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EFFECT OF WATER STRESS ON GROWTH, YIELD AND WATER RELATION PARAMETERS OF FIVE WHEAT CULTIVARS

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ABSTRACT

Five Egyptian wheat cultivars Giza 157, Giza 160, Sakha 8, Sakha 61 and Stork S were used in the present study. Drought stress treatments were applied by prolonging the interval of water supply. Plants were watered every 2, 3, 5 or 6 weeks. Growth of all cultivars, expressed as fresh and dry weights as well as leaf area per plant was reduced as the interval of water supply was prolonged. The cultivar Giza 160 exhibited significantly higher rate of growth, whereas Sakha 8 demonstrated the least vegetative growth among the examined cultivars. Giza 160 produced significantly higher grain yield under the highest level of drought stress used. Measurements of the water relations parameters: transpiration rate, stomatal apreture size and relative water content of the leaf (RWC) showed that the same cultivar and Giza 157 maintained, to some extent, lower value of these parameters. The two cultivars Sakha 8 and Stork S produced higher grain yield and higher relative

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Key words: Drought stress - Growth - Yield - Leaf relative water content - Water relations - Wheat.

water content (RWC) under 2 weeks interval of water supply, but were the least able cultivars to cope with drought stress. In addition to the comparison made between the five cultivars under the applied drought treatments the value of the examined water relations parameters, particularly leaf RWC as criteria of drought stress resistance is discussed.

INTRODUCTION

Reduction in growth and yield of several crop plants under conditions of drought stress is well reported, e.g. in corn (Denmead and Shaw 1960), Sorghum (Whiteman and Wilson 1965; Garrity *et al*. 1983), soybean (Itoh and Kumwa, 1986) and wheat (Abdel Rahman *et al*. 1972: Soliman 1984). In wheat considerable variations in drought stress resistance among different cultivars have been observed (Soliman 1984; Johnson *et al*. 1984). Measuring yield in this important crop plant, under well watered and water-stressed conditions, is considered the best and the ultimate indicator of drought resistance (Ritchie *et al*. 1990). However, a physiologically based drought resistance parameter could aid the breeders to select the potential parental lines in wheat breeding programs (Blum 1985; Winter *et al*. 1988). Schonfeld *et al*. (1988) studied water relations as drought resistance indicators in the two American wheat cultivars TAM W-101 and Sturdy. They found that leaf relative water content (RWC) of TAM W-101 was significantly higher than that of Sturdy. This was associated with the increasing drought resistance ability exhibited by the former cultivar based on grain yield. The results of these authors are supported by the work of Ackerson (1983) on corn and agree with view of Johnson and Brown (1977) among others that turger maintainance under declining water potential may be used as a measure for evaluating drought resistance.

Stomatal adjustment and transpiration are closely associated water relations factors that determine the relative ability of plants to cope with drought conditions (Kaufmann 1981). Excessive transpiration leads to drop in the water content of leaf tissues and in turn to a reduction in the activity of metabolic processes. The value of stomatal regulation of water loss under drought stress, on the other hand, resides in maintaining gas exchange at times of low leaf water potential (Jones and Rawson 1979). However, there is substantial variability among crop plants in stomatal adjustment (Ludlow 1980). Turner (1979) pointed out that plants showing greater capacity stomatal adjustment to drought are those which exhibit dehydration tolerance mechanisms.

In Egypt, where rainfall is rare and water from the Nile is limited, agricultural development is humbered by water shortag Wheat breeding programmes have produced a number of Egyptian cultivars some of which are claimed to be drought resistant. The study of water economy of these cultivars is considered of prime importance. In the present study growth, yield and some water relations parameters of five Egyptian cultivars of wheat have been examined under well watered and drought stress treatments. The objectives of this study is to find out the cultivars best fitted to drought stress and the parameters which reflect the ability of these cultivars to withstand drought conditions.

MATERIALS AND METHODS

Grains of similar size and age of five Egyptian cultivars Giza 157, Giza 160, Sakha 8, Sakha 61 and Stork S were germinated on several layers of wet filter paper in trays. Two weeks old seedlings of uniform size were transplanted in pots of 40 cm diameter and 45 cm height with drainage outlets. These pots were filled with a soil composed of 71.6% sand, 10.4% silt and 18% clay. The soil had a field capacity (FC) of 9.7% and a permanent wilting percentage (PWP) of 5.3%. Seedlings were watered weekly with 7 liters of a modified Johnson nutrient solution (Downs and Hellmers 1975) and grown in a plastic green house in the Faculty of Science, Cairo University. The experiment was carried out over a period of 4 months, from November 1986 to February 1987. Air temperature and relative humidity were continuously recorded during the expeiment. Minimum temperature ranged between 9.3 °C in November 1986 to 13.1 °C in February 1987, while maximum temperature ranged between 14.1 °C in November 1986 to 23.5 °C

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in February 1987. Relative humidity daily mean ranged from 65.4% in November 1986 to 59.6% in February 1987. After one month of growth, 4 water regime treatments were applied by increasing the interval of water supply to 2,3,5, and 6 weeks. Soil water content was always maintained above the PWP in the 2, 3 and 5 weeks water supply intervals, whereas 6 weeks interval treatment, the water content was at the PWP of the soil.

Vegetative growth of plants was measured, including shoot fresh weight, shoot dry weight and total leaf area per plant, for 1.5, 2 and 3 months old plants. Measurements of the 3 months old plants are given here to reflect the plant growth and water-status at the end of the experiment during the plant fruiting stage. Transpiration rate, stomatal apreture size and RWC were measured within the 3rd month of plant growth.

Transpiration rate was determined by the detached leaf method where the weight loss of leaf after detachment in a certain period of time expresses the amount of transpirated water during this period. Stomatal apreture size was calculate by a modified infiltration method (Dale, 1958). A daily march of transpiration rate and stomatal apreture size was made at 8 am, 10 am, 12 noon, 2 pm and 4 pm before and after water supply. The mean daily transpiration rate and mean stomatal apreture size before water supply are given here as an indication for water status of the plants under the applied drought stress.

For the determination of RWC, sections of fully expanded leaves were weighed to obtain their fresh weights (FW) then floated in distilled water for 12 hours. After this hydration period, turged leaf sections were rapidly blotted and weighed to obtain the turged weight (TW). Leaf slices were then dried at 60 °C until a constant dry weight (DW) was obtained. Leaf RWC was calculated by the following formula:

$$RWC\% = (FW-DW / TW-DW) \times 100$$ (Barrs 1968).

After ripening yield was estimated as the mean weight of grains per plant from at least 25 plants for each treatment.

Means and standard errors of all measurements were calculated from 4 replicates for each measurement. Statistical analysis of the data was made using the " t " -test to evaluate the differences between cultivars in the examined parameters under the applied drought stress treatments. LSD values were significant at 0.05 level, and most of them were significant at 0.01 level.

RESULTS AND DISCUSSION

Measurements of vegetative growth expressed as shoot fresh weight and shoot dry weight (g./ plant) of the five wheat cultivars at the different water supply treatments are illustrated in Figs. 1 and 2 respectively. These two parameters were higher for plants of the five cultivars watered every 2 weeks and gradually decreased as the period of water supply was prolonged. The cultivar Sakha 8 showed the highest vegetative growth under the two weeks water supply interval. However as the water supply period was prolonged to 5 and 6 weeks the cultivar Giza 160 exhibited significantly higher rate of growth, whereas Sakha 8 demonstrated the least vegetative growth among the five cultivars of this study. Thus Giza 160 is the most able to grow under the treatments of drought stress imposed in the present investigation, whereas Sakha 8 is the least able to cope with water shortage with regard to biomass production. Measurements of total leaf area (cm^2/ plant) of the 5 cultivars under the variuos water supply treatments are shown in Fig. 3. In the 2 weeks interval the largest leaf area / plant was recorded for the cultivar Stork S. Under the 6 weeks interval (the highest applied level of drought stress) the highest value of leaf area / plant was attained by the cultivar Giza 160.

The reduction in vegetative growth expressed as biomass production and leaf area / plant under drought conditions seems to be common among mesophytic crop plants and has been reported in several other crops e.g. Sorghum (Whiteman and Wilson 1985), sunflower (Takami _et al_. 1982), _Phaseolus vulgaris_ cultivars (Peterson 1986), cotton (Patterson 1988; Soliman _et al_. 1990) and maize and wheat (Soliman _et al_. 1990). Measurements of leaf area of the 5 cultivars used in the present study support the data of fresh and dry weight measurements in illustrating that the cultivar Giza 160 is the best in attaining the highest vegetative growth rate under conditions of water shortage. The cultivar Sakha 8, on the other hand, produced the least vegetative biomass, while Stork S is the cultivar which produced the least leaf area / plant among the 5 examined cultivars. Poor vegetative growth expressed as dry weight was also recorded in this cultivar by Soliman (1984).

Grain yield of the 5 cultivars showed a progressive decrease with increased drought stress level resulting from prolonged water supply intervals (Fig. 4). It reflects the high sensitivity of the two cultivars Sakha 8 and Stork S to the applied drought stress when compared with the other three cultivars. Giza 157 and Giza 160 were the lowest grain weight yielding cultivars at the 2 weeks water supply period. However, under severe drought conditions; (5 and 6 weeks water intervals), grain weight productivity of the cultivar Giza 160 was highly significant greater than the other four cultivars. On yield basis, which is the best parameter of drought resistance Giza 160 is the most adaptable to drought stress of the five cultivars included in the present investigation. It is fully compatible with its relatively higher biomass production and greater leaf area when compared with the other four cultivars as the water supply interval was prolonged.

The mean daily transpiration rate and the mean stomatal apreture size for the five cultivars under the applied water stress treatments are shown in Figs.5 and 6 respectively. These figures illustrate substantial variations in these two parameters among the examined cultivars. It is evident, however that the two cultivars Giza 157 and Giza 160 exhibited lower transpiration rate and smaller stomatal apreture size under the 4 applied water supply treatments. As the water supply interval was prolonged to 5 and 6 weeks the cultivars Giza 160 clearly showed the lowest value of both transpiration rate and stomatal apreture size. The daily march of these two parameters showed a fall in transpiration rate and stomatal apreture size at 12 noon early before the attainment of the maxima of climatic stress in the afternoon between 3 and 4 pm where air temperature was above 23°C. This phenomenon is common among xeromorphic plants and may point out to a xeric tendence of the examined cultivars.

The correlation between the reduction of transpiration rate and closure of stomata under drought stress recorded here resemble results of previous studies on various plants (Ludlow 1980). This correlation indicates the stomatal regulation of water flow through the soil - plant atmosphere. Although the actual flow is influenced by other atmospheric factors and by soil water status (Kramer 1983), the correlation between stomatal adjustment and drought tolerance appear to be a valid criterion (Turner 1979; Ludlow 1980). Such phenomenon is clearly observed in the cultivar Giza 160 in the present investigation.

Measurements of leaf RWC of the five cultivars under the different water treatments are illustrated in Fig. 7. A small reduction of RWC was recorded in the five cultivars as the water supply interval was prolonged from 2 to 3 weeks. Higher leaf RWC values were scored in the two cultivars Sakha 8 and Stork S at these 2 intervals. As the water supply period was prolonged to 5 and 6 weeks a drastic reduction in leaf RWC was recorded. Under the 5 weeks interval significant high RWC was measured in the two Giza cultivars 157 and 160. Under the highest level of drought stress (6 weeks water supply interval) the later cultivar attained the highest value of leaf RWC. The ability of the cultivar Giza 160 to maintain relatively higher leaf RWC as well as its ability to lower transpiration rate and stomatal adjustment under increased drought stress indicate that this cultivar is the most likely among the examined five Egyptian cultivars to tolerate conditions of drought imposed by shortage of water supply.

Leaf RWC has been proposed as an indicator of water status in leaf tissues because it reflects the state of water supply and transpiration rate (Sinclair and Ludlow 1985). Two recent reports on two American wheat genotypes published by Schonfeld et al. (1988) and Ritchie et al. (1990) indicated that leaf RWC may be a good parameter of drought resistance. The results of the present investigation confirms the importance of leaf RWC as a measure of drought resistance criteria. Evidence substantiating the value of leaf RWC in this regard is its reflection of water balance between water supply and transpiration rate which is closely associated with stomatal opening.

The data obtained from the three water relations parameters used in the present study are in agreement with grain yield which is the ultimate and undisputed indicator of drought resistance (Ritchie et al. 1990). In addition to the data obtained about the response of the five examined cultivars the results support the view that leaf RWC is a likely screening parameter of drought resistance criteria in wheat. This view is supported by the findings of Schonfeld et al. (1988) that this character is genetically controlled by multiple genes. The use of some other water relations parameters which are simple and rapid such as those used here, in addition to leaf RWC make the selction criteria more reliable and valid.

In conclusion the results obtained from the present study reveal that :

- The two wheat cultivars Giza 160 and, to some extend, Giza 157 are the most tolerant to drought stress imposed by prolonging water supply interval. This is evident from the measurements of water relation parameters. The cultivar Giza 160 therefore may be recommended to be cultivated in dry areas where water is limited.
- The two cultivars Sakha 8 and Stork S produced higher yield under more frequent water supply and may be more suitable for cultivation in areas where water is available.
- The study substantiate the value of RWC as an indicator of plant-water status as has been recently proposed and confirms its importance as a measure of drought stress criteria.

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Fig. 1: Effect of the applied drought stress treatments on the vegetative fresh weight of the five examined wheat cultivars. Significant at $P \leq 0.01$ level.

Fig. 2: Effect of the applied drought stress treatments on the vegetative dry weight of the five examined wheat cultivars. Significant at $P \leq 0.05$ level.

Fig. 3: Effect of the applied drought stress treaments on leaf area/plant of the five examined wheat cultivars. Significant at $P \leq 0.01$ level.

Fig. 4: Effect of the applied drought stress treaments on yield/plant of the five examined wheat cultivars. Significant at $P \leq 0.01$ level.

Fig. 5: Changes in transpiration rate of the five examined wheat cultivars under the applied drought stress treatments. Significant at $P \leq 0.05$ level.

Fig. 6: Changes stomatal aperture size of the five examined wheat cultivars under the applied drought stress treatments. Significant at $P \leq 0.01$ level.

Fig. 7: Changes in leaf RWC of the five examined wheat cultivars under the applied drought stress treatments. Significant at $P \leq 0.01$ level.

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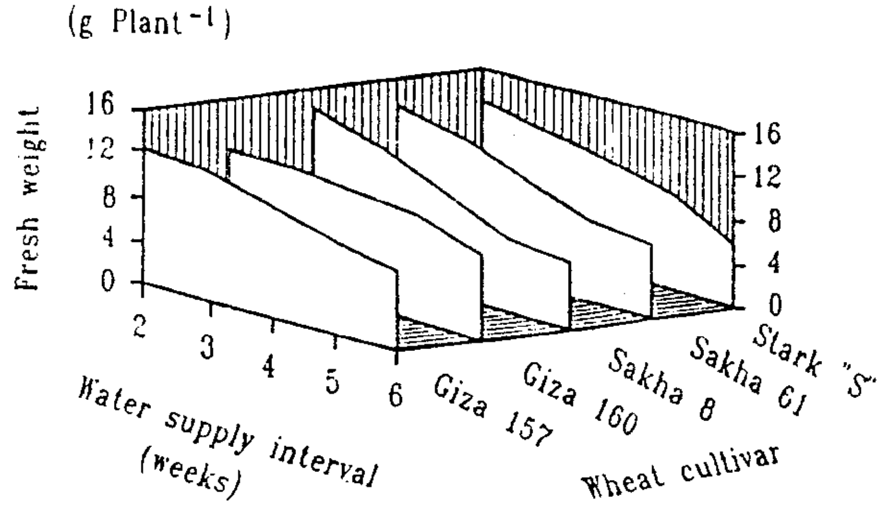

Fig. 1

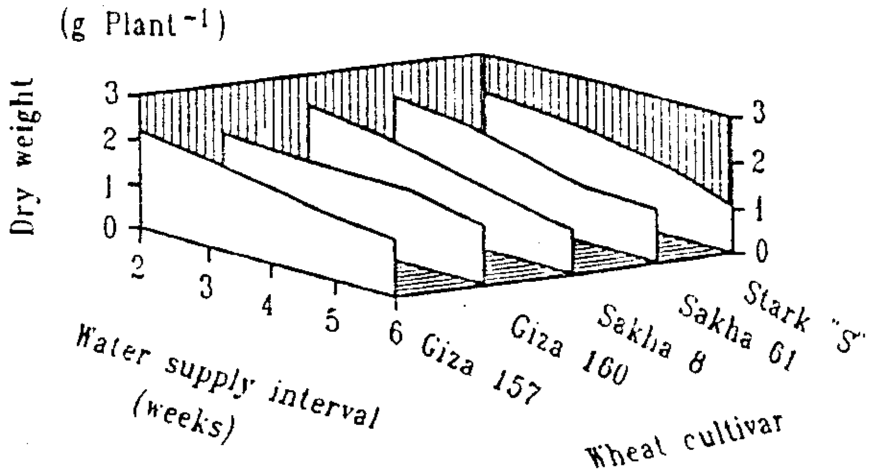

Fig. 2

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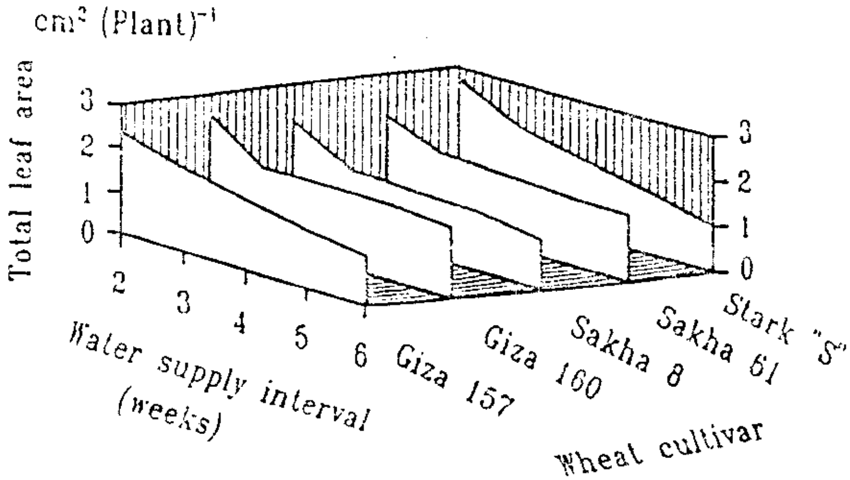

Fig. 3

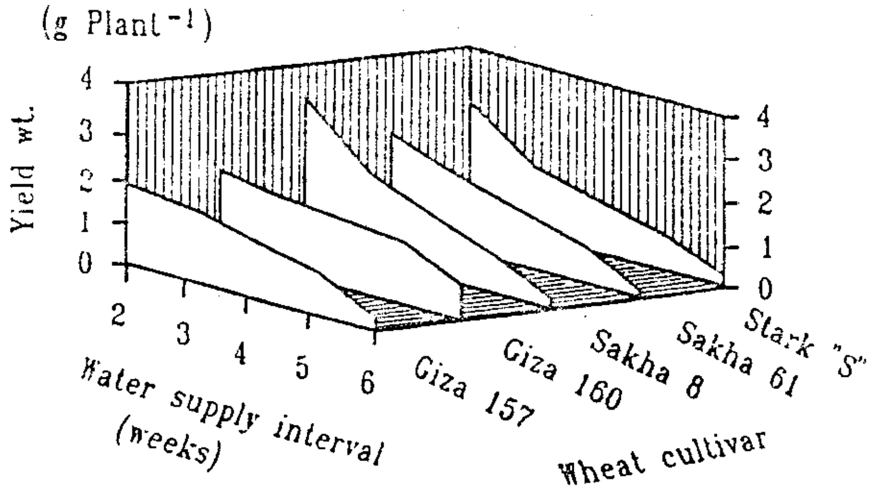

Fig. 4

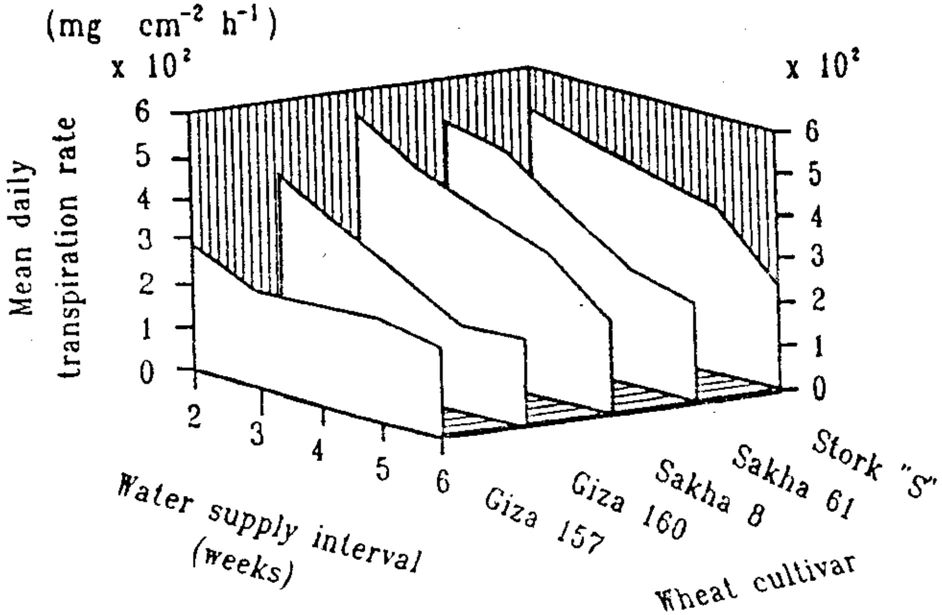
(mg cm-2 h-1)
x 10²
x 10²
Mean daily transpiration rate
0
1
2
3
4
5
6
2
3
4
5
6
Water supply interval (weeks)
Giza 157
Giza 160
Sakha 8
Sakha 61
Stork "S"
Wheat cultivar

Fig. 5

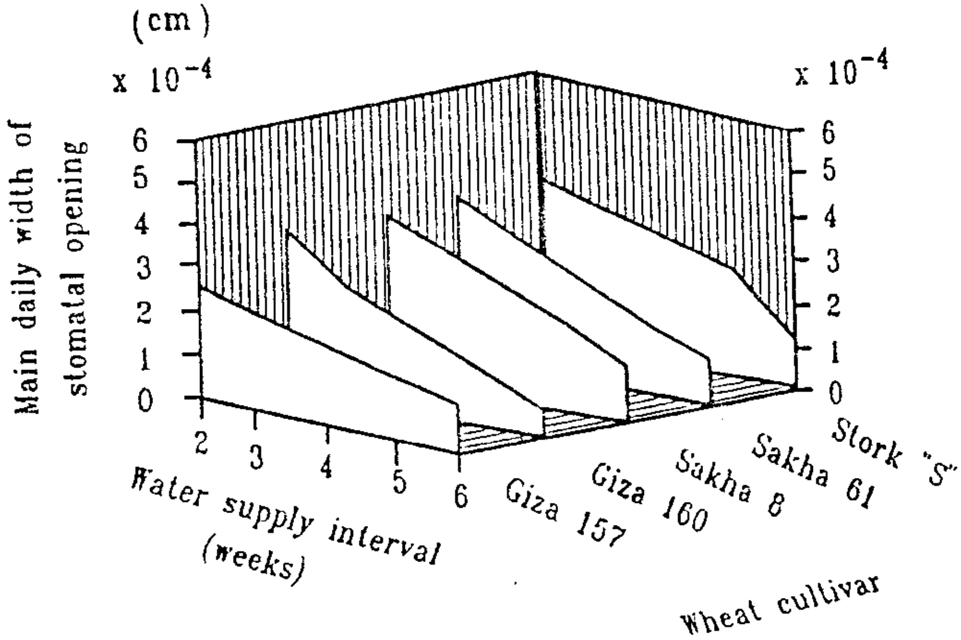
(cm)
x 10-4
x 10-4
Main daily width of stomatal opening
0
1
2
3
4
5
6
2
3
4
5
6
Water supply interval (weeks)
Giza 157
Giza 160
Sakha 8
Sakha 61
Stork "S"
Wheat cultivar

Fig. 6

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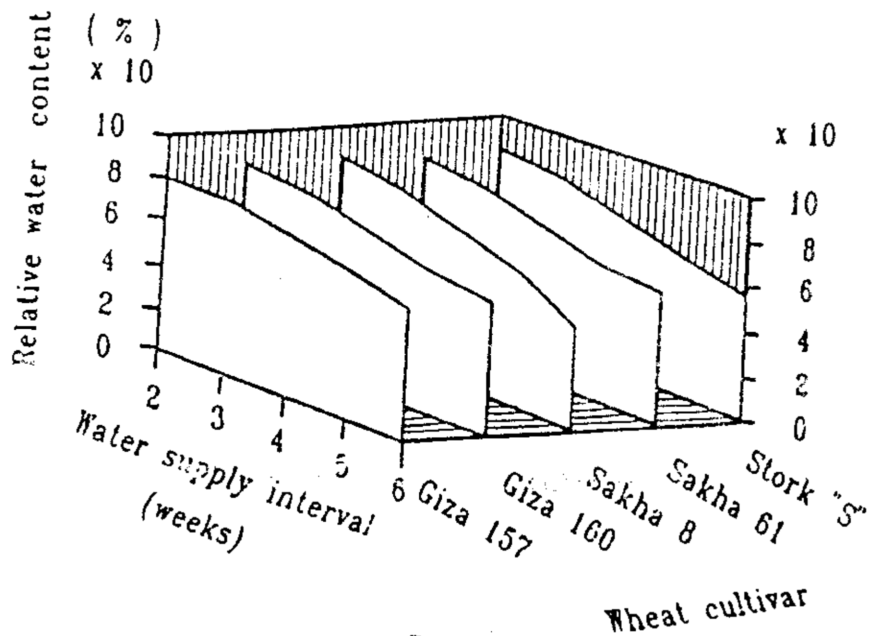

Fig. 7

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تأثير الاجهاد المائى على نمو وانتاجية ومعايير العلاقات المائية لخمسة أصناف من القمح

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الجيزة ـ مصر

تمت دراسة تأثير معاملات من الاجهاد المائى على خمسة أصناف من القمح هى : جيزة ١٥٧ وجيزة ١٦٠ وسخا ٨ وسخا ٦١ وستورك "S" وذلك بزراعة هذه الأصناف تحت ظروف مختلفة من رطوبة التربة بالرى على فترات متباعدة تتراوح بين اسبوعين وستة أسابيع. وبقياس وزن النبات الرطب والوزن الجاف ومساحة الأوراق وجد أن نمو جميع الأصناف يتناقص كلما تباعدت فترة الرى. وتبين أن الصنف جيزة ١٦٠ يفوق الأصناف الأخرى فى معدل النمو عند زيادة الاجهاد المائى، بينما كان الصنف سخا ٨ هو أقل الأصناف فى معدل النمو. وقد حقق الصنف جيزة ١٦٠ أيضا أعلى انتاجية تحت أقصى ظروف الاجهاد المائى المستخدمة فى التجربة.

وعند قياس معايير العلاقات المائية مثل معدل النتح وفتحات الثغور والمحتوى المائى النسبى للأوراق تبين أن هذا الصنف وكذا الصنف جيزة ١٥٧ لهما أقل المعدلات فى هذه المعايير مما يدل على أنهما أكثر الأصناف المستخدمة مقاومة للاجهاد المائى. أما الصنفين سخا ٨ وسخا ٦٠ فقد كانا أعلى الأصناف انتاجية وسجل بهما أكبر محتوى مائى بالأوراق عند الرى كل أسبوعين، ولكنهما كانا أقل الأصناف الخمسة مقاومة للاجهاد المائى. وقد تم عقد مقارنة بين الأصناف الخمسة تحت معاملات الاجهاد المائى كما تمت مناقشة قيمة الاستناد الى معايير العلاقات المائية وخاصة المحتوى المائى النسبى للأوراق كخاصية من دلائل مقاومة الجفاف.