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Hakan Ulukan
Ankara University, ulukan@ankara.edu.tr, Ankara-Turkey

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ORCID ID	0000-0003-0203-6851
CORRESPONDING AUTHOR	Hakan Ulukan

CLIMATE CHANGE (CC) IMPACTS ON FIELD CROPS: A GENERAL APPROACH

ABSTRACT

The field crops, like all other cultivated plants, are very sensitive to the CC with its inseparable components as known greenhouse gases (GHGs') emissions which were composed of CO_2, CH_4, N_2O, Water Vapor, CFCs, etc.. For instance, rice (Oryza sativa) crop plant takes the biggest share of 94% from the GHGs emissions as CH_4. As a strong member of the Green House Gases (GHGs) emission, the CH_4 has 300 times higher efficiency than the CO_2 and 20 times strong in this respect than the water vapour (or H_2O) in the atmosphere. As known, the most dangerous of GHGs is the CO_2 for the all living organisms and non-living things. The GHGs emission has positive –up to one degree- (the CO_2 fertilization, etc.) and/or negative (acid rains, fog, floods, hail, etc.) impacts on flora. According to scientific research findings, the world's mean temperature (1.4-5.8°C) will rise by the end of the year of 2100 and affect the many plants, ecologies, ecosystems and climatological parameters as locally or regionally or continentally. Particularly, climate change will increase of the field crops' growth and development stages, water use efficiency (WUE) balance(s), accelerates the ripening, reduces the yield (dry matter) and nutrient input/taken, etc. with another morphologic, phenologic, metabolic and biochemical traits.

Keywords: Climate Change, Greenhouse Gases (GHGs), Global Warming Field crops, Flora, Water Use Efficiency (WUE)

1. INTRODUCTION

"Climate" can affect agriculture in a variety of ways (with some parameters such as temperature, radiation, rainfall, soil moisture and CO_2 concentration) are all important variables to determine agricultural productivity. But, "global warming" also refers to the increase of earth temperature due to the release of gases such as CO_2, CH_4, CFCs, N_2O, O_3, etc. into the earth's atmosphere (IPCC, 2007, 2014). And, the climate change is attributed to the change in the composition of the global atmosphere that increases mean temperature that affects the ecology of the earth and ocean. Fuhrer (2003) reported that losses are predicted to be more intensive in some regions of the world, and that, if the earth's temperature increases by (1.4-5.8°C) by 2100, as predicted, then yield loss will be greater. The temperature rises correlates with the increase in the content of greenhouse gases CO_2 and CH_4 (Zvarzin, 2001). Prior to the industrial revolution, the level of atmospheric CO_2 was 270ppm. It has exceeded 355 ppm in modern times and it is expected to reach 600ppm during the 21st century (Rogers et al, 1994) (Figure 1). the annual percentage increase of CH_4 is 1%, the annual percentage increase of N_2O is 0.3% and tropospheric O_3 concentration also affects the situation (Krupa,

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1997). Agricultural GHGs emissions come from the soil and the main reasons for global warming are the automotive and petrochemical industries, emissions from planes, and cars, iron and steel factories (Mei et al, 2007), refineries, rice paddies (Conrad, 2002).

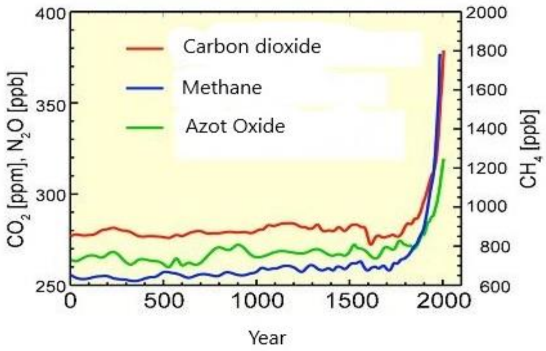


Figure 1. Some of the GHGs concentrations and global temperature changing within the last 2000 years (Di Norcia, 2008)

2. RESEARCH SIGNIFICANCE

As known, the CC is a certain seasonal change over a long period (≈ 100 years) with respect to the growing accumulation of the GHGs' in the atmosphere. And, this information is very important for the sustainability of the agricultural sector. In fact, this sector strongly needs many crucial inputs. Especially water, biodiversity, soil, biota (biodiversity…), seed, nutrients, sunlight, growing conditions, etc. can be mentioned from them. But, the CC (and its results as "global warming") is the main threat to our planet.

3. EXPERIMENTAL METHOD-PROCESS

All cultivated plants are classified into three groups such as C_3, C_4 and Crassulacean Acid Metabolism (CAM), according to the stable carbon number of the first stable product which was done by a photosynthesis via its metabolism. From the plants, the C_3 are includes all trees, grain legumes, rice (Oryza sativa), wheat (Triticum spp.), barley (Hordeum spp.), soybean (Glycine max), potato (Solanum tuberosa), vegetables, oranges (Citrus spp.), grapes (Vitis vinifera), coffee (Coffea arabica), tea plant (Camelia sinensis), peanut (Arachis hypogea), lemon (Citrus limon), peach (Prunus persica), mango (Mangifera indica), carrot (Daucus carota), cabbage, etc.; the C_4 is included maize (Zea mays), millets (Sorghum vulgare+Panicum miliaceum), Amaranthus spp., Euphorbia spp., Chenopodium spp., sugar cane (Saccharum officinarum), Bermuda grass (Cynadon dactylon), etc.) and CAM plants. CAM plants are mainly succulent and desert plants (such as Cacti, Agave (Agave spp.), The papaya (Carica papaya), Pineapple (Ananas spp.), Stonecrops (Sedum spp.), etc. and their photosynthetic activity or respiration, etc. mechanisms are rather different from the C_3 and C_4. On the other hand, the majority of the plants which we use in the agriculture sector are C_3 and C_4 types. Plants that are using the C_4 photosynthetic pathway already boost their internal concentration of CO_2, so they tend to be less affected by external increases than C_3 plants (Lenart, et al., 2006). All plants (incl. the cultivated ones) affect the CC according to the photosynthetic pathway which was explained above as C_3, C_4 and CAM). again, the results of the CC, the observed impact(s) has/have both positive and negative. In addition, it was observed that the Co_2's, which is one of the important GHGs' gas, "carbon fertilization" impact will affect the cultivated plants, especially for the C_3 plants such as wheat, barley, rye, etc., and, this impact will be very strong in grain legumes, which have a low rate of photosynthetic efficiency (Zhai and Zhuang, 2009). On the other hand, that impact will also increase their photosynthetic activity and net photosynthesis ratios; but will decrease their WUE when the CO_2 concentration increased (Dhakhwa and Campbell, 1998). It was found that response to the CO_2 fertilization might influence competition between the species, including woody species versus grasses and native grasses versus invasive (Smith, et al., 2000).

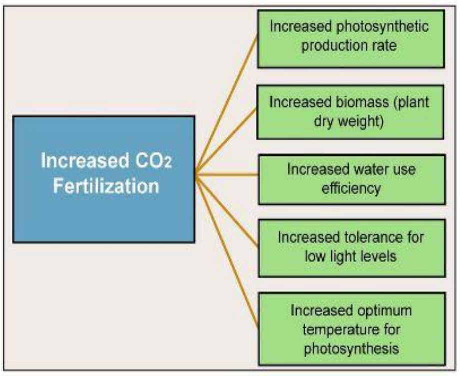


Figure 2. Some important plant responses to increased CO_2 fertilization (Lenart, et al., 2006)

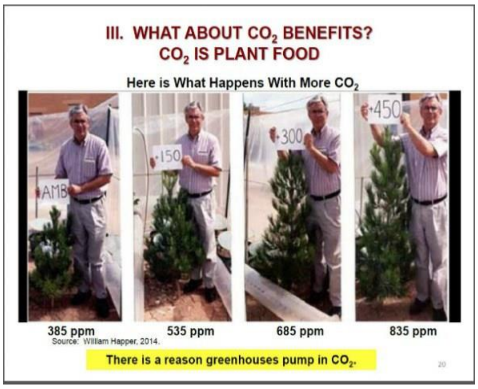


Figure 3. Elevated CO_2 impact (Anonymous, 2018c)

C_3 and C_4 plants react differently to elevated CO_2 and other climatic factors. Studies have indicated that global warming would have dramatic effects on the growth and development of field crops (Romanova, 2005), increasing CO_2 increases the water use activity with the growth, especially in grain legumes (Cutforth, et al., 2007). Increased temperature during growing seasons can reduce yields, because crops' speed through their physiological development producing less grain, faster plant growth and modifications of water, nutrient budgets and critical temperatures are between (35-40°C) particularly when stress coincides with flowering because of damage to meiosis and pollen growth, which inhibits setting of fruit and grain (Fuhrer, 2009) (Table 1). CO_2 accelerates photosynthesis and its concentration is increasing, the productivity of C_3 plants will not drop (generally) it will increase by 36.0% (Uzmen, 2007) compared with 35.0-80.0% in the grain legumes (Ziska, et al., 2001). The anatomical effect of global warming on plants generally emerges with the increase of CO_2 gas concentration due to environmental temperature and with the following interactions between the vitality of leaf and thickness, ramification and the length of the stem, life of the leaf and the thickness of leaf and length of the stem etc. 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 (Mei, et al., 2007) and morphological changings of tuberous in the C_3 plants (esp. in potatoes (Solanum spp.) and in grain legumes) (Romanova, 2005, Ulukan, 2008-2009a) (Table 2). Therefore, C_3 plants, which include all trees and shrubs as well as some cool-season invasive grasses like bromes and cheatgrass, may be more responsive to carbon dioxide fertilization than C_4 plants, which include most warm-season grasses and invasives like love grass (Eragrostis teff Rasbak) and buffelgrass (Pennisetum ciliare (L) Link.).

Table 1. Some of the CC components and responses of the field crops' selected traits' Modified from Krupa (1997), Dhakhawa and Campbell (1998), Tubiello and Ewert (2002)

Trait	Some of the CC Components			Responses
	(Elevated) CO_2	(Elevated) UV-A,B	(Elevated) O_3	
Root (bio)mass	+	?	?	Root/Shoot
Photosynthesis	+In C_3, -In C_4	-In many [C_3, C_4]	-In many [C_3, C_4]	Yield and Respiration
Leaf Conductance & Leaf Development	-[C_3, C_4]	Many are affected	-In susc.	Leaf Area
Water Use Efficiency (WUE)	+[C_3, C_4]	+[C_3, C_4]	-In susc.	Stomata Conductance and Closure
Leaf Area	More in C_3	-[C_3, C_4]	-In susc.	Interception of PAR
Leaf Thickness	+	-in majority	-In susc.	?
Maturity (%) & Harvesting	+	Unaffected	?	Vegetative stage, Yield
Flowering (Anthesis)	Happens Early	Prevents & Stimulates	- Number of Flower and Flowering Days	Vegetative Stage, Yield
Dry matter Production	Doubled in C_3, Uncertain in C_4	Wide Variation	Wide Variation	Yield
Susc. in Species & Cultivars	Changes	Changes	Changes	Yield
Resistance to drought Stress	Less susc., More susc. to drought	Less susc. to UV-B, More susc. to drought	Less susc. to O_3, More susc. to drought	Wiltness, Dwarfness, Death
Nutrients	React Less	Some are more, some are less susc.	Sensitive to O_3 damage	Dwarfness, Death
Vernalization	+	?	?	Vegetative Stage
(CO_2/O_2)	?	?	?	Photosynthesis
Respiration Rate	?	?	?	Biomass Production
Seed Formation Period	?	?	?	Yield
Biomass Production	+	?	?	Yield
Node Number	?	?	?	Biomass, Height
Weed Distribution	?	?	?	+
Seed Germination	+	?	?	Distribution
Rhizomes	+	?	?	Distribution
Seed Longevity	+	?	?	?
DNA Molecule & Sterility	+	?	?	Mutation, Death, Yield
Ecological Factors	+	+	+	Stress

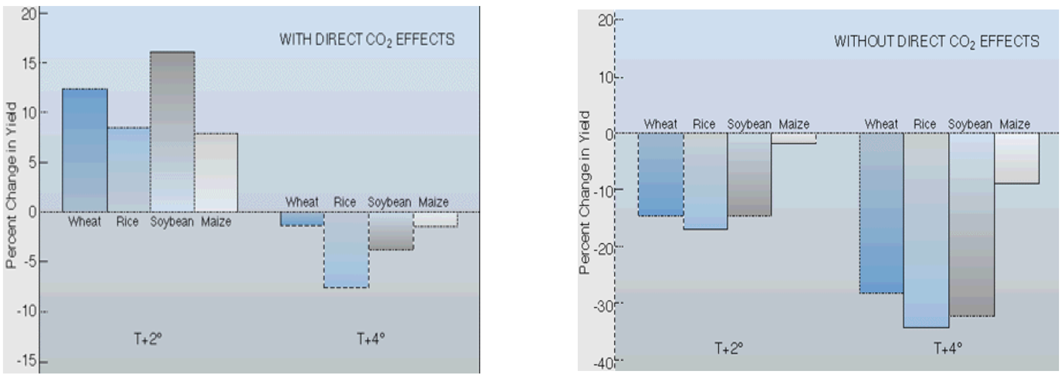
Susc. =Susceptibility
CO_2 =Carbon dioxide
UV-A,B =Ultraviolet A and B
O_3 =Ozone
\+ =Increase
\- =Decrease
? =Unknown
WUE =Wate Use Efficiency
PAR =Photosynthetic Active Radiation

The higher temperature also increases the process of evapotranspiration and decreases soil moisture availability. In addition, higher CO_2 concentration leads to increased growth and transpiration rates in some cultivated plants; it leads to an extension of the cultivation range of field crops such as grain legumes, wheat, maize, soybean, potato. Studies have indicated that a 1°C increase in global temperature will lead to reduced productivity in some field crops such as 7.0–124.0% in wheat (Triticum spp.) Fuhrer, 2009); soybean -22.0-18.0% (Fuhrer, 2009); 1.0–3.8% in barley Hordeum spp.) (Cline, 2008); 28.0% in potato (Fuhrer, 2003) and 17.0% in maize (Tables 2-3).

Table 2. Some agronomic characteristics of the world's (18) leading crops (Modified from Rötter and Geijn, 1999)

Crop	World* Production/Yield (Mt) (Hg/Ha)	Origin	Plant Type	WUE
Barley	141.277/30.108	West Asia	C_3	1.25-2.50
Beans, Dry	26.833/9.129	South and Cent. Amer.	C_3	1.40-3.30
Cassava	277.103/118.006	South and Cent. Amer.	CAM	1.30-3.30
Coconuts	59.011/48.493	Africa, Asia	C_3	1.40-3.30
Cottonseed	46.988*	South Amer.	C_3	1.40-3.30
Grapes	77.439/109.119	Asia	C_3	1.25-3.30
Maize	1.060.107/56.401	Ctr. Amer.	C_4	2.90-6.70
Oats	22.992/24.373	West Europe	C_3	1.25-2.5
Peanuts	-	Sth Amer.	C_3	1.40-3.30
Peas, Dry	14.363/18.835	West and North Asia	C_3	Unknown
Potatoes	376.827/195.790	South Amer.	C_3	1.25-2.50
Rice paddy	740.962/46.366	Asia, Africa	C_3	1.40-3.30
Rye	12.944/29.398	West Asia	C_3	1.25-2.50
Sorghum	63.931/14.279	Africa	C_4	2.90-6.70
Soybeans	334.894/27.556	East Asia?	C_3	1.40-3.30
Sugarcane	1.890.662/706.148	South East. Asia, Austria	C_4	1.25-6.66
Sweet Potatoes	105.191/121.975	South and Cent. Amer.	C_3	1.40-3.30
Wheat	794.460/34.050	Fertile Crescent	C_3	1.25-2.50

Sth.: South Cent.: Central Amer.: America
WUE: Water use efficiency (at dry mater based) * Anonymous, 2018a



T: Temperature

Figure 4. Calculated change in world-averaged crop yields of (4) major cereals [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 on the left) and without (on the right) direct CO_2 effects on plant growth and water use (Rosenzweigh and Hillel, 1995, Mengü, et al., 2008)

4. RESULTS AND DISCUSSION

National or international agreements should be done which include powers to regulate both CO_2 emissions and use of water resources according to the contribution to global climate change and GHGs. Efficient use of nitrogenous fertilizer can reduce nitrous oxide emissions and ruminants are the major emitters of CH_4 (Prasad, 2009). The use of artificial and excessive nitrogen fertilizer should be avoided, crop rotation pattern(s) followed which incorporate animal feed and edible legumes because of their ability to translocate (C) compounds to their storage organs (Ulukan, 2009a); alternative energy sources should be used; zero soil tillage (Çakır, et al., 2009) should be used, organic agricultural techniques should be promoted, and organic material(s) should not be burned.

5. CONCLUSION AND RECOMMENDATIONS

Continental areas are projected to warn more than the oceans and coastal areas, and the poles are predicted to warm faster than equatorial areas. They exhibit known responses to weather and climate that can have a large impact on crop yield since atmospheric concentrations of greenhouse gases continue to increase at unprecedented rates, efforts have been made to understand the implications for the biodiversity at the cultivated plants' level, consequently crop production. First of all, needed agreements should be done without delaying which include powers to regulate both CO_2 emissions and use of H_2O resources. Efficient use of nitrogenous fertilizer should be realized, crop rotation pattern(s) should be performed which incorporate animal feed and edible legumes because of their ability to translocate (C) compounds to their storage organs (Nemecek, et al., 2008; Ulukan, 2009b); alternative energy sources should be used; minimum soil tillage techniques should be used (Ulukan, 2008; Çakır, et al., 2009); and an end product ((mainly straw) certainly) should not be burned.

NOTICE

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