



## WHEAT YIELD AND ANTIOXIDANT ENZYMES RELATIONSHIP UNDER DIFFERENT SOIL WATER CONTENT

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**Keywords:** Wheat, Yield, Antioxidant enzymes, Soil moisture content

### ABSTRACT

The objectives of this study were to examine the relationship between wheat yield cultivars (Sakha 93 and Giza 168) and antioxidant enzymes such as catalase (CAT), superoxide dismutase (SOD), peroxidase (POD), ascorbate peroxidase (APX) and phenylalanine ammonia-lyase (PAL) activities under different soil water content i.e. low, moderate and high content by irrigation at 80% ETo (1280m<sup>3</sup>/fed.), by 100% ETo (1600m<sup>3</sup>/fed.) and 120% ETo (1920m<sup>3</sup>/fed.), respectively. Two lysimeter experiments were carried out in two successive seasons i.e. 2006/2007 and 2007/2008 to estimate wheat yield and one experiment in plastic bags carried out of the greenhouse to determine the antioxidant enzymes of 28 days wheat plant under three different soil water content i.e. providing wheat seedlings with aforementioned treatment. Exposing wheat cultivars i.e. Giza 186 or Sakha 93 to water stress by irrigation at 80% ETo (1280 m<sup>3</sup>/fad.) exerted an increase in CAT, SOD, POD, APX and PAL over those irrigated at 100% ETo (1600 m<sup>3</sup>/fad.) or at 120% ETo (1920 m<sup>3</sup>/fad.), but the previous enzyme activities in the tissue of Saka 93 surpassed of that of Giza 168 cultivar. spike weight and weight of 100 grain/plant of Sakha 93 cultivar overcome that of Giza 168 at low soil moisture content (80% ETo), whereas opposite results were obtained at high and moderate water content (120% and 100% ETo) in the first growing season (2006/2007) and spike weight/plant in second growing season (2007/2008). There was a proportional relationship between increasing soil moisture content and grain yield/plant but the

difference between moderate water content 100% ETo (1600 m<sup>3</sup>/fed.) and high water content 120% ETo (1920 m<sup>3</sup>/fed.) was not significant. Providing 28 days wheat plant with low water content, decreased wheat yield/plant and its attributes comparing with moderate water content for the two studied cultivars. The current study indicates that Sakha 93 cultivar was the most tolerant cultivar compared with Giza 168.

### INTRODUCTION

Water deficiency limits wheat productivity and influences its quality. However, there is limited understanding about the relationship between antioxidant basis and wheat productivity under different soil water content which may be contribute towards adaptation to such unavoidable environmental constraints (Blum, 1996 and Saranga *et al* 2002). Among crop plants, wheat (*Triticum aestivum* L.), which often experiences water-limited conditions, is an attractive study system because of the natural genetic variation in traits related to different soil water content (Loggini *et al* 1999). Drought stress invariably leads to oxidative stress in the plant cell due to higher leakage of electrons towards O<sub>2</sub> during photosynthetic and respiratory processes, leading to enhancement in reactive oxygen species (ROS) generation (Asada, 1999). During optimal conditions, the balance between ROS formation and consumption, is tightly controlled by an array of antioxidant enzymes and redox metabolites (Noctor and Foyer, 1998). This includes superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), peroxidases (POX), Phenylalanine ammonialyase (PAL) which provides an efficient protection against lethal ROS in all the sub-cellular organelles of the plant cell

(Moller, 2001). The level of the activities of antioxidant enzymes are generally increased during abiotic stress conditions and correlate with enhanced cellular protection. During different soil water, the plant water relations play a key role in the activation and/or modulation of antioxidant defense mechanism (Menconi *et al* 1995; Srivalli *et al* 2003 and Selote & Chopra, 2004). In addition, exposing plants to drought caused a reduction in grain yield (Pan *et al* 2003), grain weight/spike (Charti and Lales, 1990), number of grains/spike (Wang *et al* 1993), grain weight, grain index (Imam *et al* 1995). The present study was an effort to understand the yield of Sakha 93 and Giza 168 cultivars and antioxidant enzymes relationship under three different soil water content.

#### MATERIALS AND METHODS

Three experiments, two on lysimeter and one on plastic bags were conducted. The first two of the lysimeter in the Experimental farm at Arid Lands Agricultural Graduate Studies and Research Institute- Hadayek Shobra-Kalubia Governorate- Egypt, during 2006/2007 and 2007/2008 growing seasons, whereas the third of plastic bags in the campus of the Experimental Farm of Faculty of Agriculture, Ain Shams University at Hadayek Shobra- Kalubia Governorate- Egypt out of the Green House to study the relationship between two wheat (*Triticum aestivum*. L.) cultivars Sakha 93 and Giza 168 yield and antioxidant enzymes under three different water content i.e. low, moderate and high by irrigation at 80%, 100% and 120% ETo respectively. Every lysimeter experiment concluded the combinations of the two cultivars with the three treatments of water content allocated in a randomized complete block design in three replicates. The total amount of irrigation water was calculated according to Penman-Montieth method (Allen *et al* 1995) for studying the effect of water content on yield of the aforementioned cultivars from fifty plants chosen at random from three replicates at harvest (dead yellow stage). The following data were recorded, tillers No./plant, spike weight/plant (g), grain yield/plant (g), weight of 100 grains (g), straw yield/plant (g), biological yield/plant (g), tillering index % (No. of spikes/No. of tillersx100), crop index% (total grain wt./ straw wt. x100) and Harvest indexes (%) (total grain wt./biological yield x100).

The third experiment included 180 plastic bags which were the combinations of the previous 6 treatments and 30 replicates arranged in a randomized complete block design to study the response of antioxidant enzyme to different soil water content of wheat plants. Every plastic bag was 10 x 10 x15cm size, it was filled with the same sandy soil of the lysimeter then sown with wheat grains. After 28 days from sowing, 60 plants were chosen randomly from every replicate and the following data were measured;

Peroxidase activity (POD) (Hammer-Schmidt *et al* 1982), superoxide dismutase activity (SOD) (Beauchamp and Fridovich 1971), ascorbate peroxidase activity (APX) (Nakano and Asada, 1981), catalase (CAT) activity (Aeby, 1984) and phenylalanine ammonia-lyase activity (PAL) (He *et al* 2001).

#### Statistical analyses

Data of the experiment was subjected to proper statistical analysis of variance according to (Snedecor and Cochran 1980). Duncan test was used to compare between means. Data were statistically analyzed using the analysis of variance adopting a SAS package.

#### RESULTS AND DISCUSSION

##### Yield response to different soil water content

Data reported in Table (1) elucidate the effect of soil water content on number of tillers/plant, spike weight/plant, 100 grain weight, grain yield/plant and biological yield /plant. Wheat plants were provided with low, moderate and high water amount by irrigation at 80% ETo (1280m<sup>3</sup>/fed.), 100% ETo (1600m<sup>3</sup>/fed.) and 120% ETo (1920m<sup>3</sup>/fed.) respectively to Sakha 93 and Giza 168.

Data revealed that low water content significantly increased the number of tillers/plant for Sakha 93 and Giza 168 by 49.3% and 47 % comparing with moderate water content treatment respectively in the first season, whereas the difference was not significant in the second season. In addition the numbers of tillers/plant under low water content for Sakha 93 overcome that of Giza 168.

Table 1. Effect of soil water contents on number of tillers/plant and grain yield/plant (g), biological yield/plant, spike weight/plant, weigh of 100 grain/plant of wheat Sakha 93 and Giza 168 cultivars in two growing seasons (2006/2007 and 2007/2008)

2006-2007 season															
characters															
Cult.	Number of tillers/plant			Grain yield / plant (g)			Biological yield/ plant			Spike weight/ plant (g)			Weight of 100 grains (g)		
	Sakha 93	Giza 168	mean	Sakha 93	Giza 168	mean	Sakha 93	Giza 168	mean	Sakha 93	Giza 168	mean	Sakha 93	Giza 168	mean
80% ETo (1280m <sup>2</sup> /fed.)	5.12a	4.76ab	3.70B	0.64b	0.61b	0.62B	3.95ab	3.11b	3.53A	1.38cb	1.08c	1.23B	3.20ab	2.50b	2.85B
100% ETo (1600m <sup>2</sup> /fed.)	3.43ab	3.24b	3.34B	1.03ab	1.14ab	1.08A	3.73ab	3.64ab	3.69A	1.82ab	1.80abc	1.81A	3.40a	3.22ab	3.31AB
120% ETo (1920m <sup>2</sup> /fed.)	3.92ab	3.49ab	4.49A	1.30a	1.30a	1.30A	3.90ab	4.74a	4.32A	1.46abc	2.15a	1.81A	3.24ab	3.77a	3.57A
mean	4.16A	3.83A		0.99A	1.02A		3.86A	3.83A		1.55A	1.68A		3.28A	3.16A	
2007-2008 season															
80% ETo (1280m <sup>2</sup> /fed.)	2.80a	2.68a	2.74A	0.59b	0.58b	0.59B	5.32c	5.65bc	5.49C	1.39bc	1.16c	1.28B	3.10a	2.91a	3.01A
100% ETo (1600m <sup>2</sup> /fed.)	2.73a	3.15a	2.94A	1.23ab	1.60ab	1.42A	6.59abc	7.19ab	6.89B	1.93abc	2.26abc	2.10A	3.44a	3.29a	3.37A
120% ETo (1920m <sup>2</sup> /fed.)	2.64a	3.00a	2.82A	1.98a	1.54ab	1.76A	7.57a	8.03a	7.80A	2.93a	2.51ab	2.72A	3.24a	3.77a	3.51A
mean	2.72A	2.94A		1.27A	1.24A		6.49A	6.96A		2.08A	1.98A		3.26A	3.32A	

Data presented as means of 3 replicates. Different letters refer to significant differences ( $P \leq 0.05$ )

The pattern change of spike weight/plant as well as 100 grain weight by exposing to low water content of the two cultivars was similar to those of number of tillers/plant.

Regarding grain yield/plant, decreasing was noticed in it by increasing water amount from 1280m<sup>3</sup>/fed. to 1600m<sup>3</sup>/fed. under the current investigation but the rate of Sakha 93 reduction was less than Giza 168 i.e. 37.9% and 46.5% respectively. In the same time, there was not significant increase in grain yield/plant for Sakha 93 over Giza 168, indicating that harmful effect of exposing Giza 168 to soil moisture stress was more pronounced than Sakha 93. Consequently, Sakha 93 was more tolerant to the reduction of soil moisture than Giza 168 cultivar.

Data reported in Table (2) indicate the effect of soil water content on crop, tillering and harvest indexes. Concerning crop index, increasing soil moisture content significantly increased by irrigation at 80% ETo (1280m<sup>3</sup>/fed.) to 100% ETo (1600m<sup>3</sup>/fed.) and decreased at 120% of ETo (1920m<sup>3</sup>/fed.) for Sakha 93 Giza 168 cultivars in the two growing seasons except Sakha 93 in the second season which did not differ significantly. These results indicate that the increase in the grain weight overcome that of straw weight reaching its maximum at 100% ETo (1600m<sup>3</sup>/fed.) for both two cultivars. In the first growing season, the reduction of Sakha 93 crop index by irrigation 80% ETo (1280m<sup>3</sup>/fed.) (20%) exceeded these of Giza 168 (18.66) comparing to 100% ETo (1600m<sup>3</sup>/fed.) indicated that the rate of increase in grains of straw weight of Sakha 93 was more pronounced than Giza 168 compared with their straw weight. In the second growing season, the difference was most significant.

Comparing harvest index of Sakha 93 cultivar to Giza 168 cultivar under moisture content of the soil, revealed that they were less in Sakha 93 cultivar than that of Giza 168 in the first season.

The number of spike to the number of tillers % in the first growing season tended to increase significantly by increasing soil moisture content up to 100% ETo (1600m<sup>3</sup>/fed.) in the first season, on the contrary, these increases were not significant in the second growing season. These results were similar for both cultivars. It could be concluded that the grain yield to the aboveground biological yield

increased by increasing soil moisture content from 80% ETo (1280m<sup>3</sup>/fed.) to 100% ETo (1600m<sup>3</sup>/fed.) for Sakha 93 and Giza 168 cultivars but this percentage was more for the former cultivar than the latter one indicated that the dry matter allocated wheat grain was greater in Sakha 93 than in Giza 168. It could be noticed that Giza 168 cultivar was more sensitive to lack of water than Sakha 93 cultivar, Table (2). Singh and Bhan (1998) reported that the increase in wheat yield attributes was due to more water supplies, which may increase cell turgidity, opening of stomata and finally increasing the partitioning of photosynthesis to sink. Water deficit induced oxidative stress which causes inhabitation of photosynthesis activity due to imbalance between light capture and its utilization (Foyer 2004). Salram and Saxena (2000) found that a marked reduction in chlorophyll content under stress for all tested wheat cultivars, whereas some genotypes were able to maintain the reduction of its content.

#### Antioxidant enzymes response to different soil water content

The effect of soil water content on antioxidant enzymes of 28 days wheat plant cultivars are reported in Table (3) and Figures (1), (2), (3), (4) and (5), respectively.

Data reported in Fig. (5) indicate that exposing wheat cultivars i.e. Giza 168 or Sakha 93 to different water content i.e. low amount by irrigation at 80% ETo (1280 m<sup>3</sup>/fad.) exerted an increase in superoxide dismutase over those moderate content by irrigation at 100% ETo (1600 m<sup>3</sup>/fad.) or high amount by irrigation at 120% ETo (1920 m<sup>3</sup>/fad.). These results were similar for both cultivars. The percentage increase for Sakha 93 cultivars under low content (1280 m<sup>3</sup>/fad.) was 284.2% and 19.6% comparing to moderate and high amount, whereas for Giza 168 cultivar was 82.7% and 194.4% for the same respective treatments. Alscher *et al* (2002) found that reactive oxygen species (ROS) are produced in both unstressed and stressed cells, they added that plants have developed defense systems against ROS, involving both limiting the formation of ROS as well as instituting its removal.

Maximum values of ascorbate Peroxidase Fig. (1), catalase Fig. (2), Phenylalanine ammonia-lyase Fig. (3), peroxidase Fig. (4), superoxide dismutase Fig. (5), were found in the leaf tissues of 28 days

Table 2. Effect of soil water contents on crop, tillering and harvest indexes of wheat Sakha 93 and Giza 168 cultivars in two growing seasons (2006/2007 and 2007/2008)

2006-2007 season									
Characters									
Cult.	Crop index %			Tillering index %			Harvest index %		
	Sakha 93	Giza 168	mean	Sakha 93	Giza 168	mean	Sakha 93	Giza 168	mean
Treat.									
80% Eto (1280m <sup>3</sup> /fed.)	17.80c	22.49bc	20.14B	81.73b	91.66ab	86.69B	14.88b	18.21ab	16.55B
100% Eto (1600m <sup>3</sup> /fed.)	37.80ab	41.15a	39.47A	95.51a	93.60a	94.55A	27.23a	29.10a	28.17A
120% Eto (1920m <sup>3</sup> /fed.)	24.20abc	26.14abc	25.17B	93.19a	91.12ab	92.16AB	19.41ab	18.73ab	19.07B
mean	26.60A	29.92A		90.14A	92.12A		20.51A	22.01A	
2007-2008 season									
80% Eto (1280m <sup>3</sup> /fed.)	12.96b	12.86b	12.77B	88.80a	88.53a	88.67A	11.13b	11.20b	11.16B
100% Eto (1600m <sup>3</sup> /fed.)	23.64ab	30.02ab	26.83AB	80.35a	79.47a	80.16A	18.67ab	21.78ab	20.23A
120% Eto (1920m <sup>3</sup> /fed.)	41.21a	25.50ab	33.36A	88.13a	72.18a	79.92A	28.87a	19.93ab	24.40A
mean	25.85A	22.79A		85.77A	80.06A		19.56A	17.64A	

Data presented as means of 3 replicates. Different letters refer to significant differences (P≤ 0.05)

Table 3. Effect of soil water content on anti-oxidative enzymes of 28 days old wheat plant cultivars

Soil moisture content	Cultivars	Superoxide dismutase (SOD) (IU.mg <sup>-1</sup> protein)	Ascorbate peroxidase (APX) (IU. mg <sup>-1</sup> protein)	Peroxidase activity (POD) (IU. mg <sup>-1</sup> protein)	Catalase (CAT) (IU. mg <sup>-1</sup> protein)	Phenylalanine ammonia-lyase (PAL) ( $\mu$ mol. h <sup>-1</sup> mg <sup>-1</sup> protein)
80% ETo (1280m <sup>3</sup> /fed.)	Giza 168	53 $\pm$ 1.2c	1755 $\pm$ 60.1b	1456 $\pm$ 58d	9774 $\pm$ 600.34c	8.13 $\pm$ 0.005b
	Sakha 93	73 $\pm$ 1.3a	1073 $\pm$ 60.3a	5692 $\pm$ 60a	14834 $\pm$ 600.58a	9.32 $\pm$ 0.008a
100%ETo (1600m <sup>3</sup> /fed)	Giza 168	29 $\pm$ 1.2d	1030 $\pm$ 59.9c	1191 $\pm$ 41e	8555 $\pm$ 600.25d	6.09 $\pm$ 0.005c
	Sakha 93	19 $\pm$ 1.3e	818 $\pm$ 60.3d	1785 $\pm$ 60c	6478 $\pm$ 600.36e	3.47 $\pm$ 0.008e
120%ETo (1920m <sup>3</sup> /fed.)	Giza 168	18 $\pm$ 0.96e	683 $\pm$ 60.7e	1452 $\pm$ 60d	7226 $\pm$ 600e	4.47 $\pm$ 0.006d
	Sakha 93	61 $\pm$ 1.53b	1764 $\pm$ 60.5b	4165 $\pm$ 40b	11165 $\pm$ 600.54b	5.68 $\pm$ 0.003c

Data presented as means of 3 samples. Different letters refer to significant differences (P $\leq$  0.05)

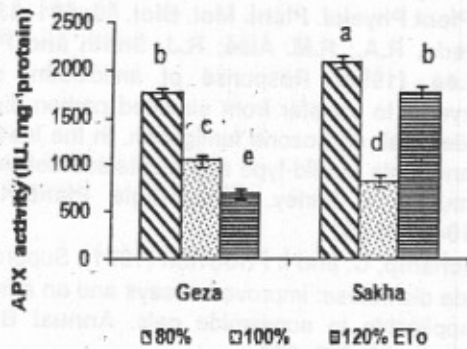


Fig. 1. Ascorbate Peroxidase

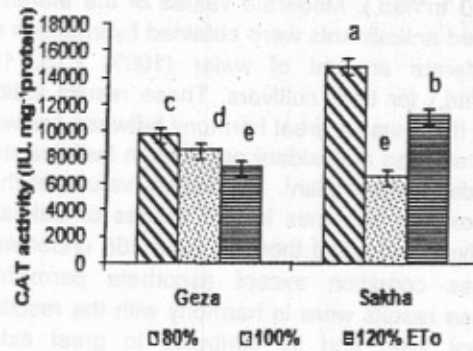


Fig. 2. Catalase

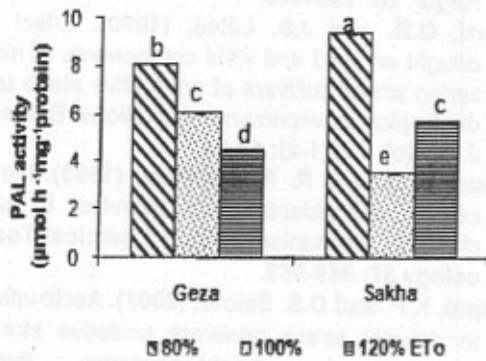


Fig. 3. Phenylalanine ammonia-lyase

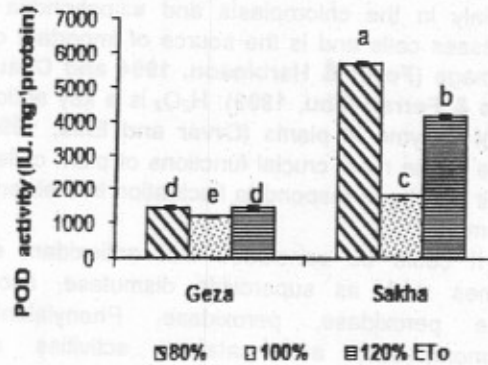


Fig. 4. Peroxidase activity

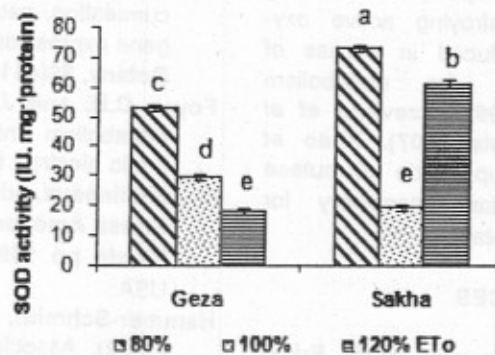


Fig. 5. Superoxide dismutase

Effects of different soil water content on activity of antioxidant enzymes of two 28 days wheat cultivars (Giza 168 and Sakha 93). Means of 3 samples  $\pm$  SE. Bars with different letters are significant different ( $P < 0.05$ )

wheat plant cultivars i.e. Sakha 93 and Giza 168 by irrigation with low amount of water (80% ETo, 1280 m<sup>3</sup>/fad.). Moderate values of the aforementioned antioxidants were obtained by irrigation with moderate amount of water (100% ETo, 1600 m<sup>3</sup>/fad.) for both cultivars. These results indicate that there was a great harmony between soil water content and antioxidant activities in leaf tissues of 28 days wheat plant. In addition, values of these antioxidant enzymes in leaf tissues of Sakha 93 cultivar surpassed those of Giza 168 under water stress condition except ascorbate peroxidase. These results were in harmony with the results of wheat yield and its attributes to great extent. (Foyer 2004 and Pel et al 2000) reported that water deficit is known to generate active oxygen species (AOS). Among these, H<sub>2</sub>O<sub>2</sub> is produced mainly in the chloroplasts and mitochondria of stresses cells and is the source of important cell damage (Foyer & Harbinson, 1994 and Chaudiere & Ferrari-Illou, 1999). H<sub>2</sub>O<sub>2</sub> is a key antioxidant enzyme in plants (Orvar and Eills, 1997). One of the most crucial functions of plant cells is their activity to respond to fluctuation in their environment.

It could be concluded that antioxidant enzymes such as superoxide dismutase, ascorbate peroxidase, peroxidase, Phenylalanine ammoniolyase, and catalase activities are acted as antioxidant defense enzymes to minimize the concentration of superoxidases and hydrogen peroxide under stress conditions. Their activities are important in limiting oxidative damage and destroying active oxygen species that are produced in excess of those normally required for metabolism (Hertwig & Felerabend, 1992; Azevedo et al 1998 and Chopra & Selote 2007). Shao et al (2007) reported that superoxide dismutase is component of antioxidant machinery for drought resistance in higher plant.

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## العلاقة بين محصول القمح والانزيمات المضادة للأكسده تحت مستويات مختلفه من الماء الأرضى

[٢٤]

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### يمكن تلخيص نتائج التجربه كالتالى

### الموجز

١- ادى تعرض نبات القمح الى الكميته القليله من الماء الى انخفاض فى المحصول وبعض مكوناته فى كل من الصنفين.  
٢- وجدت هناك علاقه طرديه بين زياده محتوى الماء الارضى ومحصول الحبوب / نبات ولكن لم يظهر اى فرق معنوى بين كميات الرى المعتدله والعالیه لكل من الصنفين.  
٣- ادى تعرض شتلات نبات القمح الى الكميته القليله من الماء الى زياده معنويه فى نشاط انزيمات البيرواكسيديز والسوبراكسيد ديسميوتيز والاسكوريات بيرواكسيديز والكتاليز والفينيل الانين امونيليز بالمقارنه مع شتلات نبات القمح المرويه بكميه معتدله ومرتفعه من الماء فى كل من الصنفين مع ملاحظه ان نشاط الانزيمات المضاد للاكسده زادت فى انسجه نبات الصنف سخا ٩٣ مقارنة مع الصنف جيزه ١٦٨، وبذلك يمكن القول ان الصنف سخا ٩٣ قد تفوق على نظيره جيزه ١٦٨ تحت ظروف الارض الرملية فى هذه الدراسه.

تهدف هذه الدراسه الى اختبار العلاقه بين محصول صنفين من القمح (سخا ٩٣ وجيزه ١٦٨) ونشاط انزيمات مضادات الاكسده (نشاط البيرواكسيديز والسوبراكسيد ديسميوتيز والاسكوريات بيرواكسيديز والكتاليز والفينيل الانين امونيليز) تحت معاملات مختلفه من محتوى الماء الارضى منخفضه بالررى عند ٨٠% ومتوسطه بالررى عند ١٠٠% ومرتفعه بالررى عند ١٢٠% من البخر نتج العيارى . تم اجراء مجموعتان من التجارب الحقلية اثناء موسمى الزراعه ٢٠٠٦/٢٠٠٧ و ٢٠٠٧/٢٠٠٨ بهدف تقدير محصول القمح بينما اجريت التجربه الثانيه فى اكياس بلاستيكيه خارج الصوبه بهدف تقدير نشاط انزيمات مضادات الاكسده فى شتلات نبات القمح عمر ٢٨ يوم تحت نفس المعاملات سابقه الذكر التى تمثل الكميات سابقه الذكر (منخفضه ١٢٨٠ م<sup>٣</sup>/ فدان ومتوسطه ١٦٠٠ م<sup>٣</sup>/ فدان ومرتفعه ١٩٢٠ م<sup>٣</sup>/ فدان) من المياه.