

## Impact of Climate Change Conditions on Some Chemical Compounds of Wheat as Indicators for Photosynthetic Efficiency

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**Abstract:** Different plants build chemical compounds through photosynthesis process which in turn is greatly affected by surrounding environmental conditions. One of the most important environmental challenges that face plant production is the phenomenon of climate change that result mainly in increased temperature and elevation of carbon dioxide concentrations in air. This study aims to investigate the impacts of predicted climate changes conditions on photosynthetic efficiency in wheat crop using carbon dioxide concentration ranging between 800: 1000 ppm and temperature about 4.5°C higher than open air in the environmental chamber. Some chemical compounds were measured as indicators for photosynthetic efficiency. Obtained results showed that: 1. There was a decrease in the percentage of photosynthetic pigments i.e. chlorophyll a, chlorophyll b and carotene in wheat leaves grown in environmental chamber (predicted climate change conditions) than in open air in both the first and second seasons. 2. Values of lipid, protein and fiber content were increased while carbohydrate and ash were decreased in wheat grains grown in the environmental chamber during both seasons than that grown in open air. 3. Moisture percentage was decreased in first season and increased in second season in wheat grains grown in the environmental chamber than that grown in open air. 4. There was an increase in the percentage of serine and glycine amino acids (photorespiration indicators) in wheat leaves grown in environmental chamber than that grown in open air during both seasons.

[Yossife, H.; M.M. Eldanasoury; T.B. Fayd; M.K. Hassanein and B.A.A. Ali. **Impact of Climate Change Conditions on Some Chemical Compounds of Wheat as Indicators for Photosynthetic Efficiency.** *N Y Sci J* 2017;10(9):104-110]. ISSN 1554-0200 (print); ISSN 2375-723X (online). <http://www.sciencepub.net/newyork>. 15. doi:[10.7537/marsnys100917.15](https://doi.org/10.7537/marsnys100917.15).

**Keywords:** Climate, Wheat, Photosynthetic Efficiency.

### 1. Introduction

Life on earth would be impossible without the fundamental process of photosynthesis which is mainly dependent on reaction between plant and climate elements therefore, biophysical, biochemical processes and environmental variables such as CO<sub>2</sub> concentration and temperature can have different effects on photosynthesis efficiency (Sharkey *et al* 2007). Changes in Earth's climate have been projected by the end of this century because some atmospheric "greenhouse" gases, among them carbon dioxide (CO<sub>2</sub>), are increasing (IPCC 2001). While light absorption is independent of temperature, the subsequent steps in converting light into chemical energy respond to temperature in complex ways (Kirschbaum 2004).

Heat stress due to high ambient temperatures is a serious threat to crop production worldwide (Hall, 2001). Gaseous emissions due to human activities are substantially adding to existing concentrations of greenhouse gases particularly carbon dioxide CO<sub>2</sub>, methane CH<sub>4</sub>, nitrous oxide N<sub>2</sub>O and chlorofluorocarbons CFCs. Different global

circulation models predict that greenhouse gases gradually increase world's average ambient temperature. Intergovernmental Panel on Climate Change (IPCC) report indicate that global mean temperature will rise 0.3 °C per decade (Jones *et al.*, 1999) reaching about 1 and 3-4°C above the present value by years 2025 and 2100, respectively and leading to global warming.

Wheat (*Triticum aestivum* L.) is one of the most important crops in Egypt, which plays a special role in people's nutrition. Ninety-five percent of the cultivated wheat is used for the preparation of bread and other baked products, while the remaining 5% is durum wheat, which is used essentially for making pasta and macaroni (Bushuk, 1998). However, Egypt supplies only 40% of its annual domestic demand for wheat (Salam, 2002). But unfortunately environmental stresses, such as salinity, drought, extremes of temperature and heavy metals cause impaired plant growth and productivity worldwide (Anjum *et al.*, 2011).

Heat stress is a major limitation to wheat productivity in arid, semi arid, tropical and subtropical

regions of the world (Fischer, 1986). Exposure to higher than optimal temperature reduces yield and decreases quality of cereals (Wardlaw *et al.*, 2002). Heat stress reduce wheat photosynthesis either via damage to photo system II (Paulsen, 1994) or inhibition of Rubisco activates (Law and Crafts-Brander, 1999), increased respiration (Berry and Bjoekman, 1980) or disruption to the respiratory mechanism (Lin and Markhart, 1990) and decreased starch synthesis in developing grains (Bhullar and Jenner, 1985).

In general, higher CO<sub>2</sub> concentrations increase plant production due to higher rates of photosynthesis and water utilization and reduce grain protein concentration, which results in lower grain quality (Ludwig and Asseng 2006). Meanwhile, the duration of a plant's developmental stages is extremely sensitive to climate conditions, especially temperature (Cleland *et al.*, 2007) because high temperatures generally reduce the growth duration by accelerating phenological development (Marcellos and Single, 1972; Butterfield and Morison, 1992 and Asseng *et al.*, 2004).

In this investigation we focus on the Impacts of predicted climate change conditions (increased CO<sub>2</sub> concentration and temperature) on photosynthetic pigments level (chlorophyll a, chlorophyll b and carotenoids), serine, glycine amino acids and chemical composition (carbohydrate, lipids, protein, fiber, moisture, ash) of wheat crop.

The main objectives were to evaluate effect of increased CO<sub>2</sub> concentration and temperature increase on some chemical compounds of wheat as indicators for photosynthetic efficiency of wheat plant.

## 2. Material and methods

The present study was carried out at Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center (ARC), Ministry of Agricultural and Land Reclamation during the period from 2013 to 2015 in open field and in semi automated control environmental chambers conditions.

The present investigation consisted of 2 experiments which included two trials on wheat (*Triticum aestivum*) Giza 168 CV in the successive winter seasons of 2013/2014 and 2014/2015, respectively.

Grains of wheat cultivar were kindly obtained from Field Crops Research Institute (FCRI) Agriculture Research Center (ARC), Ministry of Agriculture and Land Reclamation, Cairo, Egypt.

Grains of wheat were sown at the proper recommended seeding rate at the suitable soil depth in growing pantry 4.5 m in length, 1.5 m in width and 50 cm in depth and filled with suitable amounts (3.375 m<sup>3</sup>) of dry clay soil. Wheat grains were sowed on 17th

of November in 2013/2014 and 12th of November in 2014/2015 winter seasons, respectively. Three replications were randomly assigned for each one of the investigated four growth conditions.

Semi automated growth chambers were previously designed to evaluate the effect of climate change conditions (increase of carbon dioxide concentration and temperature) on wheat.



Figures (1): Semi automated growth

The walls of the chamber were covered with glass while the ceiling was covered with transparent plastic sheet as in green house. Carbon dioxide was pumped through horizontal pipe net above growing pantry from carbon dioxide cylinder (Figures 1).

Pumping of carbon dioxide is controlled by electric valve connected to electric timer which allows passage of carbon dioxide at regular intervals to maintain carbon dioxide concentration within required level which is monitored via infrared sensor specific for carbon dioxide (RAEGuard) with accuracy of 0:50000 ppm (Figure 2).



Figure (2): RAEGuard carbon dioxide sensor

Emerged crop seeds were exposed from emergence till plant maturity and harvest to the following two climatic conditions:

- 1- Growing pantry and normal conditions.

Wheat was grown in growing pantry where air temperature and carbon dioxide concentration were unchanged.

- 2- Growing pantry with increased temperature and CO<sub>2</sub> concentration in semi automated control chamber. Wheat was grown in growing pantry where air temperature and CO<sub>2</sub> concentration were artificially increased. Air temperature increase was estimated to be of average of about 4.5°C more than external environment and CO<sub>2</sub> concentration was

between (800-1000 ppm). Such treatment may simulate the predicted climate change conditions at the end of current century.

Cultural practices (irrigation, fertilization, hand-weeding and pest control) in all the investigated treatments were properly practiced according to Field Crops Research Institute recommendations. Temperature data recorded along wheat growth period under open air (normal condition) and under semi automated growth chambers (CO<sub>2</sub> enrichment chamber) s were presented in Table (1).

#### Determination of photosynthetic pigments in wheat leaves

To extract photosynthetic pigments from plant leaves, 0.2 g of fresh leaves was homogenized with 10 ml of 100% acetone in a porcelain mortar and centrifuged at 2500 rpm for 10 min. The supernatant was separated and the absorbencies were quantity estimated spectrophotometrically using spectrophotometer apparatus at 662 and 645 nm for chlorophyll a and b, respectively and 470 nm for carotene. Amounts of each of the three pigments were calculated using the following equations of **Lichtentaler and Wellburn (1985)**.

Chlorophyll a (µg/ml) = 11.75 A<sub>662</sub> – 2.350 A<sub>645</sub>

Chlorophyll b (µg/ml) = 18.61 A<sub>645</sub> – 3.960 A<sub>662</sub>

Carotenoids (µg/ml) = 1000 A<sub>470</sub> – 2.270 Chl a – 81.4 Chl b/227

#### Determination of wheat grains chemical composition

A quantitative estimation for the values of chemical composition *i.e.* carbohydrates, lipid, protein, fiber, moisture and ash in harvested wheat grains was conducted. Values % of each component was digitally measured for harvested wheat grains from each sample using Near-Infrared (NIR) spectroscopy apparatus, model DA1650, manufactured

by FOSS Corporation. Assessments were obtained at wavelength region from ~750nm to2500nm of the electromagnetic spectrum. The estimation of the chemical composition was done at the Central Laboratory, Faculty of Agriculture, Al Azhar University.

#### Determination of serine and glycine amino acids for wheat leaves

The determination of serine and glycine amino acids was done by using automatic amino acid analyzer (AAA 400 INGOS Ltd) in the Faculty of Agriculture Research Center, Cairo University through the two following steps:

**First step:** Extraction of free amino acids from flag leaf of wheat, which was done according to the method of **Shalabia (2011)** as following:-

1. The dried and defatted grinding sample (Ca. 1.00 g) was extracted by boiling under reflux with ethyl alcohol (80%) in reflux, for 2 hours.

2. After filtration, solution was evaporated until to be free from ethyl alcohol.

3. Then the residue was dissolved in diluting buffer "citrate buffer".

Second step: Hydrolysis of total amino acids, which was carried out according to the method of **Csomos and Simon-Sarkadi (2002)** as following:-

1. The dried and defatted grinding sample (Ca.0.2g for solid sample) or (200µl for liquid sample) was hydrolyzed with 6N HCl (10 ml) in sealed tube, heated in oven at 100°C for 24 hours.

2. The resulting solution was completed to 25ml with de-ionized water.

3. After filtration, five ml of hydrolysate was evaporated until to be free from HCl vapor.

4. Then the residue was dissolved in diluting buffer "citrate buffer".

**Table (1) Temperature data for wheat experimental growth period in the two seasons:-**

Date	Normal conditions			Semi automated control chamber		
	Min	Max	Ave.	Min	Max	Ave.
First season						
Nov-13	15.6	27.0	21.3	19.3	33.1	26.2
Dec-13	9.0	20.7	14.9	13.5	25.8	19.6
Jan-14	8.9	21.4	15.2	13.3	26.6	19.9
Feb-14	10.4	22.6	16.5	12.6	26.8	19.7
Mar-14	13.2	25.4	19.3	17.6	31.4	24.5
Second season						
Nov-14	13.9	25.5	19.7	18.2	30.7	24.5
Dec-14	10.8	23.3	17.1	15.0	27.7	21.3
Jan-15	8.2	19.9	14.1	12.1	24.7	18.4
Feb-15	9.0	20.9	14.9	13.9	25.6	19.8
Mar-15	13.2	25.0	19.1	17.9	30.1	24.0

### 3. Results and Discussion

#### Impact of climate change conditions on photosynthetic pigments in wheat leaves

Elevated of the concentration of carbon dioxide CO<sub>2</sub> 800-1000 ppm and increasing temperatures about 4.5°C resulted in a reduction in the level of photosynthesis pigments. Table 2 shows these results in the two seasons.

Photosynthetic pigments of wheat leaves were negatively affected by the increases of temperature and CO<sub>2</sub> concentration in environmental chamber treatment. Elevated of CO<sub>2</sub> concentration up to 800-1000 ppm combined with increasing of air temperature by about 4.5°C than comparable open air decreased to different extents the concentration of chl.a, chl.b and carotenoides in wheat leaves (Table 2). In the 1<sup>st</sup> season the recorded reductions were amounted to 26.9, 29.5 and 26.0 % respectively. Analogous values in the 2<sup>nd</sup> season were estimated by 28.7, 29.3 and 26.0% for the same respective pigments.

It is worthy to notice that the used environmental chamber conditions (temperature and CO<sub>2</sub> levels) were simulated to the predicted climate changes at the end of current century.

Deleterious impact of high temperature on photosynthetic pigments can be attributed mainly to the thermal dynamic oxidation of high temperature on pigment molecules and (or) to the severity of cell drought caused by high temperature. In this respect **Moursi and Fayed (1979)** pointed out that decreases in cell moisture potential not only destructive photosynthetic pigment molecules but also inhibits the generation and formation of new pigment molecules. Moreover, traits associated with heat tolerance in wheat differences in photosynthesis among genotypes under heat stress have been shown to be associated with a loss of chlorophyll and a change in the chlorophyll a:b ratio due to premature leaf senescence (**Al-Khatib and Paulsen, 1984 and Harding et al., 1990**)

Several studies indicated that the high temperature modifies the structure and damages the photosynthetic pigments. (**Briantais et al. 1996; Srivastava et al. 1997; Crafts Brandner and Salvucci 2002; Allakhverdiev et al. 2008; Kreslavski et al. 2009 and Mohanty et al. 2012**). **Nayyar and Gupta 2006** stated that high temperatures cause drought that inhibits the photosynthesis of plants, causes changes in chlorophyll contents and components and damage to the photosynthetic apparatus. Recently, **Haque et al. 2014** concluded that an early effect of increased temperature in the photosynthetic apparatus is the inhibition of the activity of the PSII.

#### Impact of climate change conditions on wheat grains chemical composition

In both seasons, the chemical composition of wheat grains was analyzed and the percentages of carbohydrates, lipid, protein, fiber, moisture and ash composition parameters under both different conditions in our experiments were determined. Table (3) shows the results of chemical composition analysis.

Chemical composition of wheat grain was affected by climatic changes pattern in the tested environmental chamber. Results in Table (3) clear that elevation of CO<sub>2</sub> concentration and temperature decreased carbohydrates and ash percentage of wheat grains than those of open air condition. This trend is true in both the two experimental seasons. Interpretation of such finding could be attributed to the stimulative impact of temperature on cell respiration (mitochondrial respiration and photorespiration) rates. High temperature dramatically increased photorespiration of wheat and other C3 plants, since temperature coefficient (Q<sub>10</sub>) of photorespiration processes (C3 plants) equaled by 3.0 (**Moursi and Fayed 1979**). Therefore, net assimilation rate (NAR), dry matter accumulation and productivity of C3 crop plants must be declined under high temperature climate conditions (**Moursi and Fayed 1979 and Fayed 2000**).

Heat stress developed from direct heat and CO<sub>2</sub> increases (Table 1), reduced photosynthesis via damage to photo system II (**Paulsen, 1994**) and (or) inhibition of rubisco activase (**Law and Crafts-Brandner, 1999**), increased respiration (**Berry and Bjorkman, 1980**) or disruption to the respiratory mechanism (**Lin and Markhart, 1990**) and decreased starch synthesis in developing grain (**Bhullar and Jenner, 1985**).

High temperature of climate change simulation scenario (+4.5°C) in the studied environmental chamber treatment increased protein and lipid contents of wheat grains in both the two experimental seasons (Table 3). High temperature increase transpiration rate and disturb water potential in wheat plant which increased crude protein. **Fayed (1972)** reported that protein considered a good indicator for plant tolerance to water deficit, since adequate water supply caused hydrolysis and catabolism in protein and releasing free amino acids and ammonia as well as proline. The same finding was obtained by **Hanna-Fardoas and Abdel-Nour (2000)** who mentioned that low water supply increased seed protein compared with wet conditions. Recently, it is worthy to add that heat stress caused the synthesis and accumulation of specific proteins which ascertained during a rapid heat stress, and designated as HSPs (heat shock proteins). Herein, **Nakamoto and Hiyama (1999) and Schoffl**

*et al.* (1999) cleared that the production of HSPs increased when plants exposed either to abrupt or gradual increase in temperature and the presence of HSPs can prevent denaturation of other proteins caused by high temperature. Likewise, **Austin, (1972)** indicated that much of the variation in seed quality among seed lots is the direct or indirect result of variation in weather before or at harvest, hot dry periods generally providing good quality seed (increased protein content).

#### Impact of climate change conditions on percentage of serine and glycine amino acids

Results of the effect of elevation both CO<sub>2</sub> concentration and temperature levels on serine and glycine amino acids percentages of wheat grains in both seasons are presented in Table (4). Warming conditions of environmental chamber increased serine and glycine amino acids percentages in the 1<sup>st</sup> season by 89.9% and 26.5%, respectively. Analogous increases obtained in the 2<sup>nd</sup> season were valued by 77.0 and 22.67%, respectively.

**Table (2): Average of photosynthetic pigments (chl.a, chl.b and carotene) levels in wheat leaves under open air and environmental chamber conditions in the 1<sup>st</sup> and 2<sup>nd</sup> experimental seasons of 2013/2014 and 2014/2015.**

Growing conditions	Chlorophyll a mg/g	Chlorophyll b mg/g	carotene mg/g
<b>2013/2014 season</b>			
Open air	7.07	8.77	52.20
Environmental chamber	5.17	6.18	38.62
Percentage of reduction	26.9%	29.5%	26.0%
<b>2014/2015 season</b>			
Open air	7.14	8.63	52.48
Environmental chamber	5.09	6.10	38.81
Percentage of reduction	28.7%	29.3%	26.0%

**Table (3): Values of wheat grains chemical composition (% of carbohydrates, lipid, protein, fiber, moisture and ash) under open air and environmental chamber conditions in the 1<sup>st</sup> and 2<sup>nd</sup> experimental seasons of 2013/2014 and 2014/2015.**

Growing conditions	Carbohydrate	Lipid	Protein	Fiber	Moisture	Ash
<b>2013/2014 season</b>						
Open air	69.48	1.70	17.23	2.61	7.77	1.21
Environmental chamber	66.89	1.81	19.45	3.19	7.61	1.05
<b>2014/2015 season</b>						
Open air	69.43	1.71	17.19	2.59	7.88	1.21
Environmental chamber	66.53	1.82	19.36	3.31	7.91	1.07

**Table (4): Average of serine and glycine amino acids percentages of wheat grains under open air and environmental chamber conditions in the 1<sup>st</sup> and 2<sup>nd</sup> experimental seasons of 2013/2014 and 2014/2015.**

Growing conditions	Serine %	Glycine %
<b>2013/2014 season</b>		
Open air	1.29	6.79
Environmental chamber	2.45	8.59
Percentage of increase	89.9%	26.59%
<b>2014/2015 season</b>		
Open air	1.35	6.85
Environmental chamber	2.39	8.40
Percentage of increase	77.0%	22.6%

Determination of serine and glycine amino acids levels considers good criteria for photorespiration activity in plant tissues. Since oxygenation of rubisco in chloroplast produced glycolate that transaminated to glycine which moves to the mitochondrion (**Moursi and Fayed 1979**). Inside the mitochondrion two glycine molecules probably combined to form serine amino acid, ammonia and CO<sub>2</sub> molecules.

**Harley and Sharkey 1991**, concluded that the increase in the level of serine and glycerin indicates an increase in the rate of photorespiration due to fixation of oxygen by rubisco (ribulose-1,5-bisphosphate-carboxylase/oxygenase) and the subsequent reactions of photorespiration might provide the cell with an additional method for the synthesis of sink products such as glycine and serine instead of carbohydrates.

**Conclusion:**

Obtained results obviously clear the deleterious impact of global warming weather conditions of predicted climate change scenario on photosynthetic efficiency and productivity of wheat (C3) plant. Simulative predicted global warming conditions are sourced in our investigation from the elevation of CO<sub>2</sub> concentration and ambient air temperature in environmental chambers. Such heat stress conditions treatment exhausted net assimilation rate tools of wheat plant by decreasing their leaves photosynthetic pigments values and reducing grain carbohydrates accumulation and stimulating photorespiration rate indices.

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9/12/2017