# Vulnerability and adaptation strategies for sunflower crop under climatic changes conditions in Egypt

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**Abstract:** A field trial was carried out during the two sunflower growing seasons 2010 and 2011 to find out the negative effects of climate change (CC) phenomenon on production and water productivity of sunflower crop. The experiments were carried out at Sakha and Giza Agricultural Research Stations. The sites represent middle north Nile Delta and middle Egypt areas, respectively. Global Circulation Models (GCMs) and the dynamic crop growth model OILCROP-SUN which imbedded with the computer program "DSSAT" was used to assess the potential impact of climate change on sunflower crop productivity. The results showed that climate change could decrease sunflower seed yield about 16, 9 and 7 % at Sakha; 22, 19 and 13 % at Giza for sunflower genotypes of Sakha53, Hybrid19 and Hybrid20, respectively. In addition, it will caused reduction in crop water productivity about 21, 14 and 11 % at Sakha; 28, 25 and 20 % at Giza, for the same respective sunflower genotypes. Choosing the appropriate adaptation strategies can significantly contribute in reducing the negative impact of climate change on sunflower productivity along with its water productivity. For example, increasing the amount of irrigation water with 10-20% can be resulted in minimizing the negative impact of climate change. Egypt is facing a series water shortage at present and under climate change, the results showed that skipping last irrigation has the least negative effect on crop production.

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**Keywords:** sunflower, OILCROP-SUN, DSSAT, climate change and adaptation measures.

## 1. Introduction

The Third Assessment Report (TAR) by Gitay *et al.,*2001 concluded that climate change (CC) and variability will impact food, fiber and forests (FFF) around the world due to the effects on plant growth and yield of elevated $CO_2$, higher temperatures, altered precipitation and transpiration regimes, and increased frequency of extreme events, as well as modified weed, pest and pathogen pressure.

Van Ittersum *et al.* (2003) simulated higher risk of salinization in arid and semi-arid regions, due to more water loss below the crop root zone. Howden *et al.* (2003) focused on the consequences of higher temperatures on the frequency of heat stress during growing seasons, as well on the frequency of frost occurrence during critical growth stages. Parry *et al.* (2007) indicated that yields of grains and other crops could decrease substantially across the African continent because of increased frequency of drought, even if potential production increases due to increases in $CO_2$ concentrations. Debacke *et al.* (2017) had pointed out that climate change is characterized by higher temperatures, elevated atmospheric $CO_2$ concentrations, extreme climatic hazards, and less water available for agriculture.

The overall results of Kapour (2010), in Italy, indicated that an increase of temperature, in the range between 1.3 and 2.5 C$^o$, is expected in the next 100 years. The reference evapotranspiration (ETo) variations would follow a similar trend; as average over the whole region, the ETo increase would be about 15.4%. The precipitation should not change significantly on yearly basis. The net irrigation requirements (NIR), in respect to annual situation, is the greatest for olive trees (65%), wheat (61%), grapevine (49%), and citrus (48%) and it is slightly lower for maize (35%), sorghum (34%), sunflower (33%), tomato (31%) and sugar beet (27%).

Egypt is one of the countries that strong likely to the severe adverse impacts of the climate change, particularly on decreasing water supply as well increasing crop water needs. Abou Hadid (2006) analyzed the impact on, vulnerability of, and adaptation to climate change in the production of some major food crops and irrigation water requirements in Egypt. The results showed that there is an overall reduction in crop yields (wheat and tomato) under climate change even when adaptation is taken into account.

Sunflower, as an oil crop, is one of the major crops in Egypt. The national production of sunflower and other oil crops does not meet the current demand for oils. Increasing population growth, and the limited area for agriculture require new ways to increase agricultural productivity in general and oil crops in specific.

The aim of the present study is to determine the impact of climate change on sunflower crop. Moreover, intensive analysis dealing with the adaptation strategies owing to decreasing such negative effects.

## 2. Procedures.

### Selection of the field experimental sites

To achieve the objectives mentioned above, two sites were selected at Sakha and Giza research stations to conduct the concerning field trials. Sakha site represents the conditions and circumstances of the middle northern part of Nile Delta, while Giza site is located in the middle Egypt. Sakha site lies at 31º-07΄N. Latitude and 30º-57΄E Longitude with an elevation of about 20 m above mean sea level, while Giza site lies at 30º-03΄ N Latitude and 31º-13΄ E Longitude with an elevation of about 19 m above mean sea level. Particle size distribution (Klute,1986) and some soil chemical parameters (Jackson,1973) of the two sites are presented in Table 1. Soil at both sites are clayey in texture with low organic content, light in both salinity and alkalinity.

**Table 1: Particle size distribution and some soil chemical characteristics at Sakha and Giza sites.**

| Particle size distribution | Sakha site | Giza site |
|---|---|---|
| Sand % | 16.13 | 15.95 |
| Silt % | 23.77 | 30.51 |
| Clay % | 60.10 | 53.18 |
| Textural class | Clayey | Clayey |
| **Chemical analysis** | | |
| Organic matter % | 1.37 | 1.80 |
| Available N ppm | 62.76 | 40.00 |
| Available P ppm | 10.45 | 19.00 |
| Available K ppm | 101.98 | 304.00 |
| Ec mmhos / cm | 1.92 | 2.65 |
| pH, 1: 2.5 suspension | 8.40 | 7.40 |

Some soil moisture constants and bulk density at Sakha and Giza sites are presented in Table 2. Data indicated that the soil at each site is having high field capacity and wilting point as a result of the high clay content. Therefore, the available water in the effective root zone of 60 cm soil depth which can be used by the growing plants is fairly high.

Table 2: Soil moisture constants and bulk density for Sakha and Giza experimental sites.

| Soil depth (cm) | Field capacity (%,wt) | Wilting point (%,wt) | Available moisture (%,wt) | Bulk density (gm/ cm$^3$) | Available moisture (mm) |
|---|---|---|---|---|---|
| **Sakha site** | | | | | |
| 00 – 15 | 47.50 | 25.82 | 21.68 | 1.26 | 40.98 |
| 15 – 30 | 39.78 | 21.62 | 18.16 | 1.30 | 35.41 |
| 30 – 45 | 38.40 | 20.87 | 17.53 | 1.29 | 33.92 |
| 45 - 60 | 36.39 | 21.41 | 14.98 | 1.38 | 31.01 |
| Average | 40.52 | 22.41 | 18.46 | 1.31 | Total 141.3 |
| **Giza site** | | | | | |
| 00 – 15 | 41.80 | 18.60 | 23.20 | 1.20 | 41.80 |
| 15 – 30 | 33.70 | 17.50 | 16.20 | 1.20 | 29.20 |
| 30 – 45 | 28.40 | 16.90 | 11.50 | 1.20 | 20.7 |
| 45 - 60 | 28.00 | 16.50 | 11.50 | 1.30 | 22.4 |
| Average | 32.98 | 17.38 | 15.60 | 1.23 | Total 114.1 |

Agro-meteorological data (Table 3) at Sakha and Giza sites in 2010 and 2011 summer seasons were obtained from the Agro-meteorology and Climate Change Unit; Soils, Water and Environment Research Institute (SWERI); Agricultural Research Center (ARC), (unpublished data).

### Agronomic practices

Seedbed preparation owing to obtain high seed emergence was executed based on the recommended practices as issued by agriculture research center (ARC). In this regard, the area of the field trial was accomplished with good leveling using Laser technique for obtaining high uniformity distribution of irrigation water onto the cultivated area which resulting in healthy growing plants. The main way towards increasing irrigation efficiency with surface irrigation, the traditional watering system in Egypt is through precise soil leveling. Moreover, a basal dose of P-fertilizer equaled 37.2 kg $P_2O_5$/ ha was applied during land preparation procedure.

Three sunflower genotypes were investigated; Sakha53 variety (V1), hybrid19 (V2) and hybrid20 (V3). The sunflower genotypes were assessed in Randomized Complete Blocks Design with four replicates. The experimental plot area was equaled 25 m². Sunflower seeds were sown on 6/6/ 2010 and

29/6/2011 at Sakha and on 6/6/2010, and 16/ 6/ 2011 at Giza. Seeding rate was 12 kg/ ha. Sowing spacing was 20 cm between the adjacent plants and 70 cm between furrows. The recommended nitrogen level of 88.8 kg N/ ha was added in two equal applications before life (first after sowing irrigation) and the following irrigation as urea (46.5 % N). The potassium fertilizer dose of 120 kg/ ha as sulfate potassium (48% $k_2O$) was applied before the second watering at the same time with the second application of N fertilizer.

**Table 3: Average agro-meteorological data at Sakha and Giza sites in 2010 and 2011 seasons**

| **Sakha site** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Month | Season | T, max. | T, min. | T, av. | W.S | R.H | S.R |
| June | 2010 | 33.5 | 19.3 | 26.3 | 1.2 | 61 | 625 |
| | 2011 | 32.0 | 17.2 | 24.6 | 1.3 | 65 | 625 |
| July | 2010 | 33.1 | 20.4 | 26.8 | 1.2 | 67 | 610 |
| | 2011 | 33.0 | 19.4 | 26.2 | 1.1 | 64 | 610 |
| August | 2010 | 34.0 | 21.2 | 28.5 | 1.1 | 70 | 579 |
| | 2011 | 33.5 | 19.8 | 26.7 | 1.0 | 67 | 579 |
| September | 2010 | 33.4 | 19.2 | 26.3 | 1.0 | 65 | 507 |
| | 2011 | 33.2 | 17.7 | 25.5 | 0.9 | 69 | 507 |
| October | 2010 | 30.7 | 17.0 | 23.9 | 0.8 | 59 | 412 |
| | 2011 | 28.0 | 14.0 | 21.0 | 0.9 | 65 | 412 |
| **Giza site** | | | | | | | |
| June | 2010 | 37.0 | 22.7 | 30.0 | 1.6 | 51 | 627 |
| | 2011 | 35.2 | 21.7 | 28.5 | 2.0 | 55 | 627 |
| July | 2010 | 36.3 | 23.9 | 29.9 | 1.8 | 67 | 613 |
| | 2011 | 37.3 | 23.5 | 30.4 | 1.9 | 59 | 613 |
| August | 2010 | 38.3 | 25.3 | 31.3 | 1.8 | 61 | 577 |
| | 2011 | 36.5 | 23.9 | 30.2 | 1.5 | 60 | 577 |
| September | 2010 | 35.8 | 23.4 | 29.1 | 2.1 | 59 | 512 |
| | 2011 | 35.2 | 22.7 | 29.0 | 1.7 | 59 | 512 |
| October | 2010 | 33.8 | 21.5 | 27.4 | 1.9 | 59 | 417 |
| | 2011 | 30.9 | 18.7 | 24.8 | 1.8 | 58 | 417 |

Where: Tmax, Tmin, Tav, W.s, R.H, and S.R are; maximum, minimum, average temperature in °C. W.S= wind speed, m/sec. R.H= relative humidity,%. S.R.= solar radiation, $cal/cm^2/day$.

**Vulnerability study**

Vulnerability study for sunflower crop under climate change conditions was estimated with the OILCROP-SUN model included in DSSAT3.5 (Tsuji *et al.,* 1998). Equilibrium doubled $CO_2$ climate change scenarios were derived from the Canadian Climate Center (CCCM) and the Geophysical Fluid Dynamic Laboratory (GFD3) general circulation models (GCMs). The simulation was performed for a period of 25 years (1975 – 1999) for Sakha and 30 years (1960 – 1989) for Giza.

Crop water productivity was estimated according to Smith (2002). Crop water productivity is defined as Crop yield / Water consumptive used as ET.

**Adaptation Studies**

To minimize the negative impact of climate change on sunflower, number of adaptation strategies were examined, these are

- **Sowing dates**

Base treatment (June 10), 1st of May, 10th of May, 20th of May, 1st of June, 20th of June.

- **Irrigation amounts**

Base amount, Base amount -10 %, Base amount -20 %, Base amount +10 %, Base amount +20 %.

- **Skipping irrigation at different growth stages**

Without skipping under current, without skipping under climate change, skip. at 2nd irri., skip. at 3rd irri., skip. at 4th irri., skip. at 5th irri., skip. at 6th irri.

**3. Results and Discussion**

**Vulnerability study**

Results as recorded in Tables 4 - 5 indicated that climate change resulted in decreasing seed yield by 16, 9, 7 % at Sakha and 22, 19, 13 % at Giza, for sunflower genotypes of Sakha53 (V1), Hybrid19 (V2) and Hybrid20 (V3), respectively. The variety of V1 was more sensitive to climate change as compared with the two others. However, the variety of V3 was more tolerant.

Regarding crop water productivity (CWP), results indicated that CWP under current conditions ranged from 0.62 to 0.81 kg seeds/ $m^3$ consumed water at Sakha site, and 0.46 to 0.60 at Giza site. However, the corresponding values under climate change are ranged between 0.54 to 0.64, and 0.37 to 0.45 kg seeds/ $m^3$ consumed water. The highest CWP under climate change conditions was found for V1 at Sakha and V2 at Giza. On the contrary, the lowest values were recorded with V2 and V3 for the same respective sites.

**Table 4: Impact of climate change (CC) on sunflower seed yield and crop water productivity (CWP) at Sakha site.**

| Sunflower genotypes | Seed yield (kg/ ha) | | Change % | CWP (kg/ $m^3$) | | Change % |
|---|---|---|---|---|---|---|
| | Current | CC | | Current | CC | |
| V1 | 3348 | 2797 | -16 | 0.81 | 0.64 | -21 |
| V2 | 2582 | 2358 | -9 | 0.62 | 0.54 | -13 |
| V3 | 2899 | 2711 | -6 | 0.70 | 0.62 | -11 |

Notes: V1: Sakha53; V2: Hybrid 19; V3: Hybrid 20

**Table 5: Impact of climate change (CC) on sunflower seed yield and crop water productivity (CWP) at Giza site.**

| Sunflower genotypes | Seed yield (kg/ ha) | | Change % | CWP (kg/ $m^3$) | | Change % |
|---|---|---|---|---|---|---|
| | Current | CC | | Current | CC | |
| V1 | 2892 | 2260 | -22 | 0.58 | 0.42 | -28 |
| V2 | 2993 | 2413 | -19 | 0.60 | 0.45 | -25 |
| V3 | 2294 | 1989 | -13 | 0.46 | 0.37 | -20 |

**Adaptation studies with sunflower seed yield**

**Adaptation under different sowing dates**

At Sakha site, results as presented in Figs.1 indicate that the suitable sowing date for the studied sunflower genotypes was 1st to 10th May. Sowing V1, V2 and V3 on1st May increased sunflower seed yield by 7, 23 and 23 % as compared with base sowing date under climate change (10th June). The lowest seed yield registered for sowing on 20th June for all sunflower genotypes under study.

Regarding Giza site, the optimum sowing date was 1st May as shown in Fig. 2. The highest decrease in grain yield of 27 % was observed by V1 when sown on 20th June, while the lowest decrease with 2 % was shown by V3 when sown on 1st May. Thus weather plays vital role in sunflower productivity. Optimum growth temperature is corresponds to the optimum temperature for photosynthesis. High temperature affects plant development and speeds crop growth through the developmental processes.

**Fig. 1: Simulation of sunflower seed yield at different sowing dates (as adaptation strategy) under climate change conditions compared to current conditions at Sakha area.**

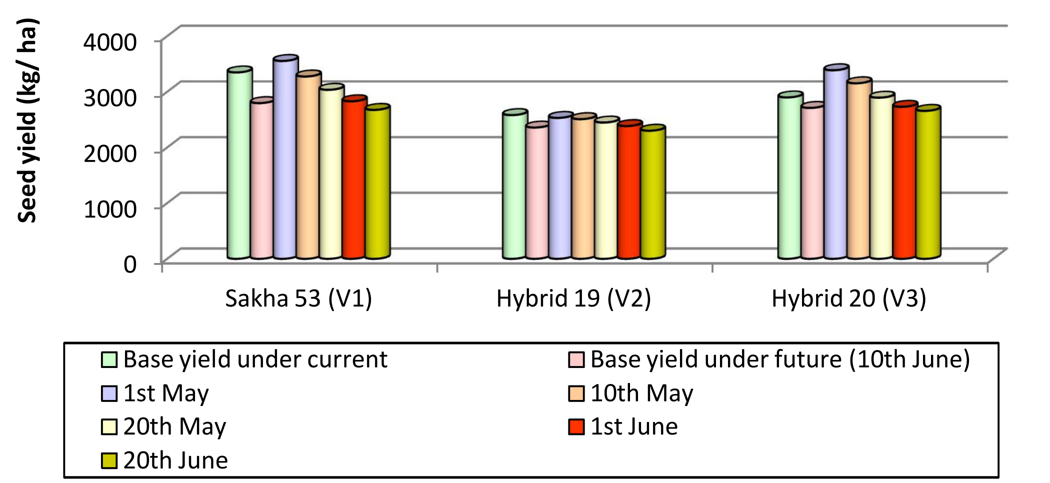
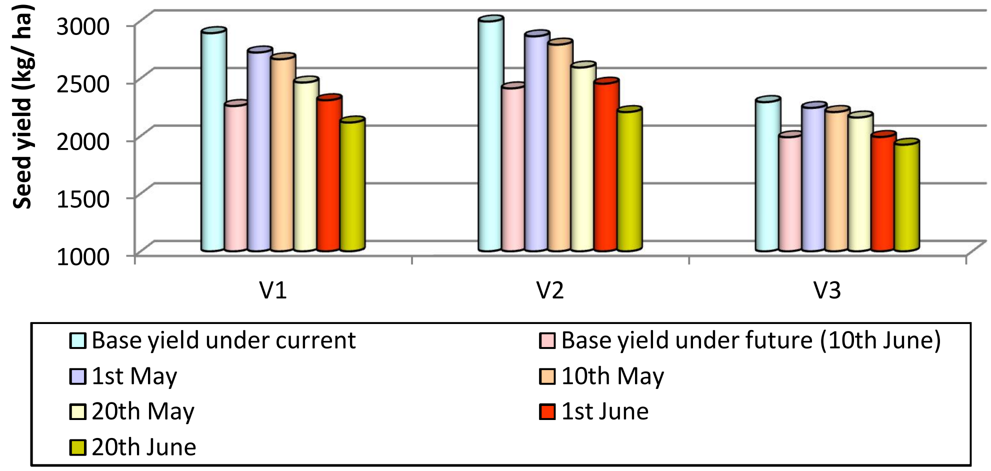


Fig. 2: Simulation of sunflower seed yield at different sowing dates (as adaptation strategy) under climate change conditions compared to current conditions at Giza area.

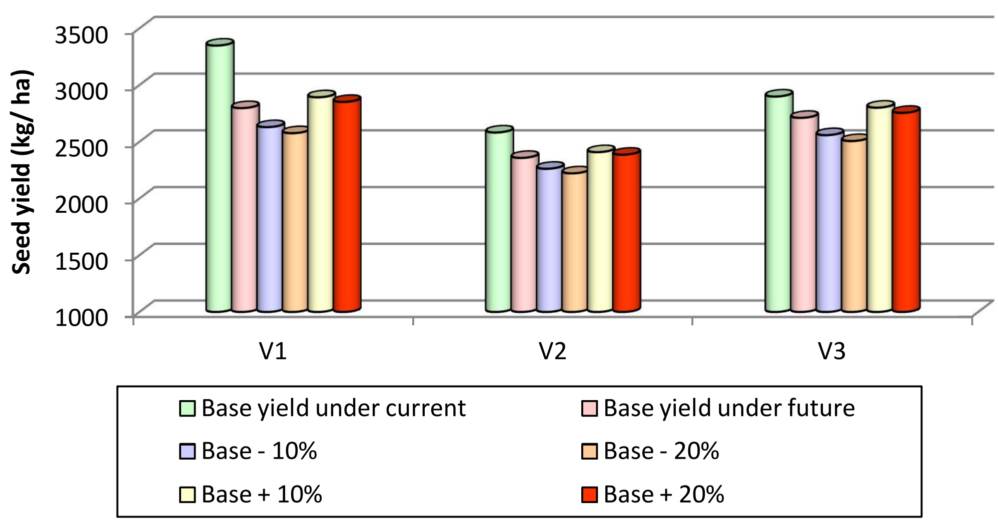


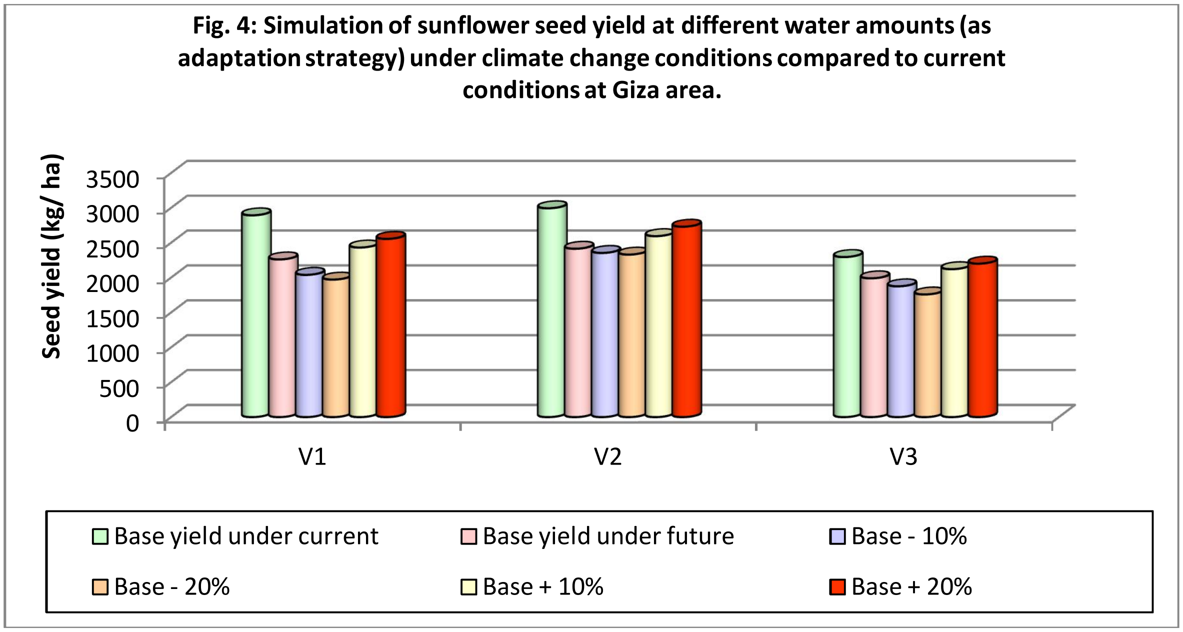

**Adaptation under different irrigation water amounts**

At Sakha site, Increasing amount of irrigation water caused an increase in sunflower productivity under climate change conditions as shown in Fig. 3. Increasing amount by 10 % could increase yield up to 3 % as compared with base yield under climate change, and 2 % only with increasing amount 20 %. However, decreasing amount of irrigation water by 10 to 20 % could decrease yield from 21 to 23 % for V1; 12 to 14 % for V2; 12 to 14 % for V3.

For Giza site, Impact of increasing amount of irrigation water applied on sunflower seed yield take the same trend as at Sakha site. Results as presented in Fig 4 clearly show that increasing water amount by 10 % or 20 % could increase seed yield by 6 to 11 %, respectively. However, under decreasing water amount by 10 % or 20 %, the corresponding reduction in seed yield ranging from 18 to 32 %.

Fig. 3: Simulation of sunflower seed yield at different water amounts (as adaptation strategy) under climate change conditions compared to current conditions at Sakha area.

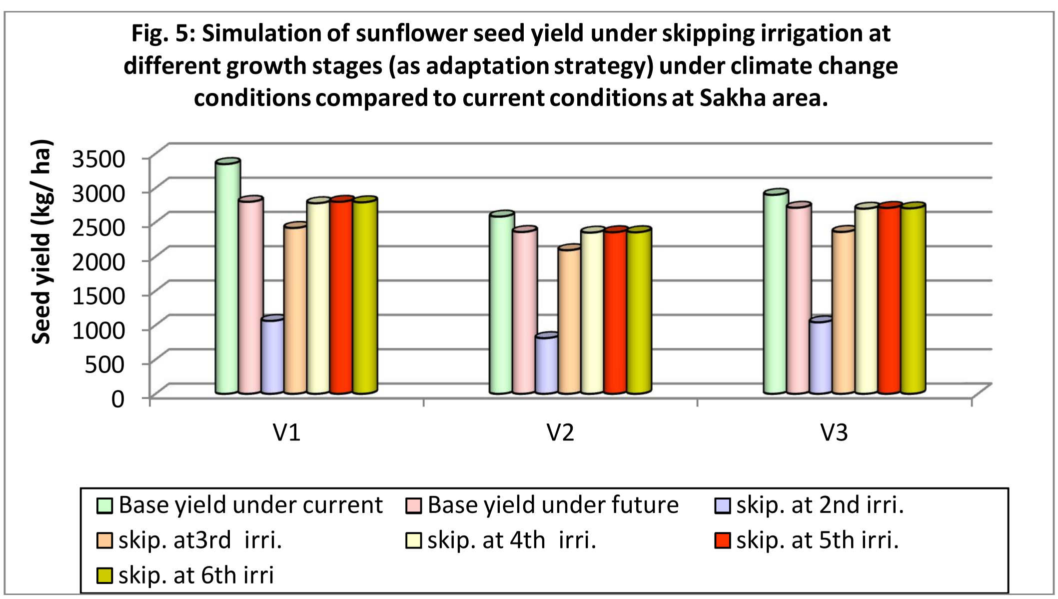


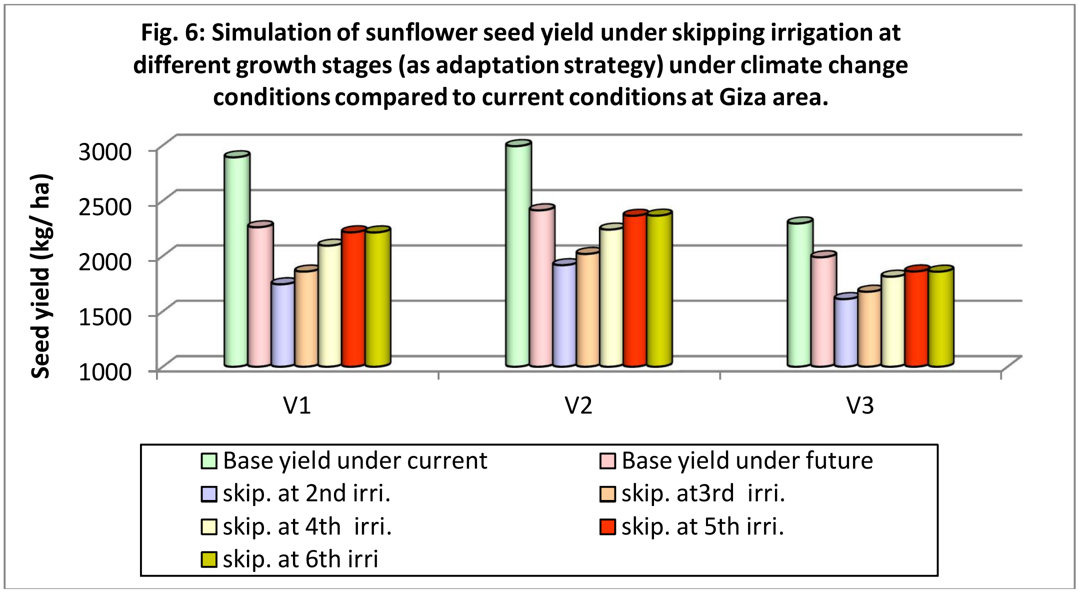



**Adaptation under skipping irrigation at different growth stages**

For Sakha site, skipping irrigation at any stage of plant growth or prolonging the period between successive irrigations under climate change conditions will cause major decreasing in crop productivity as shown in Fig. 5. The highest reduction in sunflower productivity found with skipping at the 2nd irrigation, skipping at this stage resulted in reduced crop productivity by 68, 69 and 64 %, for V1, V2 and V3, respectively. In addition, the less shortage in crop productivity happened when skipping was done at last irrigation (6th irrig.) which caused decreasing in crop productivity by 17, 9 and 7 % for the same respective sunflower genotypes.

For Giza site, results as recorded in Fig. 6 indicate that skipping watering at 2nd irrigation under climate change could reduce crop productivity ranging from 30 to 40 %. Results indicated also that skipping irrigation at the last irrigation (6th irri.) or at 5th watering caused less reduction in crop productivity than the other skipping irrigation treatments. Decreasing percent at these stages registered 23, 21 and 19 % for the respective genotypes of V1, V2 and V3.






**Adaptation studies with crop water productivity (CWP)**

**Adaptation under different sowing dates**

Simulation of CWP under different sowing dates at Sakha and Giza sites as presented in Figs. 7 - 8 illustrate that early sowing date gave the highest CWP in both sites as compared with late sowing date. The superior variety under this character was obtained for V1 at Sakha which superior by 40 and 5 % as compared with V2 and V3, respectively. However, at Giza the superiority in CWP was for V2 which increased by 5 and 28 % as compared with V1 and V3, respectively.

In addition, under excess or deficit irrigation water amounts, results as recorded in Figs. 9 and 10 indicate that CWP was increased by increasing irrigation water amounts (base +10 or 20%) in both sites. The superior varieties were found for V1 and V2 in both sites, respectively.

Regarding the impacts of skipping irrigation at different growth stages on CWP, results as shown in Figs. 11 and 12 indicate that skipping at 2$^{nd}$ irrigation gave the lowest CWP in both locations, while, skipping at last irrigation (6$^{th}$ irri.) or 5$^{th}$ irrigation gave the highest CWP values.

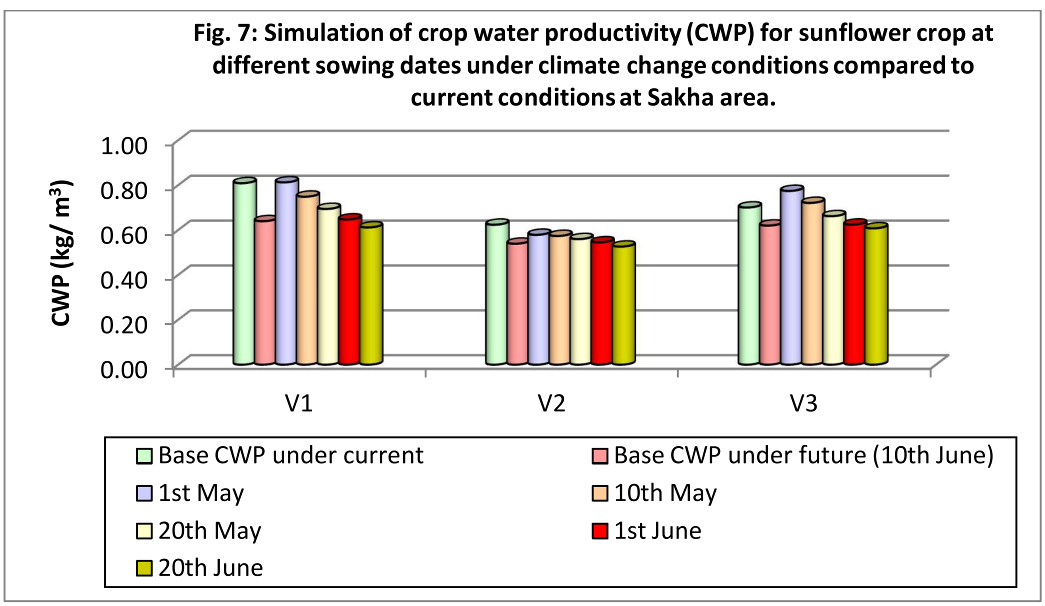


**Fig. 8: Simulation of crop water productivity (CWP) for sunflower crop at different sowing dates under climate change conditions compared to current conditions at Giza area.**

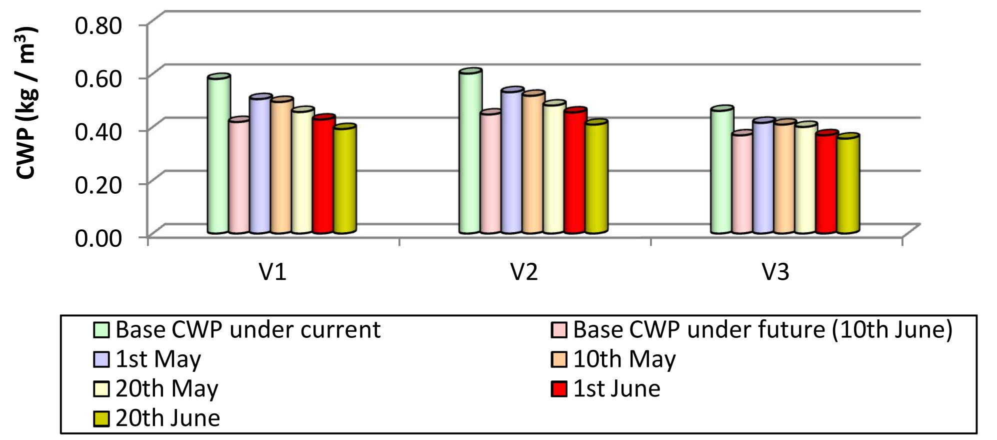



**Fig. 9: Simulation of crop water productivity (CWP) for sunflower crop at different water amounts under climate change conditions compared to current conditions at Sakha area.**

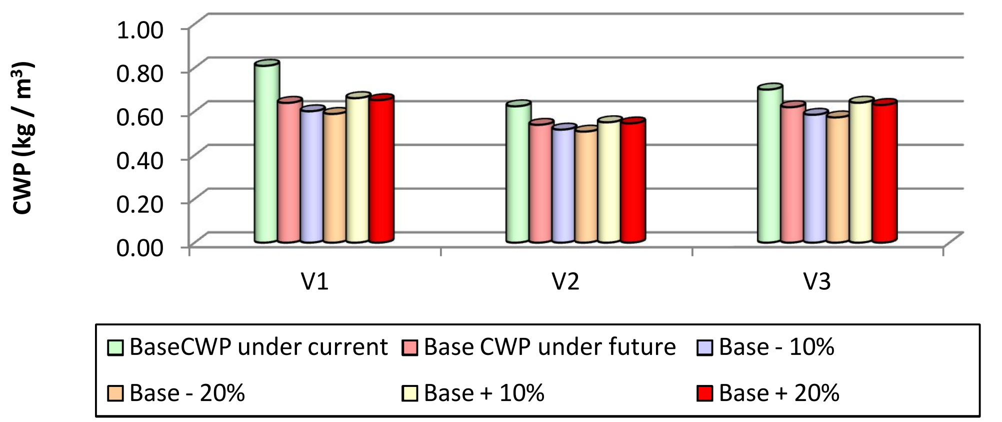



**Fig. 10: Simulation of crop water productivity (CWP) for sunflower crop at different water amounts under climate change conditions compared to current conditions at Giza area.**

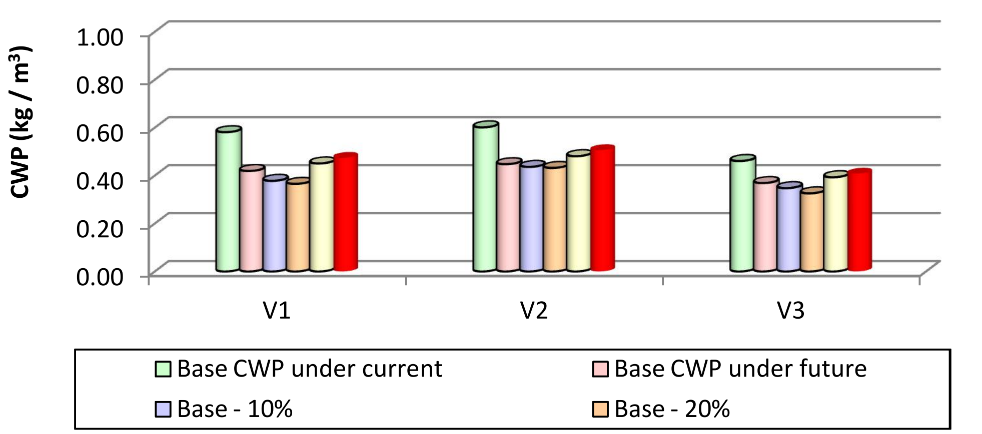


**Fig. 11: Simulation of crop water productivity (CWP) for sunflower crop under skipping irrigation at different growth stages under climate change conditions compared to current conditions at Sakha area.**

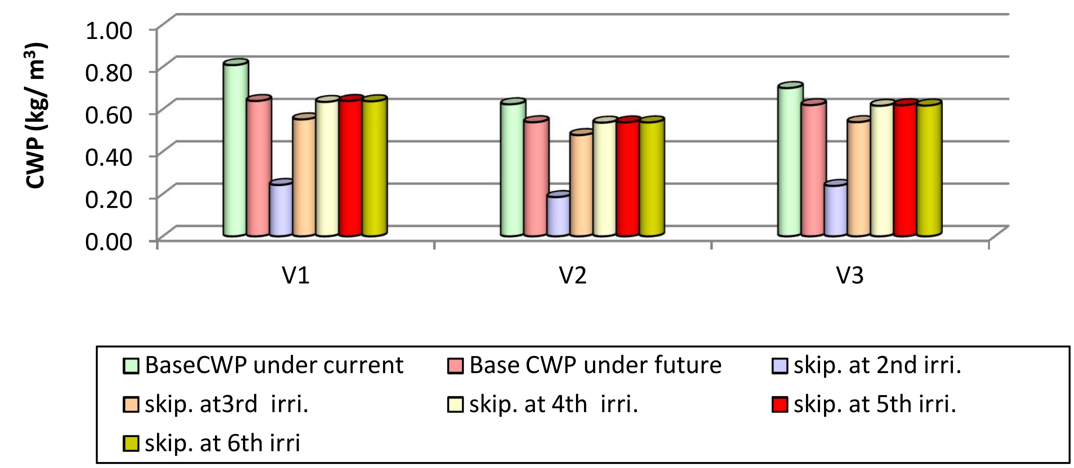
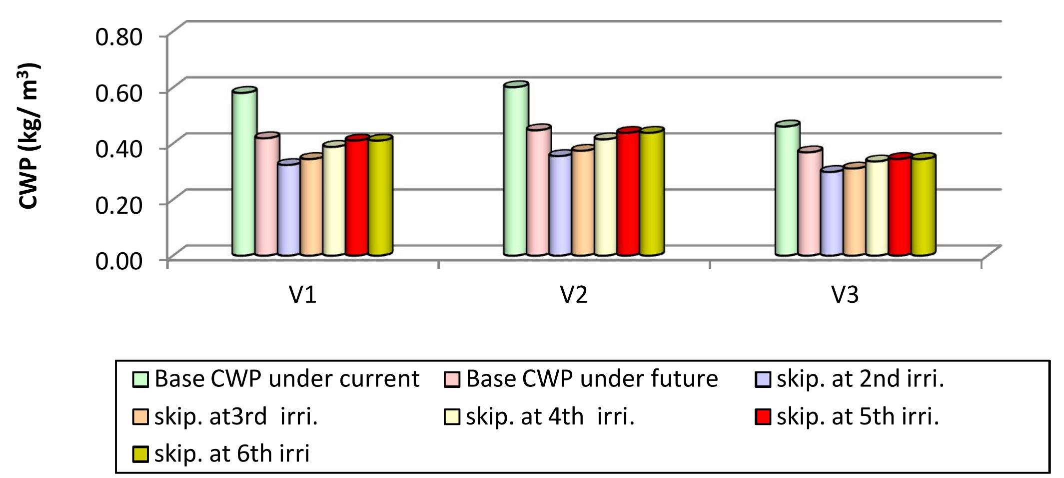



**Fig. 12: Simulation of crop water productivity (CWP) for sunflower crop under skipping irrigation at different growth stages under climate change conditions compared to current conditions at Giza area.**




**Conclusions and recommendations**

In Egypt, climate change will adversely affected the productivity of sunflower crop.

Global Circulation Models (GCMs) and the dynamic crop growth model OILCROP-SUN which imbedded with the computer program **"DSSAT"** was used to assess the potential impact of climate change on sunflower crop.

The results showed that sunflower crop will decrease from 7 to 16 % at Sakha and from 13 to 22 % at Giza. In addition, crop water productivity (CWP) will decrease from 11 to 21 % at Sakha and from 20 to 28 % at Giza.

Choosing the appropriate adaptation strategies can contribute significantly in reducing the negative impact of climate change on the agricultural sector. The results illustrate the promised strategies to identify the suitable adaptation package for sunflower crop in each climatic zone. For example, increasing the amount of irrigation water 10 - 20% can be contributed in minimizing the negative impact of climate change.

Under water shortage that facing Egypt, the results showed that skipping last irrigation has the least negative effect on crop production.

Moreover, the use of the appropriate crop varieties in each climatic zone will have a positive effect on crop productivity under future conditions.

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