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Review Article

Responses of Cultivated Plants and some Preventive Measures against Climate Change

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ABSTRACT

World previously underwent four major disasters and another disaster is expected due to rapidly occurring climate change. The majority of rays of light, which reach the ground from the sun in (6-8 min) cause greenhouse effect and increase the earth temperature since they are not reflected back. With climate change, polar ice-caps melt and flow into the ocean, the level of the sea raises, fresh water reserves are decreasing (due to the increase of salt water) and ecosystem components, which are essential for life and biological diversity are eroding. The organisms are forced to migrate to regions, which are lowly affected by climate changing. The resulting species and habitat shifts result in some organisms (*Tarantula* spp., *Castanea* spp., *Malus floribunda*, etc.), whose natural habitat is humid regions, such as tropical and coastal regions, can be encountered in temperate and inland regions (e.g., Turkey). Many great and famous lakes and wetlands disappeared (e.g., Aral, Salda, Meke Lakes) and snow and ice on many mountains has melted (e.g., Mount of Kilimanjaro, Ilgaz Mountains, etc.) in the world. Similarly, the effects of climate change on cultivated plants (C_3, C_4, CAM) are dramatic and this issue has been examined physiologically and agronomical. It is suggested that concerned institutions should immediately develop necessary plans, programs and collaborative mechanisms to combat climate change effects.

Key Words: Agro-morphologic traits; Cultivated plants; Climate change; Preventive measurements

INTRODUCTION

"Climate change" refers to the increase of earth temperature due to the release of gases such as CO_2, CH_4, CFCs, N_2O, O_3 into the earth's atmosphere (IPCC, 2007; Anonymous, 2008a & c; Ulukan, 2009). These gases affect the interaction between the first and the second atmospheric layers (troposphere & stratosphere) by preventing the reflection of solar rays (Krupa, 1996; IPCC, 2007). Although international agreements e.g., 1997–Kyoto Protocol (Oberthür, 2001) were signed in order to limit these undesirable and dangerous developments, some countries are reluctant to participate and address this crucial issue. There are lots of signs of climate change such as melting glaciers and sea ice, sea-level rise, earlier flowering and ripening dates, longer growing seasons, coral bleaching, migration of plants and animals towards the poles, etc (Anonymous, 2009e). It was estimated that due to climate change, an increase in air temperature of (2.0–6.3°C) will occur by 2100 in Europe continent (Fernandes *et al.,* 2009).

The effect of climate changing on vegetation can be dramatic, due to variations in the amount of CO_2 available for photosynthesis. Prior to the industrial revolution, the level of atmospheric CO_2 was 270 ppm. It has exceeded 375 ppm in modern times (Rogers *et al.,*1994) and it is expected to reach 600 ppm during the 21^{st} century (Langley & Megonigal, 2010). In addition to increases in CO_2, the annual increase of CH_4 is 1.0% and that of N_2O is 0.3%, whilst tropospheric O_3 also affects the situation (Krupa, 1997). In addition, climatic factors such as temperature, precipitation, moisture and pressure affect the development of the plants, either alone or by interacting with others factors (Patterson *et al.,*1999; Cutforth *et al.,* 2007).

Climate warming due to an antropogenic increase in greenhouse gases is predicted to increase the earth's average surface temperature during the next 50 to 100 years (Egli *et al.,* 2004). Consequences of increasing temperature in several organisms point to changes in physiology, time of life cycle events, and distribution of individual species with shifts toward higher altitudes or latitudes (Fernandes *et al.,* 2009). Penuelas and Filella (2001) conclude that many ecological (carbon sequestration, nutrient & water cycles, species competition, pests & diseases, bird migration & reproduction & species interactions), agricultural (crop suitability, yield potential, length of growing season, risk of frost damage, epidemiology of pests & diseases, timing and amount of pesticide use & food quality) and socio-economic and sanitary (duration of the pollen season & distribution & population size of disease vectors) factors depend strongly on plant and animal phenology. These, in turn, are increasingly influenced by climate change.

Various agricultural activities in the spring season are less affected by climate changing than in the summer season (especially blooming). The main reasons for climate

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changing are the automotive and petrochemical industries, emissions from factories, planes and cars, iron and steel establishments (Mei *et al.,* 2007), refineries, rice paddies (Conrad, 2002; Ulukan, 2008), over-use of nitrogen-based fertilizers (Fuhrer, 2003), erratic and/or insufficient agricultural applications, forest fires, devastation of natural vegetation and green spaces (Fuhrer, 2003; Olesen & Bindi, 2004; Anonymous, 2009a) and burning of agricultural biomass (e.g., sugarcane & rice stalks, stubble) (Houghton, 2005; Ulukan, 2008). The effects of CO_2 are most significant, since its overall contribution to climate changing is 300 times bigger than other greenhouse gases. On the other hand, ice on Greenland is melting (2000 to 2008, 1500 gigatons-one gigaton & 0.75 mm per year) but new research findings show that it is disapearing much faster than previously thought and this means that ocean levels are also rising more quickly (Anonymous, 2009b).

A gradual increase in the earth's temperature results in the following events: big masses of ice are melting in the poles and accordingly biological diversity in the poles is disappearing. The melting of the polar ice caps releases very large amounts of fresh water into the oceans and a rise in sea level is predicted between 2-50 cm (Tan & Shibasaki, 2003; Olesen & Bindi, 2004; Anonymous, 2008c). Sea level rise may submerge some countries (e.g., Tuvalu Islands); it may lead some countries to build preventive structures (such as Dam) (e.g., The Netherlands), which provide revenue from the coastal trade, while some countries will have to take both long-term and short-term measures (e.g., the Maldives).

Frequency of particularly "*hot and dry*" weather events has increased significantly following the trend on local and regional scale with an unpredicted dimension; water sources, dams, flora and fauna are negatively affected (Olesen & Bindi, 2004). The range of various diseases and insect species has shifted in response to changing climate (Patterson *et al.,*1999; Fuhrer, 2003; Olesen & Bindi, 2004; Houghton, 2005; Anonymous, 2008a & c). Aim of this paper are to (i) evaluate of the effect of climate change on the cultivated plant's anatomical, agro-morphological traits with the agricultural aspect (s), (ii) express the some agro-morphologic responses of cultivated plants, and finally, (iii) sort out and itemize the some agricultural measurements against climate change.

Plant species and their reaction to climate changing: With respect to their photosynthetic pathways, plants are grouped into three categories as C_3, C_4 and CAM. The C_3 plants include small grain cereals such as wheat, barley, oats, rice, rye, all legumes, potato, vegetables and their tree formations; C_4 plants include coarse grain cereals and grasses such as maize, millet, sugarcane; CAM plants include such as pineapple, which has very different photosynthetic mechanism. Since legumes belong to C_3 group, their photosynthetic activity and net photosynthesis rate increases but water use efficiency decreases when CO_2 concentration increases (Dhakhawa & Campbell, 1998); but they are excessively affected by increased temperature (Brown & Rosenberg, 1999; Cuthforh *et al*., 2007). However, this situation is completely different for C_4 plants. All plants in this group are significantly affected by increased temperature; they can die with a small change in the CO_2 concentration (Tubiello & Ewert, 2002). The third group, CAM (Crassulacean Acid Metabolism) plants [e.g., Pineapple (*Ananas comosus* Merr.)], are not affected by temperature increases, as the CAM mechanism allows the plant to keep leaf stomata closed during the hotter parts of the day, thereby reducing loss of water through evapo-transpiration (Ulukan, 2008).

Previous studies have indicated that climate change may have dramatic effects on the growth and development of field crops (Romanova, 2005). Increased CO_2 concentration increases the water use activity with the growth, especially in legumes (Cutforth *et al.,* 2007). It was also pointed out that increase in CO_2 increases productivity. However, positive effects are masked and negative effects will emerge due to increased temperature (Song *et al*., 2009). There are many complex processes and interactions that determine crop yield under climate change. These metabolic events in plants depend upon mean temperature, the interaction between water stress and CO_2 (Fig. 1 & Table I) and the interaction between ozone (O_3) and a range of environmental variables (Challinor *et al.,* 2009). Previous studies have indicated that the sensitivity of C_3 photosynthesis to temperature declines as plants become limited by CO_2, much like the patterns exhibited by C_4 plants (Ward *et al.,* 2008). Like CO_2, temperature has important phenological effects on plants and their responses such as time of decomposition, flowering (anthesis), N mineralization net photosynthesis, maintenance respiration, growth respiration, etc. (Norby *et al.,* 2004).

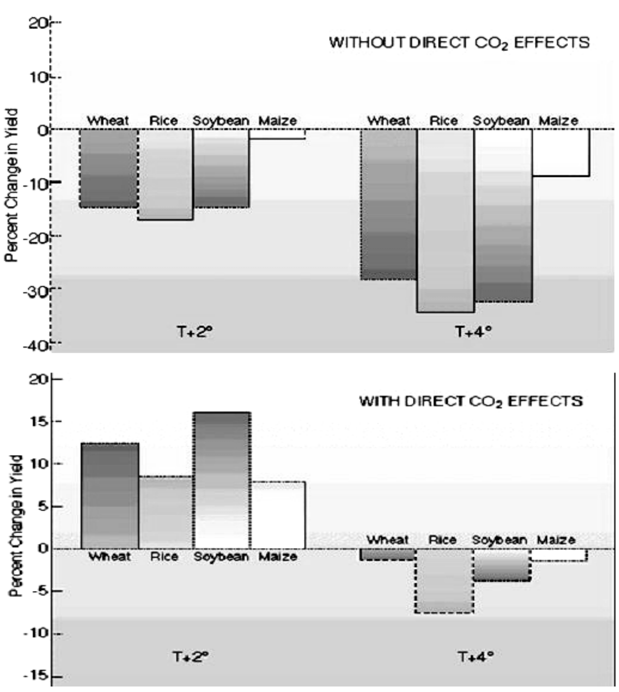
The effect of climate changing on productivity and cultivation of cultivated plants: Plants serve as indicators of climate change that can be compared with temperature measurements. In some cases, certain phases of plant growth and reproductive cycle are very sensitive to specific climatic factors (Wahid *et al*., 2007; Anonymous, 2009c). Researchers at the universities of Leicester and Oxford in the UK have identified a single gene responsible for controlling the plant growth responses to elevated temperature; a breakthrough that could potentially have an enormous impact on crop production as climate changing increases (Anonymous, 2009d). Studies have indicated that 1^oC increase in global temperature will lead to reduced productivity in some cultivated plants, such as: 7.0–124.0% in wheat (You *et al*., 2009); 1.0–3.8% in barley (Brown & Rosenberg, 1999; Fuhrer, 2003; Bindi & Howden, 2004; Anonymous, 2008a & c; Cline, 2008); 28.0% in potato (Fuhrer, 2003); 17.0% in maize and soybean (Allen *et al*., 2003; Thomson *et al.,* 2005) and 15.0% in rice (Kobiljiski & Dencic, 2001; Fuhrer, 2003). Furthermore, increased temperature causes changes in the soil moisture content (Saleska *et al.,* 1999). This leads to the cultivation of plants, which are adapted to drier conditions.

Table I: Effect of some global warming factors on the cultivated plants traits

Trait	Elevated CO_2 gas	Elevated UV-B ray	Elevated O_3 gas
Photosynthesis	Increase in C_3 to 100%; less happens in C_4 or not	Decrease in many C_3 and C_4	Decrease in many C_3 and C_4
Leaf conductance	Decrease in C_3 and C_4	Most of them are not affected	Decrease in susceptible species and cultivars
Water use efficiency	Increase in C_3 and C_4	Increase in C_3 and C_4.	Decrease in susceptibles
Leaf area	More in C_3	Decrease in C_3 and C_4	Decrease in susceptibles
Leaf thickness	Increase	Increase in most of them	Increase in susceptibles
Maturity rate	Increase	Non affected	Decrease
Flowering	It happens early	Prevents or stimulates	Number of flower and fruit decreas, flowering delays
Dry matter production and yield	Doubled (almost) in C_3 but unclear in C_4	Only yield decreased in most of them	Only yield decreased in most of them
Species cultivars	There is a big difference in C_3 and C_4	They show a great variance	They show a great variance
Susceptibility of species and cultivar	Can be varied	Varied	Varied
Susceptibility to drought stress	Less susceptible	Less susceptible to UV-B; but, more susceptible to water deficiency	Less susceptible to O_3; but more susceptible to water deficiency
Susceptibility to mineral (nutrition) stress	They give less responses	Some of less, some of more susceptibles	Very susceptible to O_3 damage

C_3 : Small grain cereals, rice, soybean; C_4: Coarse grain cereals, sugarcane;
CO_2: Carbodioxide gase; UV-B: Ultraviyolet (B) ray; O_3: Ozon gase (Modified from Krupa, 1997; Dhakhawa & Campbell, 1998; Fuhrer, 2003)

Fig. 1: Calculated change in world-averaged crop yields of four major cereal grains [wheat, rice, soybean (= C_3) and maize (= C_4)], as a result of increases of 2°C and 4°C in average global surface temperature, with (top) and without (bottom) direct effects of CO_2 on plant growth and water use (From Rosenzweigh & Hillel, 1995; Mengü *et al.*, 2008)
T= Temperature



Species which can tolerate stressful environmental conditions in the era of climate change will be chosen; and this adaptation is likely to have a vital importance from the standpoint of plants breeding (Semenov & Halford, 2009). Higher CO_2 concentration leads to increased growth and transpiration rates. It leads to extension of the cultivation range of crops such as wheat, corn, legume, soybean and potato. This causes extra CO_2 generation, which is used by the plants (Crews & Peoples, 2004; Anonymous, 2008b). In this process, called as CO_2 fertilization, metabolic rates will increase and plants will age more rapidly, since temperature and the length of the vegetation process are directly proportional and the shortening of the period between cultivation and harvest (Tubiello & Ewert, 2002). Furthermore, productivity will drop and a vicious circle will emerge, since plants will produce too small dry matter (Ulukan, 2009). On the other hand, if the yield is desired to be enhanced, cool season cereals with "*vernalization*" requirement will be certainly affected negatively by temperature increases. As higher CO_2 accelerates photosynthesis and its concentration is increasing, the productivity of C_3 plants will not drop (generally) it will increase by 36% (Uzmen, 2007) compared with 35-80% in legumes (Ziska & Bunce, 2000; Ziska *et al.,* 2001; Nemecek *et al*., 2008).

According to the findings of a satellite-imaging study, there can be shift ranging between five days to three weeks in the cultivation period of various crop species (Motha & Baier, 2005; Cutforth *et al.,* 2007). Previous studies indicated that a temperature rise of (0.6-0.7°C) between the years (1981-2002) caused a global loss of 40 million m^3 of wheat, corn, and barley production (Brown & Rosenberg, 1999; Fuhrer, 2003). A temperature rise of 1°C is predicted to result in the loss of 5 trillion dollars worth of cereals alone based on estimates made in 1981 and these losses are predicted to be more intensive in some regions of the world (Fuhrer, 2003). Furthermore, if the earth's temperature increases by 1.4-5.8°C by 2100, as predicted, then yield loss will be greater. This prediction is supported by the findings of many researchers (Mei *et al.,* 2007; Khanduri *et al.,* 2008).

The effects on some anatomical and morphological features of the cultivated plants: Plant phenology is strongly controlled by climate and as a consequence, phenological temporal changes observed during last decades can be attributed to the recent climate change. Therefore, plants are a reliable bioindicator of climate change, but this conclusion is not a novel finding, since many studies have demonstrated this fact yet (Gordo & Josesanz, 2010). So, the anatomical effect of climate change on plants generally emerges with the increase in CO_2 concentration due to ambient temperature and also with the following interactions between: vitality of leaf (that is the life of the leaf) and thickness, ramification and the length of the stem, life of the leaf, thickness of leaf and length of the stem etc (Rosenzweigh & Hittel, 1995; Krupa, 1997; Olesen & Bindi 2004; Khanduri *et al.*, 2008). Furthermore, it results in following: a shift in growth and development period of plants cultivated in the field; the closure of stoma and reduced water intake by increasing the number of chloroplasts in the cells (Romanova, 2005; Mei *et al.,* 2007), excessive development of green sections and, accordingly, seed productivity, due to an increase in the ratio of root/stem [e.g., cotton (*Gossypium* spp., carrot (*Daucus* spp.), soybean]. Fauna that perform an ecological role of "dusting" among cultivated plants (Ulukan, 2009) and factors which lead to changes and limitations in the geographical distribution of flora and fauna (Evans *et al.,* 2004), are mostly affected by these negative developments, either directly or indirectly.

The borders of the distribution are determined by immigration to the regions where the temperature-effects and/or the concentration of green house gases are less acute (Olesen & Bindi, 2002). On the other hand, there will be both qualitative and quantitative reductions in "irrigation water" and of vital agricultural inputs; agricultural production will decline due to salinization and inappropriate soil management; nutrients in the soil will be washed away, due to excessive rain; inappropriate irrigation and agricultural techniques, etc. (Olesen & Bindi, 2004; Gordo & Josesanz, 2010) and the productivity of the soil will significantly decrease; soil will be prone to erosion; this will be reflected from the quality and quantity of the production outputs and affect all concerned parameters (Anonymous, 2008c). For instance, some C_4 plants (such as maize & sorghum) are significantly affected by climate changing– particularly by CO_2 concentrations. Furthermore, some changes emerge in the morphology of some root and tuberous plants in the C_3 group over time (Olesen & Bindi, 2004; Romanova, 2005; Ulukan 2008).

CONCLUSION

Patterns of variability among species are poorly understood but a number of biological characteristics, such as pollination mechanism, life form or water content, are related to differential responses among taxa. Hovewer, increasing evidence suggests that with increased temperatures, the length of the growing season has been extended during the 20th century for most of the Northern Hemisphere. So, "crop yield" in a given area depends primarily on the level of technology, climatic and soil conditions and the incidence of plant diseases, weeds and other pests. The projected level of warming is not evenly distributed around the globe: continental areas are projected to warm more than the oceans and coastal areas and the poles are predicted to warm faster than equatorial areas. It is clear that elimination of negative effects of climate change on field crops is impossible, although rational approach may be to develop means to minimize the effects. Since "climate change" do not have selectivity and it is an approaching danger. The elimination of the this formation is impossible, since agricultural activity can not relinquish the use of modern technology, as it plays a key role in the interaction of countries and people and the provision of nutrition and shelter. The most reasonable strategy will be to minimize (even to slow down) agricultural factors effectively and fairly, without ignoring the causes of climate change. Therefore, agreements such as powers to regulate both CO_2 emissions and use of water resources, according to "the contribution to climate change" may be made more effective. Measures should be taken to reduce N_2O release resulting from excessive nitrogenous fertilization. The use of artificial nitrogen fertilizer should be largely avoided. Crop rotation designs should be adopted, which incorporate animal feed. Alternative energy sources should be used; zero/null or minimum soil tillage techniques should be chosen; the cultivation area of some field crops such as common wheat (*Triticum aestivum*) and corn should be decreased and the cultivation area of durum wheat (*Triticum durum*) and corn should be increased. Environmentally friendly (organic) agricultural techniques should be promoted and organic material (s) should not predominantly be burned.

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