted tillering one. Elevated CO2 will increase tiller numbers in all cultivars, thus potentially limiting the expression of the 'tin' trait. Leaf nitrogen concentrations will be more depressed by elevated CO2 in the restricted tillering line due to sinking limitations and corresponding down-regulation of photosynthesis (Löw, Rebetzke, Dreccer, Chapman, & Seneweera, 2015).

Growth and yield of wheat

Under high carbon dioxide amount, the green leaf area index of the main shoot was increased. Due to increase in leaf area duration, biomass increase at high carbon dioxide. Doubling of carbon dioxide increases the yield 40% due to more assimilation rates. Thus, high amount of carbon dioxide shows positive effects on yield. High carbon dioxide affects the photosynthesis and reduced water availability. At anthesis, stem and ear dry weights and plant height increases 174%, 5%, and 9cm respectively and biomass at maturity was 23% more at 680ppm carbon dioxide. Grain numbers per spikelet and grain number per ear were increased by 0.2 and 5 grains respectively. Grain yield increase by 33% (Mulholland *et al*., 1997).

RICE

Rice (*Oryza sativa* L.*)* is one of the most important cereals it is used as a staple. Almost 90% of the world rice is grown in Asia. In tribe oryzae, there are 12 generas and it has 22 species. Between 2 cultivated species O. sativa is one of the most important species. The chromosome number of *Oryza sativa* 2n=24. It has a diploid genome (The Biology and Ecology of Rice (Oryza sativa L.) in Australia, 2005). It is a monocot and it has annual growth but in tropical areas, it also survives as perennial. Its lifestyle is semi-aquatic. It requires flooding water up to the reproductive phase. There are three important stages of rice are germination, vegetative growth, and reproductive.

Effect of high-temperature stress on Rice

Increased temperature causes the sterility of spikes which leads to heat injury during the emergence of panicles. The temperature of air increases in temperate regions speeds up the development of rice so the time from transplanting to harvesting is reduced. Its drawback is a reduction in the photosynthetic yield development. Whereas in the regions of high latitude warming of atmosphere cause the increase in the period of rice growing season. Yield and season length are uncertain due to the difference between air temperature and leaf temperature. The temperature of the leaf is warmer than air temperature which causes the rapid increase in yield (Cho & Oki, 2012).

Effect of cold stress on Rice

When rice plant is under cold stress then it disturbs the metabolisms leading to change in the various physiological functioning of rice plants. Cold stress triggers the reduced chlorophyll content and fluorescence (Fv/Fm). The amount of MDA and ROS has been increased due to which injury to photosynthesis takes place. Proline, soluble sugars, and antioxidants accumulate in plant and protect it from further damage. These physiological parameters are also important because the extent of cold tolerance can be measured by identifying the genes.(Zhang, Chen, Wang, Hong, & Wang, 2014).

Criteria for the cold tolerance evaluation

The loss in the fresh weight depicts cold stress because water loss is not a reliable indicator of stress because leaf area and plant variety affect the measurement of water content. Visually we can measure the cold stress by using the seedling growth scale which is more reliable. Parents tolerant to cold are selected from germplasm. Their evaluation should be at reproductive stage. QTLs are used to identify cold tolerance by the development of linkage maps and molecular markers. (Zhang *et al*., 2014).

Effect of drought Stress on Rice

Among abiotic stresses water deficiency is a major stress. It highly affects the yield and growth of the plant. There are 3 most critical stages of growth. If a drought comes on these stages, then plant is damaged the most. These are anthesis, vegetative and seedling. If water deficiency occurs on vegetative growth, then delays in panicle initiation take place. At flowering water stress is highly damaging it affects pollination, grain abscission, and flower abortion. There is less translocation of assimilates to the reproductive organs (C. M. Singh, 2012).

Drought tolerance in rice

Rice is a water loving crop and it is more susceptible to drought. Inter cellular volume, cell size and leaf area has been reduced by water stress. Less the water move from stomata into atmosphere more will be the drought tolerance. Lower water content in the leaves are due to less soil moisture which leads to lose turgor pressure by guard cells and reduction of size of stomata take place. Plant may survive through prolong period of stress by closing stomata which leads to increase in water content in leaf and ultimately increasing the water potential and photosynthetic activity. Cuticular wax is present in dry land rice than irrigated rice. So it makes the leaves thick and leathery which prevents the water loss from the surface. Plant also saves from drought stress by rolling and death of leaves. It is the mechanism of drought tolerance and could be use as very useful selection criteria. Deep root system also involves in drought tolerance (C. M. Singh, 2012).

Effect of salinity stresses on Rice

Salt-affected soil is the major problem faced now days. It reduces the productivity of rice in many areas of the world. The leaves of varieties were studied which were damaged by NaCl. They differ in the sensitivities of NaCl. Rice seedlings of 3 weeks were then subjected to salinity levels of 0,6,12 dsm for the period of 1 week. Then the difference in the growth rate, Na ion uptake, and antioxidants capacities was analyzed. Accept Pokkali the growth rate of all the varieties were disrupted. IR28 and Hitomebore were salt sensitive. Increase in peroxidase activity and decrease in superoxide dismulase under salt stress, higher Na ion accumulation increased lipid peroxidation and electrolyte leakage has been observed in Hitomebore. Pokkali is salt tolerant and shows only minute increase or decrease in peroxide activity and superoxide dismulase. Na ion accumulates electrolyte leakage, and lipid peroxidation was unchanged in Pokkali. Cellular toxicity of NaCl in rice is due to free radical that damaged the membrane. Tolerant varieties have protection mechanism which is mainly due to the specific activity of antioxidant enzymes.(Maribel L Dionisio-sese, n.d.).

Effect of carbon dioxide concentration on Rice

In laboratory rice grown on a high level of CO_2 produced more tillers than rice at ambient CO_2 level. At higher CO_2 the yield of rice plants prompted. There are 4 important parameters which are associated with increased CO_2 level for positive performance.

1. Enhanced photosynthetic activity
2. Decreased stomatal aperture
3. Changed biomass partitioning
4. Increased total biomass

Reduction in the aperture of stomata leads to increase in canopy temperature of rice. So the transpiration suppressed. The increase in the rate of photosynthesis takes place by the rise in intercellular CO_2. If the plant is subjected to elevated CO_2 level for the long term it results in a decrease in photosynthetic activity. This process is named as acclimation of rice photosynthesis to elevated CO_2 (Cho & Oki, 2012).

MAIZE

Maize (*Zea mays* L.) belongs to the family *Poaceae*. It is the most important cereal crop and cultivated worldwide. It is also very important for humans as well as animal food. It is also used in the manufacturing of certain products. The tribe of maize is *Maydeae*. There are species in genus *Zea*. The species of *Zea* are referred as teosentie. The Number of chromosomes in maize is 2n=20. Sexes in maize are separate. Pistillate is referred as the female and staminate as male. Pistillate is on top and tassel has a lower position than pistil or cob (Ministry of Environment and Forest, India).

Effect of heat stress on Maize

Heat stress for a long time at the early stages of development of kernel leads to abortion or its growth has been disrupted. Short period high-temperature stress can also hamper the development of the kernel. Kernels which are subjected to short-term heat stress showed recovery but that was partial. The mechanism is not the same in the long-term heat stress.

Abscisic Acid (ABA)

The study showed that important reason behind the disruption of kernel growth is mainly due to the change in hormonal balance. At early growth stages during kernel development, there is a decline in ABA level in nonstressed kernels, leads to normal physiological processes which are important in the development and growth of endosperm. This process does not take place in heat stressed kernels. In heat stress, there is an increase in ABA concentration at later developmental stages leads to maturity of kernels and dormancy of embryo (Cheikh & Jones, 1994).

Cytokinins

Cytokinins are important than ABA because thermostability of kernel development and establishment of sink potential of maize kernel has been done by Cytokinins. In several plants, Cytokinins are responsible for the thermostability like in seedlings of maize, *Sacchromyces cerevisiae* and potato tubers. Heat stress level that disrupts the kernel development of maize also lowers the endogenous level of Cytokinins. During heat stress if there is an infusion of cytokines at stem then there is increase thermo-tolerance of the developing kernels of maize (Cheikh & Jones, 1994).

Effect of cold stress on Maize

Photosynthesis is greatly reduced when the temperature is low. The main effect of chilling stress is the photosynthetic light reaction to the sink of assimilates.

Antioxidants

Due to extreme environmental factors, there is a loss of metabolic homeostasis which results in large amount production of ROS. If maize seedlings are exposed to a low temperature in the dark leads to the formation of H_2O_2. As the rate of photosynthesis decreases the increase in the generation of ROS takes place (Leipner, 2009).

Genetic basis of chilling

QTLs are used to find the genomic regions. For shoot fresh weight several QTLs have found at early growth stages. The relationship of these QTLs has also been seen for leaf chlorosis.

Molecular basis of chilling

Cytoplasmic Ca^{2+} increases when the plants are exposed to low temperature (Leipner, 2009).

Effect of drought stress on Maize

Drought is the most dangerous issues in crop production. Water plays an important role in the functioning of the plant because it is a cooling agent. Vegetative growth, seedling establishment, root growth, anthesis, photosynthesis, pollination, anthesis-silking interval and formation of grain in maize crop are seriously affected by drought. Tolerance to drought stress can be enhanced by application of nutrients. Potassium is one of the nutrients which enhance tolerance in maize plant for drought stress. It also increases osmotic potential, leaf water potential and turgor potential under drought stress as well as parameters of gas exchange have also been increased. The photosynthetic rate has also been increased by this. Sugars prepared in leaves to fruit are greatly increased, so the yield has been increased by potassium and other yield-related attributes of maize crop have also influenced by this. So the role of potassium is very important in drought tolerance to increase yield under drought stress condition (Aslam, Afzal, Yaseen, Mubeen, & Shoaib, 2013). Mustafa *et al*., (2013) reported that chlorophyll contents showed highest phenotypic and genotypic variation while root density lowest for leaf temperature. This trait can be used for selecting high yielding traits.

Effect of salinity stress on Maize

Nineteen varieties of hybrid maize were tested at early growth stages under controlled environmental conditions in different nutrient media. At a concentration of 250mm NaCl was added in nutrient media for salinity stress for 6 days. Plants are then allowed to grow. After 17 days it is harvested and has been analysed for root and shoots dry matter production. Extent of damage to leaf and the amount of several other ions like Ca, K and Na in the shoots and roots has also been observed. Different varieties have different responses. 2 varieties C 7993 and Maverick considered as more tolerant. Due to salinity shoot dry matter reduced more. Higher the sodium concentration in shoot the higher will be the salt tolerance. Intolerant varieties Ca/Na and K/Na is greater (Eker, Cömertpay, Konufikan, Ülger, & Öztürk, 2006).

Effect of CO_2 concentration

Maize is a C4 plant when the partial pressure of CO_2 is elevated than the ability of C4 plants to accumulate more biomass has also been increased. Its mechanism so far is not so clear. Elevated pressure of CO_2 stimulates the growth of stressed as well as watered plants. Mainly it is due to the increase CO_2 assimilation rate in leafs which takes place due to increase in intercellular P (CO_2). Secondly, it is due to a reduction in the rate of stomatal conductance and also due to the rate of leaf transpiration. Less transpiration rate increases the rate of CO_2 assimilation in leafs. The growth rate has also been increased by improvement in shoot water relations, it also conserves soil water and the temperature of the leaf has also been increased (Ghannoum, Caemmerer, Ziska, & Conroy, 2000).

BRASSICA

Brassica is an important oilseed crop which comes to third position in the world as a source of vegetable oil after soybean and palm oil. The genus *Brassica* belongs to the family *Brassicaceae*, which comprises of 100 species. It includes rapeseed (*Brassica napus* L.), mustard (*Brassica juncea* L.), turnip rape (*Brassica rapa* L.), cabbage (*Brassica oleracea* L.), black mustard (*Brassica nigra* L.) and Abyssinian cabbage (*Brassica carrinata L.*) which are mainly grown for vegetables, oil, fodder or condiments (Ashraf & McNeilly 2004). According to Lallu and Dixit (2008), the optimum average temperature is 26°C for proper germination and seedling establishment of *Brassica* plants. *Brassica* crops are mainly affected by salinity, heat, and drought stress because they are mainly grown in arid and semiarid areas. Wild relatives of Brassica possess useful traits for tolerance to salinity, drought and cold stress conditions (Warwick 1993).

Effect of heat stress on *Brassica species*

Effect on germination and growth

Temperature stress beyond threshold levels caused a severe reduction in pollen germination and pollen tube length resulted in pollen mortality and fruit setting (S. K. Singh, Kakani, Brand, Baldwin, & Reddy, 2008).

High temperature severely reduced germination and survival of seedling in Brassica (Rathore & Raja, 2014).

Effect on reproductive stage

Reproductive stage is considered as the most susceptible stage affected by heat stress in most crops where temperature stress has been studied (Hall, 1992; Paulsen, 1994). Canola is cultivated both during winter and spring seasons so exposed to frost and high temperature extremes. It has been reported that *B.juncea* is better adaptive to semiarid prairie than other two species *B.napus* and *B.rapa* (Rakow, 1995). It is stated that temperature affects all crucial steps of reproductive cycles such as pollination fertilization, embryogenesis and gametogenesis (Angadi *et al.,* 2000; Singh *et al*., 2008). Raceme yield of *Brassica* was reduced by heat stress. It has been found that flowering and flower pattern of *Brassica* severely affected by heat stress.

Effect on yield

High temperature cause reduction in seed production as a result of decrease flowering, disruption in fertilization, fruit abortion and post fertilization (Young *et al.*, 2004). Heat stress have no effect on flower production but it has severe effects on silique and seed production (Young *et al*., 2004). It has been reported by Angadi *et al.,* (2000) that greater yield reduction occurred during early flowering than pod development when Brassica species exposed to 35/15°C day/night temperature for 7 days. 50% reduction in yield was also reported by Angadi *et al.* (2000) and young *et al.* (2004).

Effect of cold stress on *Brassica species*

Effect on germination and other morphological characters

Morrison *et al*., (1989) reported that 5°C was the optimum germination temperature for canola. Low temperature reduces the final percentage and rate of germination, which results in delayed and reduced seedling emergence of canola species (Zheng *et al.,* 1994). Nykiforuk and Johnson-Flanagan (1994) found that significant reduction in canola germination occurred at temperatures less than 10°C. Vigil *et al.* (1997) stated that 65 to 81 growing degree days (GDD) are required for the emergence of spring canola seedlings. Nykiforuk and Johnson-Flanagan (1994) found differences in growing degree days among the species and seed lots. Cebert and Rufina (2007) observed an inverse response among cultivars between freeze damage and seed yield. Low sub-optimal temperature not only decreases the rate of seed germination but it also increases the percentage of non-germinators (Marshall, Dunlop, Ramsay, & Squire, 2000).

According to Blackshaw (1991) and Livingston and De Jongs (1990) spring canola which is seeded into suboptimal soil temperatures had lower emergence and poor stand establishment due to rotting of seeds in the cold soils. It is stated that early spring frosts are more problematic to canola seeded in fall, which emerges earlier than early spring seeded canola (Willenborg *et al.,* 2004). Fall seeding entails seeding into hard and cold soil, which leads to poor soil to seed contact (Kirkland and Johnson, 2000). It has been observed from the experiments that plants showed marked retardation of leaf lamina expansion with rate of expansion similar in two genotypes. Cold effects with short freezing treatment results in decreased cell wall thickness (Uta *et al.*, 2008).

Effect on yield

An experiment was conducted by Cebert and Rufina (2007), in which twenty genotypes of winter canola at varying stage of flowering and pod filling were exposed to three incidences of naturally occurring severe spring frosts which cause reduction in most of yield components such as destruction of photosynthetic green tissues due to late spring frosts, destruction of developing pods and primary yield loss due to dropping off of fertilized flowers after late spring frosts.

Effect of drought stress on the *Brassica species*

Effect on morphological and physiological processes

A significant decrease in the stem height of rapeseed cultivars has reported by Sadaqat *et al.,* (2003) under water stress conditions. Decreased soil moisture resulted in the reduction of a number of branches per plant (Sadaqat *et al*., 2003; Naeemi *et al.,* 2007). Water deficit stress caused a reduction in the plant height which is related to decline in photosynthesis products resulted by decreased soil moisture conditions which ultimately cause the plant not to reach its genetic potential (Hossein, Rad, & Zandi, 2012). Drought stress has adverse effects on many processes of plants such as photosynthesis reduction, stomatal exchange, protein synthesis and accumulation of dry matter that affect their different growth stages (Larcher, 2003; Ohashi *et al.,* 2006; Hossein, Rad, & Zandi, 2012). Plant respond to drought stress through developmental, physiological and biochemical changes and this response depend on upon several factors such as stress intensity, stress duration and genotype (Moradshahi *et al.,* 2004). Moaveni *et al.,* (2010) stated that leaf area index (LAI), total dry matter (TDM), and crop growth rate (CGR) and relative growth rate (RGR) were varied among rapeseed cultivars which were greatly affected by drought stress.

Effect on flowering and silique formation

When after the flowering stage water deficit conditions are applied it causes a reduction in the number of silique per plant by shortening the flowering period, reproductive period and infertility of flowers and their abscissions (wright *et al*., 1996). Sinaki *et al.,* (2007) observed that water stress during flowering and siliqua formation stage caused the number of silique per plant to reduce by severe flower and silique abscissions. Results from the experiments revealed that water deficit stress caused a 37% decrease in the number of silique per plant while, the largest number of silique per plant (325) was obtained from the normal irrigation (Hossein *et al*., 2012). Daneshmand *et al.,* (2008) observed a 59% decrease in the number of silique per plant of rapeseed cultivars when exposed to water stress conditions.

Effect on yield and yield contributing traits

Nasri *et al.* (2008) observed that drought stress caused significant reduction in seed yield, number of seeds per siliqua, the number of silique per plant, 1000 seed weight, oil yield and seed oil content in five cultivars of rapeseed. Water deficiency during the flowering stage resulted in the reduction of biological yield, seed yield and the number of silique per plant while, the number of seeds per siliqua was not affected Sinaki *et al.,* (2007). Zakirullah *et al.* (2000) observed from the experiments that under water stress conditions the number of silique in the main stem, the number of branches per plant and the number of seeds per siliqua of drought-sensitive lines of rapeseed had a sharp drop however, in drought tolerant lines this reduction was not significant.

Gan *et al.* (2004) observed that Brassica juncea cultivars are more efficient at increasing number of pods than Brassica napus under stress environments which contribute to better yield. Results revealed that water stress cause reduction of seed yield produced on branches and seed yield per plant however, it did not influence seed yield produced on the main shoot which indicated that water stress does not affect directly the crop yield but it is helpful in the recovery process (Saini and Westgate, 2000). Seed yield was affected by water stress conditions when water stress was not severe but long enough to reduce assimilates supply during reproductive growth stage (Savin and Nicolas 1996; Gan *et al.*, 2004).

Effect of salt stress on *Brassica species*

Brassica species are considered as a moderately salt sensitive genus (Hayat *et al.,* 2007) which shows certain variability towards salt tolerance (Ashraf and Sharif 1997; Beltrao *et al.* 2000; Maggio *et al.* 2005). Effect of salinity and low water potential induced by PEG examined by Pace *et al.,* (2012) on the germination of one stress sensitive and stress tolerant rapeseed cultivar. Since salinity in the soil due to drought conditions remained after germination and crop emergence, the effect of salt stress found worth (Benincasa *et al.,* 2013). Ashraf and McNeilly (2004) found that *Brassica* species show a different response to salt stress at various plant developmental stages, but maintain their degree of salt tolerance throughout plant ontogeny.

Effect on germination and seedling growth

Salt stress affects all growth stages of a plant while seed germination and seedling growth stages are known to be more sensitive stages in most plant species (Ashraf *et al.*, 2004; Cuartero *et al.*, 2006; Su *et al.*, 2013). During germination salt tolerance and sensitivity not necessarily implicate tolerance and sensitivity during seedling stage and plant growth (LUTTS *et al.*, 1995; ALMANSOURI *et al.,* 2001; Benincasa *et al.*, 2013). This germination condition also affects the seedling stage and plant growth (UNGAR, 1995). According to length Benincasa et al. (2013) salt stress also reduced seedling growth.

Effects on root shoot growth and ratio

Salinity stress cause reduction in shoot growth more than root growth (Munns, 2002). Many studies revealed that salt stress in Brassica species causes a decrease in shoot/root ratio (Maggio *et al.*, 2004; (Badruddin *et al.*, 2005; Jamil *et al.*, 2005). In Brassica napus, (Basra *et al.,* 2003) found that hydro-priming and osmo-priming with PEG improve growth parameters in non-stressed conditions. In hydroponics salt stress reduced shoots length and shoot/root ratio in two cultivars of rapeseed without any significant effect on root length (Benincasa *et al.*, 2013).

Effect on phenology and physiology of plant

Due to osmotic stress which is associated with salinity stress a decrease in leaf area and photosynthesis rate may occurred (Lawlor, 2002; Kauser *et al.*, 2006; Shah, 2007 and Benincasa *et al.,* (2013), which is related to stomatal closure (Martinez *et al.,* 2007), decrease in Rubisco activities (Parry *et al.,* 2002) or alteration of photosynthesis light phase (Qiu *et al.,* 2003; GARCÍA-MORALES *et al.,* 2012). Siddiqui, Khan, & Huang (2008) found that fresh and dry weight of *Brassica napus* genotypes were significantly affected by combined effects of salt and drought stresses. Leaf area per unit dry weight significantly reduced in plants which were treated with salt stress. The leaf area, osmotic potential and stomatal conductance of each genotype were also decreased due to salt stress. Salt stress lowers the rate of water uptake by the roots and salt tolerant genotypes mainly adopt this strategy (Huang and Redmann 1995b). Lafitte 2002 found that imbalance between water uptake by roots and water loss through cause plant wilting. Salinity causes nutritional imbalances due to ions and low soil water potential in both translocation and uptake processes with toxic effects due to the accumulation of sodium (Na^+) and chlorine (Cl^-) ions in the cytoplasm (VILLALTA *et al.*, 2008).

Effect on yield

Salinity causes a reduction in yield, growth and oil production. Salinity has most common adverse effect on the Brassica crop as reduction in size, plant height, and yield as well as deterioration of the product quality (Ashraf *et al.*, 2004; Zamani *et al.*, 2010; Su *et al.*, 2013).

Effect of CO_2 concentration on *Brassica species*

Reza & Moghadam (2012) reported that elevated CO_2 increased leaf soluble carbohydrates, reducing sugars, glucosinolate concentration, and Fv/Fm ratio in *Brassica* species. However, proline and chlorophyll contents decreased under increased concentration of CO_2. Elevated CO2 increased the vegetative biomass significantly, but seed yield enhanced in only one cultivar of *Brassica napus* (Frenck *et al.,* 2011). Chakraborty and Uprety (2012) reported that elevated CO2 enhanced yield attributes such as seed yield, total number of pods per plant, pod dry weight per plant, number of seeds per pod, thousand seed weight and harvest index. Higher CO_2 concentrations increased total and reducing sugars, starch and starch content significantly, however, total soluble protein decreased under elevated CO_2 in both cultivars of *Brassica*.

SUGARCANE

Sugarcane is a perennial crop. It is considered as the most economic crop of the world. Sugarcane is a C4 plant which is grown in tropical and subtropical regions. Its center of origin is New Guinea. There are five important species in the genus Saccharum viz. *S.sinense, S. notatum, S. robustum, S.officinarum and S.barberi* (Daniels and Roach, 1987). It has been cultivated on more than 20 million hectares of the world. Sugarcane is mostly known as a topical crop but it is now successfully grown in sub-tropical areas of the world around 30°N and 30°S (Blackburn, 1984). About 1.3 billion metric tons' stems are produced, which are crushable, to fulfill the need of the people. Different by-products are obtained from sugarcane for example baghass; fiber etc. Sugarcane is also an important energy source of biofuel. It is expected to be the given the rank of energy source globally (Pandey *et al.*, 2000).

Effect of temperature stress on sugarcane

The increase in temperature has a great effect on the physiological process of sugarcane. Sugarcane is included in the C4 plants. Due to the increasing temperature 8-34°C the CO_2 assimilation is increased (Gawander, 2007; Sage and Kubien, 2007). Sugarcane plant is get stressed when the temperature is above 35C.when the temperature is above 38°C then the process of photosynthesis is slowed down, as a result, the plant growth remains half. Erahim *et al.* (1998) stated that if the temperature is low 15°C then the growth of sugarcane is limited the growth stages of sugarcane named emergence and sprouting are badly affected due to high temperature. Rasheed *et al.* (2011) stated that due to high temperature stress the emergence of sugarcane will be poor. If the temperature is above 32°C, then the cane quality will be more affected. Clowes *et al.*, (1998) explained the reason that if there is the high temperature at the night time usually stops the growth of internodes and leaves ultimately there will be a reduction in the sucrose production.

It has been studied that due to change in temperature there will be more threat to the crops due to some biotic factors for example insect, pests and weeds etc. (Neu meister, 2010). Some diseases like Ratoon Stunting disease and smut reduce the sugarcane yield (Clows *et al.*, 1998). If the temperature continuously rises, then the weeds may be mutated and more difficult to control. Temperature is very important at the stage of Ripening and maturity. But if there is fluctuation in the temperature at that stage for example if the temperature is high at that stage then the sugarcane yield will be low (Gawander, 2007).

Effect of cold stress on sugarcane

Sugarcane is very sensitive to cold stress because it requires high temperature for its growth (Wahid *et al.*, 2009). Survival of sugarcane can be at very less temperature above zero but its growth is lesser at 20°C. If there is cold stress then the growth of sugarcane is reduced in the spring season, it will result in a very short period of growth ultimately there will be a loss in yield. There should be resistance in sugarcane leaves to not to have frost injury (Wahid *et al.*, 2009).

Effect of drought stress on sugarcane

Water scarcity is the major factor due to which crop yield becomes less up to 70% (Gosal *et al.*, 2009; Morison *et al.*, 2008). Tillering and growth phase of sugarcane are very much sensitive to water stress conditions (Ramesh, 2000). Plants need CO2 to make their food. If water is not available to plants, then they cannot respire properly. So the stomata do not open to transpire which is also the limiting factor in photosynthesis process of sugarcane (Taiz *et al.*, 2006; Molina, 2002). Different physiological functions in the plant are controlled by the amount of water that how much water is present in the plant body. If that water quantity changes then relative water content has a direct effect on the photosynthesis activity of the sugarcane plant (Graca *et al.*, 2010). When water content decreases in the sugarcane plant then uptake of carbon dioxide is decreased and stomata are closed (Buckley, 2005). Sugarcane needs a specific amount of water but if the relative water content is decreased up to 10-20 % then sugarcane sensitive plants are badly affected (Graca et al., 2010). Different physiological functions in the plant are controlled by the amount of water that how much water is present in the plant cells. Drought affects the morphological traits of plants due to which the yield of the cane is reduced. Genetic studies on sugarcane show that there is no fixed pattern of changes in the expression of genes due to drought (César, Andrade, Terto, Silva, & Almeida, 2015).The yield of the crop is limited up to 70% (Gosal et al., 2009) Sugarcane under stress showed symptoms like reduction in stomatal conductance, leaf photosynthesis rate, photosystem II, the number of tillers. All these symptoms lead towards the reduction in biomass of shoot. It is noted that on sand soil symptoms appeared within 7-10 days than on muck soil(Zhao, Glaz, & Comstock, 2010).

Effect of salinity stress on sugarcane

Salinity is also a major stress for the plants. At different growth stages, sugarcane has different effects of salinity. Due to high salinity stress, there will be osmotic stress in the plant body and different plant metabolic processes are disturbed greatly (Zhu, 2001). Different genotypes were used under three different salinity levels. These were 2.5, 8 and 12 dSm^{-1}. At high level two genotypes performs well and showed high yield of cane juice and sucrose (Akhter *et al.*, 2001). In vitro salt tolerance of three varieties of sugarcane checked. They were also checked for embryogenic callus production and callus induction. In order to check the salt tolerance growing calli was subjected under two different subcultures and with different NaCl concentration added to the culture for 4 weeks. Genotypes were compared on the basis of embryogenic callus production, percentage of callus induction and relative fresh weight growth. Some varieties responded more to callus induction. Three varieties were having high embryogenic callus production. Calli necrosis and reduced growth is due to the NaCl (Gandonou *et al.*, 2005).

Effect of CO2 concentration on sugarcane

Sugarcane is a C4 crop and is mostly grown in tropics and subtropics. Photosynthesis of sugarcane increases, when the level of carbon dioxide under controlled environment has elevated. Stomatal conductance has reduced which increase the water use efficiency. This is also associated with increased carbon dioxide level(Zhao & Li, 2015).

Conclusion

This paper summarizes the climate change effects in the scenario of climatic variability, crop productivity, and food security. Due to global warming and climatic vulnerability plants face many environmental factors which have detrimental effects on their growth and production. These factors include heat stress, cold stress, drought stress, salinity stress and different concentrations of CO_2. Future climatic predictions indicate that temperature and CO_2 concentrations will increase, but increase or decrease of other factors like precipitation, salinity, etc. will depend on the research area location. Crop growth of various plants has been tested and modified for various factors under the changed weather and climatic conditions. The broad genetic diversity in crops provides facility to identify suitable thermal, drought, salinity tolerant cultivars for the changed climatic situation. It is time need, that Plant breeders should design their experiment under the scenario of global warming and develop the crop cultivars that are more resilient to changing climatic conditions. Suitable agronomic management practices and crop production technology will also be helpful to combat the effects of climatic change and provide high sustainable agriculture production.

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