CLIMATE CHANGE AND ITS EFFECT ON SOME PHYSIOLOGICAL PROCESSES OF THE AGRICULTURAL PLANTS

A literature review

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Abstract

Climate change is one of the most important issues because of its impacts the human being. Greenhouse gases (GHGs), among others, including carbon dioxide (CO_2), nitrogen dioxide (NO_2), and methane (CH_4) are the main components causing global warming. Different kinds of sources exist; the two most important ones are industrial emission and agricultural activities. Increasing Earth's surface temperature, changing precipitation and losing coastal land due to sea level increase are the phenomenon of climate change that can be easily identified every day. Agricultural activities are strongly associated with the climatic conditions, because most of the plant’s physiological processes such as photosynthesis, stomatal resistance, canopy temperature and flowering time are affected by environmental factors as light, temperature and CO_2 concentration. Therefore, understanding of these phenomena and its effects on agricultural activities will assist us in finding good solutions for better adaptation to climate change.

Key words: Global warming, climate change, greenhouse gases, temperature, precipitation, photosynthesis, stomatal resistance, flowering time.

1. Introduction

In this decade we can hear a lot of information about global warming and its actual effects on our planet’s life. Global warming is currently a widely discussed topic on which opinions greatly vary (Specht et al., 2016) and it is also one of the most important challenges currently facing the world (Aydin, 2010). On one side, there are climatologists, who are convinced that global warming will lead to a climatological catastrophe. On the other side, few references say that the temperature change is caused by natural climate fluctuations (Foong, 2006; Knox, 1999; Barker et al., 1999). The adverse impacts of global warming that can be catastrophic and a potential threat to the human existence, an important environmental issue is affecting entire ecosystems in the world (Melillo, 1999). These impacts include wide-scale socioeconomic changes, such as degradation and losses of natural resources, increased risk of hunger and above all waves of human migration and dislocation, especially lower agricultural production and lower crop yields (El-Sharkawy, 2014).

The GHGs including water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6) that are the main contributors to climate pattern change (Gul et al., 2009; GCRIO, 2011; Ozbayrak et al., 2011; EPA, 2013a,b), primarily responsible for current global warming (Brysse et al., 2013). They are expected to raise global average temperature over the next century by 1.8-4.0 ^{0}C, with the largest increases at higher latitudes (IPCC, 2007). The most gases emission from the agricultural activities are CO_2, CH_4, and N_2O which are the most potent long-lived GHGs (Robertson et al., 2004; IPCC, 2007) with the existing atmospheric water vapor trap the latent heat in the form of infrared radiation (El-Sharkawy, 2014).

2. Greenhouse gases (GHGs)

2.1 Carbon dioxide (CO_2)

The temperature of Earth increases significantly with CO_2 concentration. Between 1860 and 1990 global warming was 1 ^{0}K, CO_2 contributed only 0.4 ^{0}K (Onorato et al., 2011). Physically based, mathematical climate models known as General Circulation Models, indicate, depending on the model used, that doubling the level of atmospheric carbon dioxide from 350-360 ppm will raise the average global surface temperature by 1.5-4.5 ^{0}C (Climate Change, 1992). This atmospheric CO_2 concentration will probably reach 700 ppm that can result in the rising of Earth’s temperature from 1.5 to over 5 ºC by the end of this century (Metz et al., 2007; Da Matta et al., 2010).

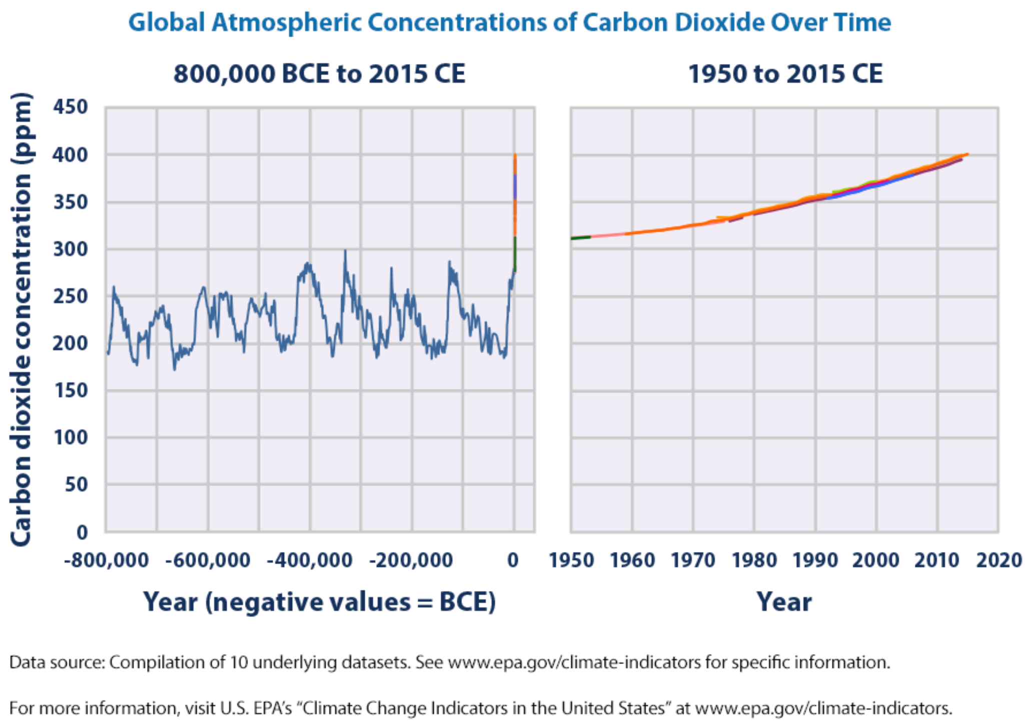

Figure 1. Concentration of Carbon dioxide in past 800000 years before 1950 C.E and from 1950 to 2015 C.E (https://www.epa.gov/climate-indicators/climate-change-indicators-atmospheric-concentrations-greenhouse-gases (date 16/8/2016))

According to United States Environmental Protection Agency (EPA, 2016) (Figure 1) trends in changing atmospheric CO_2 over the past 800,000 years, atmospheric CO_2 concentration changed between 180 ppm (800000 years before 1950 C.E) and 280 ppm (400000 years before 1950 C.E). From the preindustrial concentration of about 280 ppm, CO_2 concentration increased steadily to 400 ppm since the 2nd half of the 19th century and in the 20th century (in 2015), CO_2 has accounted for more than 50% of all GHGs and is expected to account for 55 % or more over the 21st century (Houghton et al., 1990; Keeling et al., 1989; Liu et al., 1995). About 50–60 % of total carbon emissions originate from consumption of fossil energy sources, such as coal, natural gas, and oil. From 1850 to 1980, about 150–200 billion tons of carbon were released from the burning of fossil fuels. Humans emitted 6 gigatons of carbon per year into the atmosphere from fossil fuel burning and cement production during the 1990's, yet only about half of this amount of carbon accumulated in the atmosphere (IPCC, 2001; Pataki, 2003). The average GHG emissions (CO_2) per unit of product (grain yield) from 1964 to 2005 were estimated to be 268 t CO_2/t grain. The highest GHGs emissions per annum were 386 t CO_2/t grain of cereal maize occurring in both 1983 and 1988 when both the average grain yields and the total harvested area were calculated in cereal maize field (Grace et al., 2011). Every year, current estimates are about 10–12 billion tons of carbon being released into the atmosphere, thus, contributing to global warming and climate change (Dale et al., 1993). In 2011, the top ten emitters, in terms of billions tons of CO_2 annually, were listed in a decreasing order: China (8.715), USA (5.490), Russia (1.788), India (1.725), Japan (1.180), Germany (0.748), Iran (0.624), South Korea (0.610), Canada (0.552), Saudi Arabia (0.513) (http://www.ucsusa.org/global_warming/science_and_impacts/science/each-countrys-share-of-co2.html#.V31Z0fl97IU). The current loading of CO_2 to the atmosphere is 4.1 Pg C $y^{-}1$ (Canadell et al., 2007).

2.2 Nitrous oxide (N_2O) and methane (CH_4)

Nitrous oxide and methane are significant long-lived GHGs and are the main long-lived greenhouse gases that result with global warming potential (GWP) 298 and 25 times that of CO_2 (Wassmann and Dobermann, 2006; Myhre et al., 2013; Robertson et al., 2000; Kreye et al., 2007; IPCC, 2007). Agricultural activities release significant amounts of CH_4 and N_2O into the atmosphere (Cole et al., 1997; Paustian et al., 2004). Globally, anthropogenic sources of N_2O and CH_4, which are dominated by agriculture, increased by nearly 17 % from 1990 to 2005 (Robertson and Grace, 2004; Forster et al., 2007) and 50-60 % of total anthropogenic CH_4 and N_2O emissions, respectively in 2005 (Chen et al., 2014). About 85 % of N_2O of the global flux from human sources is from agriculture with about 50 % of the global flux from de-nitrification and nitrification in agricultural soils (IPCC, 2007b). CH_4 is produced from the biological decomposition of organic materials under anoxic conditions and can be biologically oxidized in dry soils (Mosier et al., 1998a; Garcia et al., 2000). The input of nitrogen (N) fertilizers into agricultural systems are considered the dominant source of N_2O emissions from agricultural soils (Mosier et al., 1998b; Mosier and Kroeze, 1999; Grant et al., 2004; Cai et al., 2007; Bouwman 1996; Brown et al. 2000; Maggiotto et al., 2000). Moreover, N_2O emissions are projected to increase by 35-60 % till 2030 due to increasing using of N fertilizer in cultivation and animal manure production (FAO, 2002).

Rice fields have been identified as a major source of increasing atmospheric CH_4, accounting for approximately 15-20 % of global CH_4 emissions from all sources. N_2O is also produced from rice fields because of mid-season drainage and moist irrigation (Wang et al., 2013). According to Nishimura et al. (2004) over 80 % of a whole year's GWP by CH_4 and N_2O emission was contributed during rice cultivation from a paddy field used a Japanese typical conventional water and fertilizer management system. In the NPK treatment, CH_4 emission was comparably lower at the initial rice growth stage and increased with the development of soil reductive conditions and rice growth. Net CH_4 emission rates almost dropped to near zero values at the grain maturation stage, irrespective of the treatment (Kim et al., 2013). It is a well-known fact that CH_4 emitted from rice fields is transported mostly (60–90 % of total CH_4 emission) through the aerenchyma of rice plants rather than by molecular diffusion of the water–air interfaces or the release of a gas bubbles (Butterbach-Bahl et al., 1997; Aulakh et al., 2000). Since the apparent growth of the rice plant is maximized at the reproductive stage, the well-developed aerenchyma might also provide an effective channel for CH_4 gas to exchange between the atmosphere and the anaerobic soil (Nouchi et al., 1990; Butterbach-Bahl et al., 1997). In addition, the higher release of root exudates, which are good substrates for methanogenic archaea (Pusatjapong et al., 2003) increased CH_4 emissions at this stage (Aulakh et al., 2001). Vegetable cropping systems represent for one of the most intensively managed agricultural systems due to their high N fertilizer inputs, frequent irrigation and intensive cropping rotations (multiple harvests within one year). Annual N fertilizer inputs are 3-4 times greater in vegetable fields than in fields used for other crops (Huang et al., 2004; Ju et al., 2006).

3. Signs of climate change

3.1 Temperature rise

According to the Environmental Protection Agency, global warming is defined as the recent and ongoing rise in earth surface temperature (Gul et al., 2009; GCRIO, 2011; Ozbayrak et al., 2011; EPA, 2013a,b). In the last century, trends in global warming, air temperature increased at the rate of 0.075 ºC per decade over the entire 1900–2000 period (Mitchell and Jones, 2005; Girvetz et al., 2009). Nowadays, evidence indicated that the global mean surface temperature of Earth (Figure *2*) has increased over the last century by approximately 0.85 ^{0}C between 1880 and 2012, and surface temperatures across the globe are predicted to rise an additional 0.3-4.8 ^{0}C by the end of this century (IPCC, 2014); in the pre-industrial temperature was predicted that was increasing, in the range of 1.4-5.8 ^{0}C by the end of the 21st century. This increasing in global mean temperature might be reached by 2050–2080 if the emission levels of trace greenhouse gases keep rising (Metz et al., 2007).

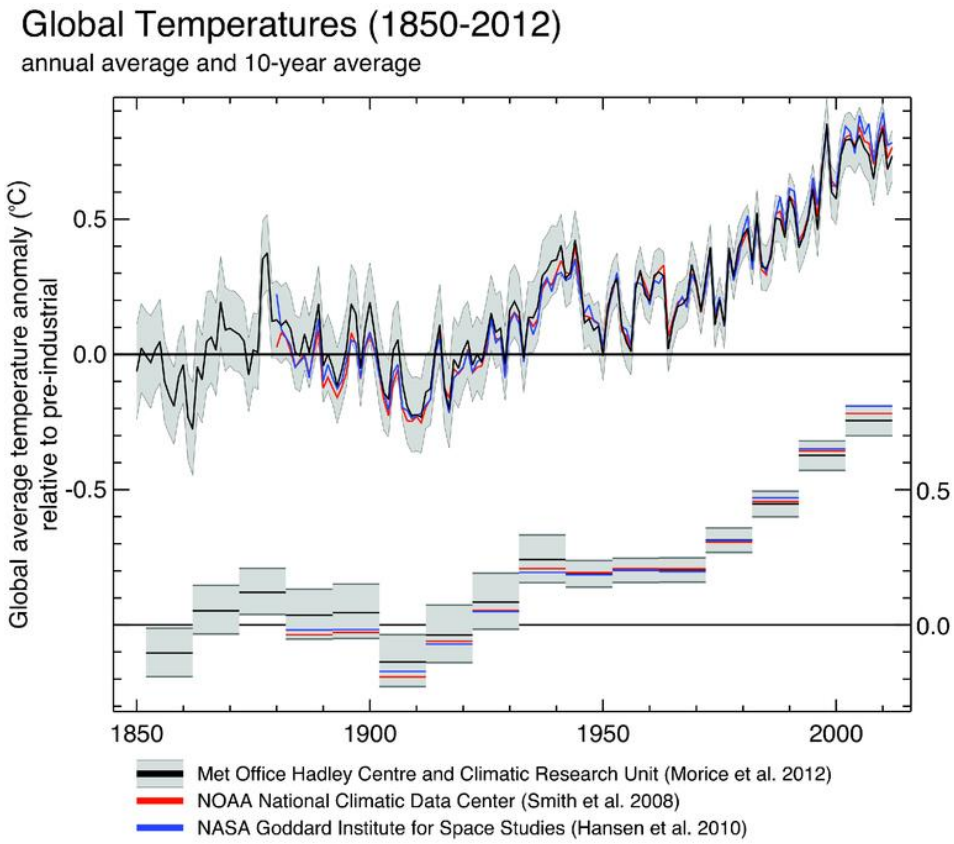

Figure 2. Observed globally averaged combined land and ocean surface temperature anomaly 1850-2012 (IPCC, 2014)

The first decade of the 21st century was actually the warmest on record (NASA, 2010; SMHI, 2010). It is clear that the climate is changing and the temperature is projected to undergo a relatively high rise in Sweden compared to the overall global mean change (Hansen et al., 2006; SMHI, 2010; Leijonhufvud et al., 2010). Trust, warming trends varies among regions of the world, Jones and Wigley (1990) analyzed available land and marine meteorological records from 1967 to 1986 and they noted that most regions in both Northern and Southern hemispheres had experienced marked warming. Few parts in the Northern Pacific and Atlantic Oceans were the only exception that experienced cooling to some extent (Otsenki, 1992; Houghton et al., 2001). Analysis of expected regional climate in the Carpathian Basin using ENSEMBLES model simulation were described by Miklos et al. (2010) the results suggested that the temperature of the selected region is expected to increase about 1-2 ^{0}C, and 3-4 ^{0}C for 2021-2050, and 2071-2100, respectively. Based on the project PRUDENCE (Bartholy et al., 2007b) expected climate change estimations for the Carpathian basin the 2071-2100 period is expected the largest warming in summer time. The mean annual temperature in Yunnan Province is projected to increase by an average of 1.6-2.5 ^{0}C by 2050 (Zomer et al., 2015). Tibetan alpine meadows are particularly sensitive to global climate change; the average surface temperature in Tibet is expected to increase 2 ^{0}C more than the global average by 2050 (Thompson et al., 2000). Recent analysis across 16 locations throughout both hemispheres and seasons predicted variable increases in seasonal air temperature in 2050 as compared to averages in 2000 (Jaggard et al., 2010). All locations are anticipated to become warmer. For example, the mean spring temperature in Manitoba (Canada) will increase from 3.7 °C to 6.4 °C; similar increases are predicted for Harbin, northern China, and Tambov, Russia. Urban areas are a subject to increased temperatures due to the influence of global warming and urbanization (Arnfield, 2003; Oke et al., 1991; Oke, 1987) and various countermeasure techniques have been studied.

In a global warming perspective, increasing earlier and warmer in springs, together with slightly warmer summers have waited. Wang et al. (2014) found that temperature the sensitivity decreased with the increase of spring temperature variability. Most meteorological stations in Europe, East Asia, and Alaska recorded a significant increase in annual maximum and minimum temperature specifically during the winter and spring. However, summer warming remains not significant (Schwartz et al., 2006). Global climate changes and associated increased winter temperatures in the Northern latitudes (Klimov et al., 2004). The air temperatures in Harbin are predicted to rise from 4.8 °C to 8.8 °C during autumn (Jaggard et al., 2010).

However, other projected estimates suggest about the nature of global warming that indicates the likelihood of an asymmetric change in temperature, where night-time minimum temperature increases more rapidly than the day-time maximum temperature (Dhakhwa and Campbell, 1998). There is substantial spatio-temporal, seasonal, and inter-annual variability in the warming trend. A faster increase in night-time temperature than day-time temperature was reported for Jiangsu province (Yuan et al., 2007). Recently, a trend of increasing differential between day-time and night-time temperatures has been observed in the literature, with more focus on higher nighttime temperature (Prasad et al., 2008; Prieto et al., 2009; Mohammed et al., 2009, 2011)

3.2 Precipitation

Other phenomena associated with climate change such as rainfall variability and higher drought frequency are becoming increasingly intense (El Yaacoubi et al., 2014). In addition, it is predicted that there will be longer periods without rain, followed by heavier rainfall events (Pitman and Perkins, 2008). Increased temperature has a large impact on stream flow. For example, a 1 ^{0}C increase in temperature can result in a 15 % decrease in the stream flow in the Murray-Darling Basin (Cai and Cowan, 2008). In Australia, the climate change is predicted to cause increasing of 4-5 ^{0}C in temperature by 2100, along with a decrease in rainfall of between 7.6 and 22.8 %, depending on the region (CSIRO, 2008). The expected change of annual total precipitation is not significant in the Carpathian Basin. The winter and autumn precipitation is likely to increase while summer and spring precipitation is likely to decrease during the 21st century (Miklos et al., 2010; Bartholy et al., 2007a, 2007b; Pieczka, 2012).

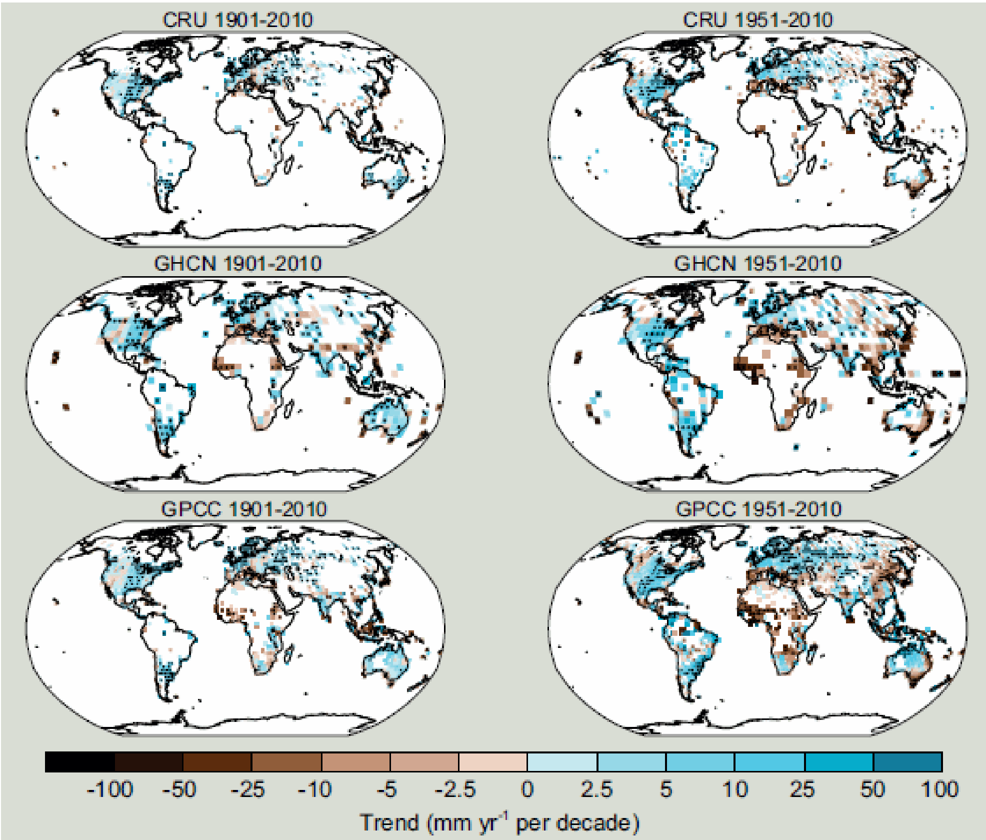

Figure 3. Maps of observed precipitation change over land from 1901 to 2010 (left-hand panels) and 1951 to 2010 (right-hand panels) from the Climatic Research Unit (CRU), Global Historical Climatology Network (GHCN) and Global Precipitation Climatology Centre (GPCC) data sets

Source: IPCC (2013)

Figure 3 shows the precipitation change averaged over global land areas since 1901 is low prior to 1951 and medium afterwards. It has been reported that global precipitation over land has increased by 3 % over the last century (Gerten et al., 2008). However, local precipitation trends vary considerably (IPCC, 2013) and precipitation has decreased since 1950 over many areas (Dai, 2013). Averaged over the mid-latitude land areas of the Northern Hemisphere, precipitation has increased since 1901. For other latitudes area-averaged long-term positive or negative trends have low confidence. There are likely more land regions where the number of heavy precipitation events has increased than where it has decreased. The frequency or intensity of heavy precipitation events has likely increased in North America and Europe. On other continents, the changes in heavy precipitation events are at most medium. Changes in the global water cycle in response to the warming over the 21st century will not be uniform. The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions, projected changes in the water cycle over the next few decades show similar large-scale patterns to those towards the end of the century, but with smaller magnitude.

4. Impact of the rise of GHGs and climate change on some agricultural crops

4.1 Physiological processes

- Photosynthesis

Photosynthesis is the only process capable of utilizing the energy of sunlight to produce organic matter from inorganic elements. Atmospheric carbon dioxide, the basic material of photosynthesis, reaches the site of the biochemical process through the stomata (Anda and Kocsis, 2007). Elevated CO_2 enhances leaf photosynthetic rates of most field crops regardless of their photosynthetic pathway (i.e., C_3, C_4, and CAM), while reducing stomatal conductance (Kimball, 1983; Kimball et al., 2002). Higher atmospheric CO_2 concentration may influence positively to plant production once the substrate for photosynthesis and gradient increase between the ambient air and mesophyll cells (Anda and Kocsis, 2007). For example, a doubling of atmospheric CO_2 concentration may increase the photosynthetic rate of plants, always increases crop productivity (Allen, 1990; Kimball, 1983a,b; Porter, 1992; Rogers and Dahlman, 1993). Increasing concentration of atmospheric CO_2 increases the rate of photosynthesis in C_3 plant species such as small grains, legumes, most trees and root crops grown under controlled conditions and reduces amount of used water in both C_3 and C_4 species such as corn sugarcane, sorghum, and millet (Brown and Rosenberg, 1997). The increase in net photosynthesis in C_3 species has been reported as high as 50-100 % when CO_2 concentration doubles compared to 10 % in C_4 species (Van et al., 1977). Kimball (1983a, 1983b, 1986) estimated that a doubling CO_2 concentration, holding other factors constant, could lead to a 34±6 % increase in agricultural yields of C_3 plants and a 14±11 % in C_4 plant with a 95 % confidence interval.

Fodor and Pásztor (2010) used the 4M crop simulation model to quantify some indices of the agro-ecological potential of Hungary and its future development under climate change. Their results indicate that the yields of the spring crop as maize, sunflower, etc. will decrease while higher yields might be expected for the autumn crops. Under high temperatures during the growing season significantly increased the proportion in the total yield of deformed tubers and tubers sprouted in the soil prior to harvest (Gaba and Tsror, 2014). Lobell and Field (2007; Wand et al., 1999; Ainsworth and Rogers, 2007) argued that the yield loss associated with global warming for C_3 crops (e.g., wheat and common beans) may reach values up to 6 % per ^{0}C and that for C_4 crops (e.g., maize, sorghum) by up to 8 %. Based on a systematic assessment, Knox et al. (2012) showed that by the 2050s, the yields in Africa could decline by up to 17 % (wheat), 5 % (maize), 15 % (sorghum) and 10 % (millet). For the southeast region of the United States, Carbone et al. (2003) demonstrated that predicted future climatic conditions decrease sorghum productivity by up to 51 %. Lobell et al. (2011) estimated that climate change from 1980 to 2008 has already reduced global production of maize by 3.8 % and wheat by 5.5 % relative to a counterfactual without climate change (Lizumi and Ramankutty, 2015). Higher leaf temperatures may have important consequences on the longevity and photosynthetic capacity of the individual leaves and at the canopy level, as aging may be accelerated and shortening the growing season (Ellis, 1990; Kimball et al., 1995; Van and Goudriaan, 1996).

- Stomatal resistance

The study of stomata is the primary importance in plants, due to their role in connecting photosynthesis and transpiration with the basic material for photosynthesis, CO_2, enters the plant tissues through the stomata, from where water vapor leaves the leaf (Anda and Kocsis, 2007). The larger the diameter of the stomata, the more CO_2 can enter the plants, but higher the water loss. In a moderate climate, the plants partially close their stomata, especially in the afternoon hours because of the limiting soil water availability (Anda, 2006).

CO_2 as a component of the atmosphere also has an influence on stomatal movements, thus plays an important role in impacting assessment of the global warming (Morison and Gifford, 1983; Cure and Acock, 1986; Dickinson et al., 1991; Long, 1991; Kimball et al., 1993; Jackson et al., 1994; Van den Geijn and Goudriaan, 1996; Bunce, 2004). This is not surprising because the aperture of the stomata determines the amount of incoming CO_2 and outgoing water vapor (Anda and Dióssy, 2010). The increasing level of CO_2 concentration has an effect through modification of stomata behavior on photosynthesis, water use efficiency and crop yield. Stomatal movements may change in response to elevated CO_2. Two responses of crops to elevated CO_2 are an increase in the rate of photosynthesis and a decrease in stomatal conductance (Van et al., 1977). The partitioning of net radiation on the leaves under elevated CO_2 concentration is modified due to a decrease in stomatal conductance, which causes a decrease in transpiration leading to an increase in leaf temperature (Kimball and Idso, 1983;Jones et al., 1985; Streck, 2005). However, decreasing the stomatal activity can be considered as an advantageous side of global climate change on the plant's water balance because they keep water inside the leaf undergo hot day (Anda and Dióssy, 2010). Therefore, it may be associated with the increased stomatal resistance resulted from growth in ambient CO_2 concentration. Transpiration is not only affected by the stomatal opening but also by the driving force for exchanging the water vapor from the leaf surface to the surrounding atmosphere. The water vapor pressure was decreasing by the increasing CO_2 level (Anda and Kocsis, 2007).

- Canopy temperature

According to Anda (2006) the cob layer (canopy) temperature is important in plant studies, since the assimilatory (or transpiration) surface is the most developed and the intensity of physiological processes are the highest at this level and they also have the capability of modifying local microclimate has come into focus on the issue of adaptations to climate change. If the canopy is sufficiently extensive, the plants may have positive feedback on the process of global warming by enhancing the amount of energy transmitted to the surrounding air. It means that the local warming may be more intense. At canopy level, warming and elevated CO_2 strengthened the influence of an external rise in air temperature. It is cooler inside the stand, as the canopy is able to compensate for external warming. The higher CO_2 level balanced out the decrease in available soil water by decreasing the opening of the stomata. At doubled CO_2 it was observed that the higher the air temperature and the lower the sensible heat. Due to the warmer surrounding air, intensive plant cooling was required, but in the model run in Keszthely, there was sufficient water in the soil for cooling purposes (Anda and Kocsis, 2007).

The incoming radiation remains after reflection from the stand and transmission to the soil provides a source of energy for heating processes (sensible heat flux) and evapo-transpiration (latent heat flux). If there is no water limitation, the main user of energy is evapo-transpiration from the plant stand (Anda and Kocsis, 2007). The within-canopy air temperature is one of the users of sensible heat flux. The air temperature has a regulatory role and governs the plant temperature and the intensity of biochemical processes (Anda, 2006). In Hungary, the average ratio of sensible to latent heat consumption is 70:30 (Anda and Kocsis, 2007) which is why the proportion of energy bound in photosynthesis was neglected in some research on plant microclimate (Jones, 1983). Earlier study in mid 1990s that use the infrared heaters (IRH) over open-field plots to study the response of ecosystems to global warming (Harte and Shaw, 1995; Harte et al, 1995). The temperature rise of a rice canopy through IRH warming is essentially the same as the warming provided by radiant heating from the sun and sky because it directly heats the canopy. The air in and above the canopy is subsequently warmed by convective sensible heat exchange with the canopy (and cooled by latent heat exchange). If the constant of temperature rise mode of operation is used, as was done herein, the warming by IRH can be directly related to a degree of canopy warming expected through global warming (Wall et al., 2011; Kimball et al., 2011; De et al., 2011). The amount of energy required to achieve a specified increase in canopy temperature by IRH is influenced by canopy conductance in response to soil moisture conditions, light intensity, temperature, humidity, and wind speed (Kimball, 2005). Less energy is required when the stomata are closed, such as occurs under water stress or at night. However, with warmer leaves, higher vapor pressure occurs in the sub-stomatal cavities in the infrared-warmed canopies, which can create unrealistic vapor pressure gradients between the inside of the leaves and air (De et al., 2011; Kimbal, 2005).

- Flowering time

Under climate warming, plants will undergo novel selective pressures to adjust reproductive timing. Adjustment between reproductive phenology and environment is expected to be higher in arctic and alpine habitats because the growing season is considerably short. As early and late flowering species reproduce under very different environmental conditions, selective pressures on flowering phase and potential effects of climate change are likely to differ between them (Giménez-Benavides et al., 2010). According to Abu-Asab et al. (2001) flowering in angiosperms is an important phenological phase. Plants in temperate areas, such as the mid-Atlantic region of North America, are adapted to an annual seasonal cycle with a winter dormancy period that is sensitive to temperature and light. Flowering time is directly related to temperature.

To investigate potential changes in first-flowering times that were examined the first-flowering records of 100 plant species, representing 44 families of angiosperms, for 29 years of the 30-year period 1970–1999 (1984 not recorded) in the Washington, DC area. Evidence for global warming is inferred from spring advances in first-flowering in plants. The trend of average first-flowering times per year for the study group shows a significant advance of 2.4 days over a 30-year period. When 11 species exhibited later first-flowering times are excluded from the data set, the remaining 89 species showed a significant advance of 4.5 days. Significant trends for earlier flowering species range from −3.2 to −4.6 days, while those for later flowering species range from +3.1 to +10.4 days. Advances of first flowering in these 89 species are directly correlated with the local increase in minimum temperature (Abu-Asab et al., 2001). Indeed, the temperature increase is linearly correlated with earliness of flowering dates. The rate of flowering earliness varies from one species to another, although some studies have shown that this trend is not always linear (Pope et al., 2013). In the Northern hemisphere, Legate et al. (2008) underlined advances in apple (*Malus Domestica Borkh.*) flowering dates during the 1980–2011 period in France and other European countries (Legave et al., 2013). In the Southern hemisphere, Grab and Craparo (2011) confirmed flowering advances in apple through an advanced full bloom around 1.6 days/decade over the period 1973–2009. In Cordoba, an increase in mean temperature of 1 ^{0}C during March-April–May induced an advance in olive full blooming of 7.6 days (Orlandi et al., 2009) with a projected flowering advance of 6.2 days/^{0}C by the end of the twenty-first century in Western Mediterranean (Osborne et al., 2000). Concerning almond species, advanced blooming dates after warm periods of dormancy were already highlighted in Spain (Alonso et al., 2011). Early blooming cultivars have shown the higher variation in blooming dates because of a slower heat completion and more variable temperatures during February. As a consequence, late blooming cultivars would show more stable blooming dates because their higher heat requirements are quickly satisfied by the higher temperatures during March (Alonso et al., 2011). Flowering advances were similarly reported in many other fruit tree species (Lu et al., 2006; Crepin ˇ sek ˇ et al., 2012; Miller-Rushing et al., 2007; Abu-AsabMones et al., 2001).

As it is the case of growth, the largest increases in reproductive output and in changes in flowering time have been measured in cultivated C_3 plants (Jablonski et al., 2002; Springer and Ward, 2007). Most (but not all) that exhibited differences in flowering timing at elevated CO_2 display accelerated flowering. To a less extent, reproductive output of undomesticated (wild) C_3 plants also tend to increase in response to CO_2 enrichment, while flowering time responses are more variable (Springer and Ward, 2007). The effects are less clear for C_4 plants, due to more limited available information. This is an area in critical need of additional research, particularly for wild perennial C_4 grasses in which south-central South America appears to be a major geographic center of origin of C_4 lineages (Sage et al., 2011).

4.2 Capacity of food production

Impacts of climate change on natural resource potential and on its viability to feed the world about 14–16 billion ha of ice-free land on Earth, about 1.3–1.6 billion ha are used for crop cultivation (about 15–18 % irrigated, and the remaining are rainfed systems), and about 3.0–4.0 billion ha are used for pastures and animal feed. Forests constitute about 28–30 % of ice-free land surface. Cropping systems, pastures, and forests account collectively for approximately 50–60 % of the Earth's land covers (Houghton 1990; FAO 2007; Tubiello et al., 2007). Numerous studies have suggested that the climatic variability and climate change can have adverse impacts on global food production and food security, the changing climate is not only projected to lead to introduce new crops, but also opportunities for crop pests and pathogens to thrive in the absence of long cold periods. Increased temperatures, changed precipitation patterns and new cultivation practices may lead to a dramatic change in crop health. Examples of diseases and insect pest problems predicted to increase in incidence and severity due to global warming are recorded (Roos et al., 2011). Climate change threatens crop harvests not only by storm, flooding and drought caused physical damage, but also by heat stress induced changes in physiological processes. For example, in China alone, there are six recorded heat damages in the past 50 years, and in particular, heat stress affected 3 million hectares and reduced grain production by 5 million tons in 2003 (Tian et al., 2009). The major inter annual-scale climatic modes, such as the El-Nino Southern Oscillation, has been playing a key role by often leading to droughts and decrease in crop yields that could further result in famine in some food insecure regions (Hansen et al., 2011; Maxwel and Fitzpatrick, 2012; Iizumi et al., 2014). Drought regions in the United States in 2012, heat waves and associated Russian wheat embargo in 2010-2011, and droughts in Australia in 2006-2008 led to low levels of cereal stock and steep increases in food prices, likely worsening the access to affordable food for many consumers, including the poor in import dependent on countries (FAO, 2007, 2010, 2012). An unfavorable climate, such as too wet or too dry condition, affects the cropping intensity as well. For instance, in the Vietnam Mekong Delta where triple rice cropping system is operated, the annual number of completed cropping cycles is affected by variations in the timing and areal extent of flooding in wet season as well as those of salinity intrusion in dry season (Sakamoto et al., 2006; Kotera et al., 2014). Due to the severe floods in 2000, the second-season rice (planted in the middle of dry season and harvested before the onset of wet season) in that year grown in the upstream area of this region was fully and continuously submerged immediately after the heading, leading to crop failure except for the floating rice varieties (Kotera et al., 2014). "In contrast, the below-normal seasonal rainfall in 2004 reduced water availability for irrigation due to high salinity, and the dry season rice in that year could not be harvested" (FAO, 2011).

5. Conclusion

Climate change, whether they are artificial or natural, continue to be a subject of intense scientific, public, and controversial political debate worldwide, particularly in the past two decades (Kerr, 1997; Soon and Baliunas, 2003; Perrow, 2010; Rivera and Khan, 2012). Because of its impacts can be catastrophic and a potential threat to the human existence, effects entirely ecosystems in the world (Melillo, 1999). Most of the GHGs have been, and still are, the product of human activities, namely, the excessive use of fossil energy in industrialized countries; deforestations in the humid tropics with associated poor land use management; wide-scale degradation of soils under crop cultivation and animal or pasture ecosystems; and the most important source of agricultural activities (de-Ritcher et al., 2016). The consequence of climate change on climatic condition which can be easy to define through Earth's surface temperature increasing, changing precipitation, sea level increasing. Therefore, climate change impacts on the plant's physiological processes such as photosynthesis, stomatal resistance, canopy temperature, flowering time that leads to affect capacity food production supporting for feeding the world population at its present size (about 7.2 billion) and hopefully can meet the demand of the ever expanding human population (about 10 billion by the end of this century). As reported by Aydin (2010), it is essential for everyone, especially those in the scientific community to have a full appreciation of the issue as well as the potential solutions to the problem so that they can initiate the necessary changes to the economies, resource utilization, behavior, and general approach to nature.

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