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INCREASING DROUGHT RESISTANCE OF WHEAT PLANT DURING GRAIN FILLING BY USING CHEMICAL DESICCANTS

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ABSTRACT

Wheat grains *Triticum aestivum* L. var. Sakha 69 were sown under different irrigation intervals and other plants were sprayed with chemical desiccants 10 days after anthesis. The plant canopy was hand sprayed with KI (0.15 % and 0.3 %) and $NaClO_3$ (1 % and 2 %).

The visual effect of chemical desiccants was observed after one week of treatment Reduction percentage for both growth and yield, showed that 0.3 % KI and 2 % $NaC10_3$ reduced significantly growth and yield parameters with less extent than drought caused by elongation of irrigation interval. High moisture stress favoured accumulation of protein content in grains and straw and accumulation of free amino acids as well as proline in shoots of wheat plant. Also total sugars and total soluble phenols were increased in plant shoots under intense drought.

Additional index words :

Senescence agent - yield components - chemical desiccants – drought - potassium iodide - sodium chlorate protein - proline - phenols - total sugar and free amino acids.

INTRODUCTION

Water deficit is one of the most common constraints to crop productivity.

Postanthesis drought stress is a persistent problem for winter wheat production, so selection for drought tolerance in breeding programmes is commonly difficult due to climatic variations (especially precipitation) between years. Chemical desiccation has been proposed as a method for improving postanthesis drought stress tolerance. (Day and Intalap, 1970; Davidson and Birch, 1978; Austin, 1989).

The use of chemical desiccants and senescing agents has been proposed as a way to create homogeneous stress environments for plant growing in the field regardless of the soil moisture level (Sabry and Taylor 1992). Leaf photosynthesis tend to decreases markedly after anthesis in grain crops as a result of drought, heat or even leaf disease (Austin *et al*., 1980, Hall *et al.,* 1989). So, it is important to use senescing agents to stimulate the effect of a terminal drought stress on the plant by stopping current photosynthesis during grain filling (Austin et al., 1980, Hall *et al*., 1989). Spraying plants grown under well – watered conditions with an oxidizing agent, at a precise time after anthesis, causes plant senescence in the absence of photosynthesis and allow plant’s potential to translocate reserve carbohydrates from the stems to the developing grain to be established (Blum *et a*l., 1991). The most common recommended chemical desiccants are potassium iodide (KI), sodium chlorate ($NaClO_3$) and magnesium chlorate Mg $(ClO_3)_2$ (Nicolas and Turner, 1995). They are considered to be the best senescence agents for field use due to their efficacy and low toxic effects (Herrett *et al*., 1962).

The objective of this study is to evaluate whether a chemical treatment with KI or $NaClO_3$ sprayed over a canopy of wheat plant 10 days after anthesis could properly mimic the effects of drought stress on growth, yield and yield components and chemical composition of wheat plant. Such treatments may be helpful in breeding programmes of field crops, especially when grown under unfavorable environmental conditions.

MATERIALS AND METHODS

The present investigation was carried out in the greenhouse of Faculty of Science, Alexandria University, Egypt, during the two growing seasons 1996-1997 and 1997-1998. Data represented in the present work concerned one year only. Plastic pots of 30 cm in diameter and 30 cm in depth were used. The pots were filled with 7kg clay loam soil characterized by 35 % clay, 27 % silt, 2.62 % coarse sand, 35.3 % fine sand, 0.16 % total soluble salts, 0.2 % organic matter, pH 7.9 and EC_s 2.32 dS/m).

Wheat grains *Triticum aestivum* L. var. Sakha 69 were sown on late November, 10 grains were placed in each pot. Two weeks later, the seedlings were thinned to 5 plants per pot, to ensure a homogenous canopy. Recommended doses of fertilizers were added, each pot received 2.2g of calcium superphosphate (15.5 % P_2O_5), 1.1 potassium sulphate (48 % K_2O) and 2.0 g ammonium sulphate (20.5 % N) before planting, 30 days after planting excess amount of ammonium sulphate 2.0g was added.

The experiment included 2 groups. The first group was represented by spraying wheat plant canopy with 2 different chemical desiccants of different concentrations 10 days after anthesis. Plants were hand sprayed with KI (0.15 % and 0.3 %), and $NaC10_3$ (1 % and 2 %) each was replicated five times. Plants were well irrigated whenever required, approximately around field capacity.

The second group, was represented by subjecting plants to drought, through prolonging irrigation intervals after 30 days from sowing. Plants were divided into four treatments, each of which was replicated five times. In the first treatment plants were irrigated four times during the growth period they were subjected to low stress (L.S.). The second treatment, plants were irrigated thrice [i.e. subjected to mild stress (M.S.)]. In the third treatment plants were irrigated twice during the growth period [i.e. stress (S)]. In the fourth treatment, plants were irrigated only once before grainfilling {i.e. severe stress (S.S)}. In all previous cases, plants were urgently irrigated before grain filling.

In addition to the previous treatments, a group of plants received normal amounts of fertilizers and water to represent the control.

The treatments of the different groups were assigned in a completely randomized design with five replications.

Plants were sampled twice after 50 (vegetative stage) and 140 days (at harvest time) from sowing for recording growth, yield and chemical composition of wheat plant.

Ethanol extract of shoots was used for the determination of sugars, total free amino acids, proline and total soluble phenols. Determination of total sugars was carried out by using the phosphomolybdic acid (A.O.A.C., 1975).

Total free amino acids were determined using ninhydrin reagent (Moore and Stein, 1954). Total soluble phenols using colorimetric method and free proline were determined according to Bates et al., (1973). Data of growth characters and yield components were statistically analyzed and the means were compared using the least significant test (L.S.D.) at 5 % level (Snedecor and Cochran, 1980).

RESULTS AND DISCUSSION

The effect of chemical desiccants was observed one week after treatment in the yellowing of the plant leaves and spikes. Table (1) show that chemical treatment as well as drought reduced different growth parameters compared to that of the control. Using a concentration of 0.15 % KI solution and 1 % $NaClO_3$ showed a reduction in growth characters, somewhat similar to that caused by drought. The percentage reduction for growth parameters was calculated according to Blum *et al*., (1983)

Percentage reduction = 100 x $\frac{(C-S)}{C}$, where C and S are the values of the variables in control and stress treatments, respectively.

Table (1): Effect of chemical desiccants and drought on growth parameters of wheat plant

aw	Shoot height (cm)	Root length (cm)	Tillers number / plant (no)	Dry weight g/plant		
				Root dry weight (g)	Shoot dry weight (g)	Whole plant dry weight (g)
Control	71.2	17.8	5.8	1.2	6.68	8.23
Chemical desiccants						
0.15 % KI	69.8	16.7	5.2	1.1	6.51	8.11
0.3 % KI	38.1	14.7	1.8	0.40	1.67	2.15
1 % $NaClO_3$	68.7	16.9	4.9	0.89	6.11	7.7
2 % $NaCLO_3$	37.9	14.2	1.9	0.42	2.1	2.0
Irrigation interval						
Low stress (L.S)	56.3	17.6	5.2	0.91	5.51	6.72
Mild stress (M.S)	46.9	15.4	3.2	0.77	4.68	5.31
Stress (S)	41.1	14.4	2.0	0.45	3.00	3.75
Severe stress (S.S)	37.2	9.5	1.3	0.40	1.60	2.11
L.S.D at 5 % level Chemical desiccants	1.13	0.24	0.130	0.01	0.21	0.11
Irrigation interval	1.51	0.43	0.30	0.04	0.30	0.31

Severe drought {stress (SS)} induced a percentage of reduction in the shoot height, root length, number of tillers and the whole plant dry weight by 47.7%, 46.6 % 77.5 and 74.3 % respectively, while KI 0.3 % caused reduction of the same parameters to the same extent, 47.4 % for shoot height, 17.4 % for root length, 68.9% for the number of tillers by 78.8 % for the whole plant dry weight, also $NaClO_3$ (2 %) reduced shoot and root length by 46.7 % and 20.2 % respectively, while tillers number per plant was reduced by 67.2 % and the whole plant dry weight by 75.6 %. Previous results were supported and interperated by Hsiao (1973), who stated that water deficit is the environmental stress which limits agricultural productivity and affects nearly all aspects of plant growth and development. Also, Ludlow (1989) mentioned that drought is one of the most serious problems that limits plant growth and crop productivity in agriculture.

It was clear in table (2), that the use of KI and $NaC10_3$ as a senescing agents significantly reduced grain yield and yield components, although the effect of drought induced more reduction. Severe drought (S.S) reduced number of grains by 68.6 %, while 0.3% KI by 66.8 % and $NaClO_3$ by 64.3 %, weight of straw per plant was reduced by 52.1 % as affected by drought, 46.3 % by the use of 0.3 % KI and 48.4 % when using 2 % $NaCLO_3$. Percentage reduction in weight of spikes per plant was 78.8 % for drought, 75.7 % for 0.3 % KI and 61.3 % for 2 % $NaCLO_3$. Similarly, the weight of grains per plant were affected by drought, reduced by 81.8 %, while 0.3 % KI reduced it by 79.9 % and 2 % NaCLO3 by 76.0 %. The percentage reduction in grain index was 36.4 %, 32.9 % and 33.7 % for drought, 0.3 % KI and 2 % NaClO3 respectively.

Previous results were aided by Royo, (1996) who found that reduction in grain yield due to drought was higher than that caused by KI treatment. Also Haley and Quick (1998), found that levels of desiccation injury were similar for 2 % $NaCLO_3$ and 0.3 % KI, where as 0.15 % KI and 1 % $NaC10_3$ treatment did not induce yield or yield component reduction.

The effect of chemical desiccant and drought on percentage yield and yield components was calculated and represented in table (2). It was observed that chemical treatment with 0.3 % KI and 2 % $NaC10_3$ showed a percentage of straw weight ranged between 50 and 52 %, spike weight between 25 and 41 %, grain weight between 30 and 32 %, number of grain per plant between 46 and 47 % and 75 % seed filling percentage.

The percentage yield for irrigation interval different according to the amount of water stress, straw weight percentage ranged between 86 % at low stress to 49.6 % at severe drought stress, spike weight percentage ranged between 70.6 to 23.9 %, Grain weight ranged between 79.8 to 28.9 %, number of grains between 92 to 45.1 % and seed filling between 93.1 to 73.6 %.

On the other hand, low concentrations of KI and $NaClO_3$ showed low change in yield percentage, the change was similar to that of low water stress (L.W).

Water deficit showed some morphological and physiological changes, it also affected different chemical aspects. Severe drought induced by irrigating plants once before grain filling led to an increase in the protein percentage by 32 %, while water stress induced by 0.3 % KI increased protein percentage by 35 % and that of $NaCLO_3$ by 35.8 % in wheat grains at harvest time, as presented in Fig. (1).

Table (2) : The effect of chemical desiccants and drought on yield, yield components and their percentage, of wheat plant.

Treatments	Weight of spikes g/plant	%	Number of grains /plant	%	Grain Index (g.)	Grain Filling %	Yield (g.) / Plant			
							Weight of grain g/plant	%	Weight of Straw g/plant	%
Control	8.70	100	143.8	100	26.4	100	3.74	100	10.29	100
Chemical desiccants										
0.15 % KI	8.20	70.1	139.7	90.3	24.6	90.1	3.39	75.2	7.51	83.2
0.3 % KI	2.11	25.0	47.6	46.0	17.7	45.5	0.75	29.6	5.52	51.5
1 % $NaClO_3$	7.9	71.2	137.2	91.6	23.2	92.3	3.52	80.0	7.70	85.6
2 % $NaCLO_3$	3.36	41.0	51.3	47.2	17.5	75.5	1.1	32.3	5.30	50.5
Irrigation interval										
Low stress	6.41	70.6	127.3	92.3	24.3	93.1	3.61	29.8	9.41	85.9
(L.S)	4.27	59.0	108.3	81.5	21.71	80.6	2.64	68.7	7.32	80.1
Mild stress	2.0	28.5	69.5	52.7	17.3	79.3	1.31	45.6	5.75	63.7
(M.S)	1.84	23.9	45.1	45.1	16.78	73.6	0.68	28.9	4.92	49.6
Stress (S)										
Severe stress										
(S.S)										
L.S.D at 5 % level Chemical desiccants	0.40	-	9.4	-	1.07	-	0.21	-	0.40	-
Irrigation interval	0.50	-	9.96	-	1.3	-	0.26	-	0.52	-

The protein content found in straw, increased by 58.5 % under severe drought stress condition, and when sprayed with 0.3 % KI and 2 % $NaCLO_3$. This may be attributed to that high moisture stress favoured accumulation of protein (Singth et at., 1973).

Water stress whether caused by elongation of irrigation interval or by chemical desiccant treatment, as in Fig. (2), induced an accumulation of total sugars. This may be accounted mostly for osmotic adjustment (Chaves (1991). The same trend was observed in free amino acids and proline accumulation in shoots of wheat plant subjected to drought as shown in Fig. (3).

According to Yoshiba et al., (1997), proline is one of the most common compatible osmolyte in water stressed plants. The accumulation of proline in dehydrated plants is caused by both activation of the biosynthesis of proline and by inactivation of the degradation of proline. Also, Kavi Kishor *et al*., (1995) reported that over production of proline enhanced growth, root biomass and development of flower in plants exposed to drought. It was clear in Fig. (4) that total soluble phenols in shoots of wheat plant were increased under chemical stress as well as elongation of irrigation interval. Under long and intense drought, phenols and in particular, phenolics with an ortho-substitution are involved in development of resistance in plants (Volarie, 1995).

In conclusion, it is believed that, chemical desiccants and senescing agents are used to stimulate the effect of a terminal drought stress on the plant and can be used to select for post – anthesis drought resistance during grain filling. There are 2 main points to assure successful treatment with chemical desiccants. Firstly to choose the suitable genotype and secondly, to detect the exact timing for plant anthesis.

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زيـادة مقاومـة نبـات القمـح للجفـاف أثنـاء إمـتلاء الحبـوب باسـتخدام المجففـات الكيميائية

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يعتبر الإجهاد المائى مشكلة قائمة لنبات القمح أثناء فترة التزهير وإمتلاء الحبوب ولذلك فإن إنتخاب أصناف متحملة ومقاومة للجفاف عن طريق استخدام المجففات الكيميائية أحد الطرق المستحدثة والمفضلة والتى تخدم برامج تربية النبات.

أجريت الدراسة تحت ظروف الصوبة، بهدف دراسة أثر استخدام تركيزات مختلفة من المجففات الكيميائية كايوديد البوتاسيوم وكلورات الصوديوم رشاً على نبات القمح قبل بداية مرحلة طرد السنابل بعشرة أيام ومطابقتها بتأثير الإجهاد المائى الناتجة من رى النباتات على فترات، مرة، مرتين، ثلاث مرات و 4 مرات أثناء فترة نمو النبات وأثر كل من المعاملتين على النمو والإنتاجية والتركيب الكيميائى لكل من النبات والبذور.

وقد أثبتت الدراسة أن إستخدام المجففات الكيميائية خاصة 3ر0 % ايوديد البوتاسيوم و 2% كلورات الصوديوم كان أثرها الضار أقل نسبياً من الأثر الضار للجفاف على النباتات، وقد أدى إستخدامها الى نقص معنوى لكل من النمو والإنتاجية بدرجة أقل من أثر الجفاف نتيجة لتباعد فترات الرى.

أدى الرى على فترات متباعدة أو استخدام المجففات الكيميائية، الى تراكم البروتين فى كل من الحبة والقش، كما أدى الى زيادة فى الوحدات الأمينية الحرة والبروتين فى سيقان نبات القمح وفى حالة الجفاف الشديد زاد المحتوى الكلى للسكريات ومجموع الفينولات الذاتية.