ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF
AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 5 (1): 45-49, 2006
ISSN 1812-5379

Promotive Effect of 5-amino Levulinic Acid on Growth and Yield of Wheat Grown under Dry Conditions

S.S. Al-Thabet
Department of Crops and Range, College of Agricultural and Food Science,
King Faisal University, Al-Hassa 31982, Kingdom of Saudi Arabia

Abstract: Impact of water stress on growth and yield of wheat (*Triticum aestivum vulgare* L.) with and without foliar spraying 5-amino Levulinic Acid (5-ALA) was studied. Role of 5-ALA on water use efficiency under water stress was also evaluated. Results showed that irrigation wheat weekly was associated with the highest biological and grain yields ha^{-1}. Water stress by prolonging irrigation interval to 21 days resulted in a significant reduction in all estimated characters, except harvest index. However, maximum Water Use Efficiency of Biological Yield (WUEB) produced with the irrigation every 14 days. 5-ALA enhanced growth and increased yield of wheat, compared with the control. Foliar spraying of 100 ppm 5-ALA ha^{-1} produced the highest biological and grain yields ha^{-1} as well as water use efficiency. Application of 100 ppm 5-ALA enhanced the tolerance of wheat to water stress. The interaction between irrigation treatments and 5-ALA concentrations significantly affected biological and grain yields ha^{-1} as well as WUEB and WUEG (Water Use Efficiency of Grain yield). Wheat plants that irrigated every 14 days and foliar sprayed with 50-100 ppm 5-ALA ha^{-1} out yielded and surpassed in WUE that grown under normal water status (irrigation every 7) and left without 5-ALA application. So, it can be concluded that foliar application of 5-AlA on wheat plants grown under drought condition as in Saudi Arabia can enhance the tolerance to drought and increase grain yield.

Key words: 5-ALA, cv. Yokorogo, irrigation interval, water deficit, grain, straw, water use efficiency

INTRODUCTION

Water is becoming scarce not only in the arid and drought prone areas, but also in regions where rainfall is abundant (Pereira *et al*., 2002). The shortage of irrigation water limits plant growth and its productivity more than any other environmental factor (Boyer, 1982). Numerous researchers have linked various physiological responses of crop plants to drought such as high relative water content and water potential (Clarke and McCaig, 1982; Ritchie *et al*., 1990), pigment content and stability under stress (Sairam *et al*., 1990; 1997; Kraus *et al*., 1995). Reduction of wheat grain yield and its components particularly were extensively reported under water stress by many investigators (Gupta *et al*., 2001; Hassan, 2003; Rayan *et al*., 1999; Abou-Khadrah *et al*., 1999; Shantha and Jagadish, 2002; Kokhmetova *et al*., 2003). Shoot dry weight, number of grains, grain yield, biological yield and harvest index in wheat decreased to a greater extent when water stress was imposed at the anthesis stage, while imposition of water stress at the boot stage caused a greater reduction in plant height and number of tillers (Gupta *et al*., 2001). Maximum wheat grain yield was obtained with shortening the first irrigation interval from six to four weeks (Mahey *et al*., 2002). Irrigation interval of 21 days significantly reduced biological and grain yields ha^{-1} of barley and this reduction might be attributed to the decrease of plant height, spike length, number of grains/spike and weight of grains/spike (Al-Khateeb, 2005).

5-amino Levulinic Acid (ALA) is a key precursor in the biosynthesis of etrapyrole compounds such as chlorophyll, phycobilin, heme and vitamin B12. 5-ALA application on plant has been often reported in relation to chlorophyll biosynthesis and plant greening (Bingshan *et al*., 1998). 5-ALA application at low concentrations has been reported to promote growth and yield of crops and vegetables over the control as observed in barley (Al-Khateeb, 2005; Yongin *et al*., 2003), potatoes, garlic and kidney bean (Hotta *et al*., 1997), wheat (Bingshan *et al*., 1998) and rice (Yongin *et al*., 2003; Hotta *et al*., 1997). The application of low concentration of 5-ALA *in vitro* showed a reduction on the accumulation of photosynthetic pigments (Makarov *et al*., 2003). Foliar application of 5-ALA with low concentration improved the growth of barley, but the highest concentrations inhibited growth and yield. 5-ALA spraying at 1.5 leaf stage improved barley growth (Yongin *et al*., 2003). Foliar spray of 50 and 100 ppm ALA ha^{-1} significantly increased grain yield. This increase was accompanying with an increase in spike length, number of grains/spike and weight of grains/spike (Al-Khateeb, 2005).

The interaction between irrigation intervals and 5-ALA concentration significantly affected barley grain yield. The highest grain yield was noticed under 7 days interval and spraying with the concentration of 50 or 100 ppm ALA. Promotive effects on barley yield were appeared under normal condition of irrigation (Hassan, 2003)

There is a little information on the combined act of water requirements and 5-ALA application for growing wheat under dry conditions. Therefore, the present investigation was planned to study the effect of water stress, foliar spraying of 5-ALA and their interaction on growth, yield and water use efficiency of wheat under drought conditions.

MATERIALS AND METHODS

Two field trials were established at the Agricultural and Veterinary Training and Research Station, King Faisal University during the winter seasons of 2002/2003 and 2003/2004. A split plot design with four replicates was used. The main plots were devoted to three irrigation regimes, i.e. irrigation every 7, 14 and 21 days with the volumes of water namely 500, 650 and 800 m^3 ha/irrigation, receiving 20, 10 and 6 irrigations/season, respectively. The consumed irrigation water quantities were 12000, 8500 and 6800 m^3 ha/season, respectively. Volume of applied water before treatments application was 2000 m^3 ha^{-1}. It was 1000 m^3 ha^{-1}, immediately after sowing and two irrigations were applied at 10 and 20 days after sowing, each with 500 m^3 ha^{-1}. The sub plots were devoted to three 5-ALA concentrations, i.e. 25, 50 and 100 ppm in addition to water as control. The dimension of each sub plot (experimental unit) was 4x5 m, occupying an area of 20 m^2. Wheat cv. Yokoroga was used in this study.

Soil analysis in the upper 30 cm of the soil surface of the experimental site indicated that the soil was sandy in texture with pH= 7.8, ECe= 4.8 dS m^{-1}, Na, K and Ca contents were 14.0, 29.0 and 10.0 Meq L^{-1}, respectively. The experimental field was well prepared through two perpendicular plows, good harrowing and leveling, thereafter it was divided into main and sub-plots by constructing irrigation channels and alleys. Wheat grains with the rate of 200 kg ha^{-1} were hand drilled in rows, 15 cm apart on the first week of November in both seasons, thereafter, the field area was watered for saturation. Plants were fertilized with nitrogen in the form of urea (46.6% N) at the rate of 200 kg N ha^{-1}, which was added into three equal portions, the first was added prior planting during land preparation. The second portion was applied at the first of tillering stage and the rest was added at panicle initiation stage. Plots were weeded using Brominal 2.5 L ha^{-1} at 30 days after sowing. Other recommended cultural practices for wheat production were followed.

At maturity, 150 days after sowing (when plants turned a straw color and grains became solid), 10 guarded plants were randomly collected from each treatment to estimate plant height (cm), spike length (cm), number of tillers/m^2, number of spikes/m^2, 100 grain weight (g). Plants in the central two square meters in each plot were harvested, left to dry, tied and threshed. Thereafter, grains and straw were separated and estimated in g^{-2}, which converted to record grain and straw yields (t ha^{-1}). Harvest index (HI) was calculated as the ratio between grain and biological yields, using the following equation:

$$HI = (\text{Grain yield/biological yield})*100$$

Water Use Efficiency was calculated by dividing the Biological yield (WUEB) or Grain yield (WUEG) in m^3 ha^{-1} (Stanhill, 1987).

Statistical analysis: Collected data of each season (year) were statistically analysed (Gomez and Gomez, 1984), thereafter the assumption of normality and the homogeneity of variances of the experimental errors was checked according to Bartlet method which reported an appropriate homogeous of errors variance. Therefore, the proper combined analysis of variance (over seasons) of the split plot design was done using the following model:

$$X_{ijkm} = \mu + Y_i + R(Y)_{ij} + A_k + (Y*A)_{ik} + R*A(Y)_{ijk} + B_m + (Y*B)_{im} + (A*B)_{km} + (Y*A*B)_{ikm} + R*B(Y)(A)_{ijkm}$$

Where, μ: is the general mean, Y: Years, R: Replicates, A: Irrigation, B: 5-ALA, $R*A(Y)_{ijk}$: Error a, $R*B(Y)(A)_{ijkm}$: Error b.

Baysian Least significant difference (BLSD) at 0.05% level of significant was used to compare the treatment means (Waller and Duncan, 1969). Computations were done using SAS Institute (1997).

RESULTS AND DISCUSSION

Irrigation interval effects: Irrigation intervals significantly affected all growth and yield characters, except harvest index (Table 1). Plants exposed to water stress by irrigation every 21 days resulted in significant (p>0.05) reduction in plant height, number of spikes/m^2, spike length and diameter, number and weight of grains/spike, 1000 grain weight as well as grain and

Table 1: Averages of wheat growth, yield, harvest index and WUEB and grain (WUEG) yields in response to irrigation intervals (Combined over 2002/2003 and 2003/2004 seasons)

	Irrigation intervals			
Characters	7 days	14 days	21 days	BLSD (5%)
Plant height (cm)	79.80	74.70	61.00	5.40
Spike No. m^{-2}	263.90	243.20	200.60	20.20
Spike length (cm)	10.90	10.10	9.30	1.00
Spike diameter (cm)	1.60	1.50	1.20	0.30
Grains No. /spike	65.30	60.80	47.55	6.00
Grains wt./spike (g)	3.20	2.70	2.20	0.50
100 grain wt. (g)	5.20	4.80	4.20	0.30
Biological yield (t ha^{-1})	19.65	16.66	12.35	0.65
Grain yield (t ha^{-1})	7.03	6.08	4.66	0.47
Harvest index	0.36	0.37	0.38	NS
WUEB (kg m^3)	1.64	1.96	1.82	0.34
WUEG (kg m^3)	0.59	0.72	0.68	0.11

Table 2: Averages of wheat growth, yield, harvest index and water use efficiency of biological(WUEB) and grain(WUEG) yields (kg m^3) in response to 5-ALA concentrations (Combined over 2002/2003 and 2003/2004 seasons)

	(ppm)				
Characters	0	25	50	100	BLSD (5%)
Plant height (cm)	69.20	71.60	72.90	73.50	NS
Spike No. m^{-2}	198.70	227.30	258.40	259.40	28.90
Spike length (cm)	9.10	10.20	10.50	10.50	0.80
Spike diameter (cm)	1.15	1.50	1.60	1.65	0.20
Grains No. /spike	50.90	56.20	61.40	63.00	5.30
Grains wt./spike (g)	2.20	2.70	2.90	3.00	0.40
100 grain wt. (g)	4.20	4.70	4.80	5.10	0.30
Biological yield (t ha^{-1})	14.28	15.71	17.35	17.53	0.63
Grain yield (t ha^{-1})	4.78	5.63	6.53	6.75	0.39
Harvest index	0.34	0.36	0.38	0.39	NS
WUEB (kg m^3)	1.60	1.76	1.93	1.94	0.27
WUEG (kg m^3)	0.53	0.63	0.73	0.76	0.16

biological yields ha^{-1} (Table 1). This was in agreement with previous results (Gupta *et al*., 2001; Ashraf *et al*., 1994) which showed a sharp decrease in plant dry weight when water stress was imposed. Exposing wheat to drought stress reduced plant height, number of kernels/ spike, 100 kernel weight, main spike per plant and grain yield ha^{-1} (Hassan, 2003). The decrease in growth characters with increasing irrigation interval showed in the present study might be due to role of water deficit in the reduction of cell turgor which may cause a reduction in cell enlargement (Pereira *et al*., 2002; Tomos, 1985). Alternatively, cell wall extensively may also contribute in reducing growth under water deficit Shantha and Jagadish (Pritchard, 1994; Frensch and Hsiao, 1995).

Slight insignificant increase was shown in harvest index as water deficit increased. Similar results were also reported by Shantha and Jagadish (2002).

It seems that the significant ($p>0.05$) reduction of wheat grain yield was much related to both reduction in weight and number of grains/spike. This reduction indicates that water deficit induced under 21 days irrigation intervals severely affected pollination processes and consequently affected number of grains/spike (Shantha and Jagadish, 2002). Moreover, the reduction in grain weight could be attributed to the lack of assimilate needed for grain filling. The reduction of growth as well as biological and grain yields under water deficit agrees with those obtained by other investigators (Gupta *et al*., 2001; Rayan *et al*., 1999; Abou-Khadrah *et al*., 1999; Kokhmetova *et al*., 2003).

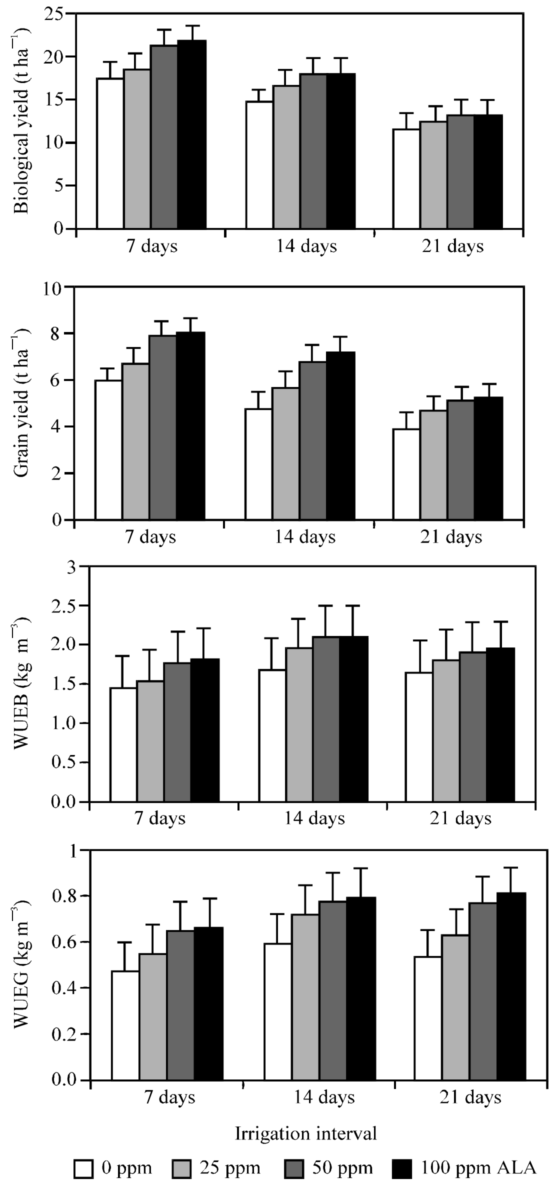

Fig. 1: Biological and grain yields (t ha^{-1}), WUEB and WUEG (kg m^3) of wheat as affected by the interaction between irrigation intervals and 5-ALA concentrations (Combined over 2002/2003 and 2003/2004 seasons). Bars=LSD (5%)

WUEB and WUEG yield for the examined irrigation intervals were significantly ($p>0.05$) increased with increasing irrigation intervals from 7 to 14 days (Table 1) and declined with increasing irrigation interval beyond 14 days. The increase in WUEG with increasing irrigation interval more than 7 days could be due to the fact that the change in grain yield was much lower than the change in the amount of irrigation water.

Results of the present study showed that the highest grain yield was found with the irrigation every 7 days, while the highest WUEB and WUEG values were obtained with the irrigation every 14 days, but with no significant effect between 7 and 14 days.

5-ALA effects: Table 2 shows that foliar application of 5-ALA had significant ($p>0.05$) effects on all estimated characters, except plant height and harvest index. Foliar spraying of 5-ALA with the rate of 50 ppm and more showed highest values of spikes/m^2, spike length and diameter, number and weight of grains/spike, 100 grain weight, grain and biological yields ha^{-1} and Water Use Efficiency on the basis of Biological (WUEB) and grain (WUEG) yields.

The application of 5-ALA at 25, 50 and 100 ppm resulted in 17.9, 36.7 and 41.2% in grain yield and 10.0, 21.5 and 22.8% in biological yield, respectively, compared with the control.

Water use efficiency on the basis of biological yield (WUEB) increased from 1.60 to 1.76, 1.93 and 1.94 kg m^{-3} with the application of 0, 25, 50 and 100 5-ALA ppm, respectively. WUEG yield followed the same trend of WUEB (Table 2). This promotive effect of 5-ALA application was also reported in wheat (Yongin *et al*., 2003). A significant increase in number of grains/spike and spike weight with the foliar application of 5-ALA was also found on barley plants (Al-Khateeb, 2005; Hotta *et al*., 1997).

Interaction effects: Results of the combined analysis for the obtained data revealed a significant interaction between irrigation treatments and 5-ALA concentrations on grain and biological yields ha^{-1} as well as WUEB and WUEG (Fig. 1).

The highest grain and biological yields ha^{-1} were obtained with irrigation wheat every 7 days and the application of 5-ALA at 100 ppm.

Wheat plants irrigated every 14 days and foliar sprayed with 50 or 100 ppm 5-ALA surpassed that grown under normal water status (irrigation every 7 days) and left without 5-ALA application (Fig. 1). WUEB reached its maximum value with irrigation every 14 days and application of 100 ppm 5-ALA (Fig. 1). It seems that 5-ALA could mitigate drought stress in wheat since a significant increase have been reported under 21 days irrigation intervals and 100 ppm 5-AlA compared with control.

In conclusion, foliar application of 5-AlA at 50-100 ppm concentration under Saudi Arabia conditions have significant promotive effects on wheat grown under normal condition with a substantial enhancement on water use efficiency of crops. Moreover, a slight mitigation effects were appeared with foliar application of 5-ALA on grain yield of wheat grown under drought conditions.

REFERENCES

Abou-Khadrah, S.H., S.A. Abd El-Hafez, F.A. Sorour and A.Z. El-Bably, 1999. Effect of soil moisture stress on wheat production, its components and nutrient uptake. 3rd Conferance of Farm Irrigation and Agro-climatology. January 25-27 A.R.C., Egypt, 1: 535-547.

Al-Khateeb, S.A., 2005. Promotive effect of 5-amino levulinic acid on growth, yield and gas exchange cacity of barley (*Hordeum vulgare* L.) grown under drought conditions. J. King Saud Univ. Agric. Sci., Riyadh, Saudi Arabia (Accepted for Publication).

Ashraf, M.Y., A.R. Azmi, A.H. Khan and S.A Ala, 1994. Effect of water stress on total phenols, peroxidase activity and chlorophyll content in wheat (*Triticum aestivum* L.). Acta Physiol. Plant., 16: 185-191.

Bingshan, L., Y. Hotta, Qu Yinglan, Z. Jinsong, T. Tanaka, Y. Takeuchi and M. Konnai, 1998. Effects of 5-aminolevulinic acid on the growth and ripening of wheat. J. Pesticide Sci., 23: 300-303.

Boyer, J.S., 1982. Plant productivity and environment. Science, 218: 443-448.

Clarke, J.M. and T.N. McCaig, 1982. Evaluation of techniques for screening for drought resistance in wheat. Crop Sci., 22: 503-506.

Frensch, J. and T.C. Hsiao, 1995. Rapid response of the yield threshold and turgor regulation during adjustment of root growth to water stress in *Zea mays*. Plant Physiol., 108: 303-312.

Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. 2nd Edn., John Wiley and Son Ltd., New York, pp: 680.

Gupta, N.K., S. Gupta and A. Kumar, 2001. Effect of water stress on physiological attributes and their relationship with growth and yield of wheat cultivars at different stages. J. Agron. Crop Sci., 186: 55.

Hassan, R.K., 2003. Effect of drought stress on yield and yield components of some wheat and tritcale genotypes. Ann. Agric. Sci., (Cairo), 48: 117-129.

Hotta, Y., T. Tanaka, H. Takaoka, Y. Takeuchi and M. Konnai, 1997. Promotive effects of 5-amino Levulinic acid on the yield of several crops. Plant growth Regul., 22: 109-114.

Hotta, Y., T. Tanaka, H. Takaoka, Y. Takeuchi and M. Konnai, 1997. New physiological effects of 5-aminolevulinic acid in plants. The increase of photosynthesis, chlorophyll content and plant growth. Biosci. Biotechnol. Biochem., 61: 2025-2028.

Kokhmetova, A., G. Sariyeva and S. Kenjebayeva, 2003. Yield stability and drought resistance in wheat. Acta Botanica Hungarica, 45: 153-161.

Kraus, T.E., B.D. McKersie and R.A. Fletcher, 1995. Paclobutrazol induced tolerance of wheat leaves to paraquat may involve increased antioxidant enzyme activity. J. Plant Physiol., 145: 570-576.

Mahey, R.K., O. Singh, A. Singh, S.S. Brar, A.S. Virk and J. Singh, 2002. Effect of first, subsequent irrigation (s) and tillage on grain yield, nutrients uptake, rooting density of wheat, soil moisture content, consumptive use and water use efficiency. Res. Crops, 3: 1-10.

Makarov, V.N., L.N. Kalitukho and L.F. Kabashnikova, 2003. The action of 5-aminolevulinic acid on morphogenic activity of callus tissue of wheat (*Triticum aestivum* L.). Vestsî Natsyyanal'naĭ Akadëmîî Navuk Belarusî. Seryya Bîyalagîchnykh Navuk, pp: 60-62.

Pereira, L., S.T. Oweis and A. Zairi, 2002. Irrigation management under water scarcity. Agric. Water Manag., 57:175-206.

Pritchard, J., 1994. The control of cell expansion in roots. New Phytologist, 127: 3-26.

Rayan, A.A., S.M. El-Marsafawy and K.A. Mohamed, 1999. Response of some wheat varieties to different sowing dates and irrigation regimes in upper Egypt. 3rd Conferance on Farm Irrigation and Agro-climatology. January 25-27, ARC, Egypt, 1: 5747-594.

Ritchie, S.W., H.T. Nguyen and A.S. Holaday, 1990. Leaf water content and gas exchange parameters of two wheat genotypes differing in drought resistance. Crop Sci., 30: 105-111.

Sairam, R.K., P.S. Deshmukh, D.S. Shukla and S. Ram, 1990. Metabolic activity and grain yield under moisture stress in wheat genotypes. Ind. J. Plant Physiol., 33: 226-231.

Sairam, R.K., D.S. Shukla and D.C. Saxena, 1997. Stress induced injury and antioxidant enzymes in relation to drought tolerance in wheat genotypes. Biol. Plant, 40: 357-364.

SAS Institute, 1997. SAS/STAT User's Guide: Statistics. Version 6.12. SAS Institute, Inc Cary, NC., USA.

Shantha, N. and R. Jagadish, 2002. Relationship of simulated water stress using senescing agent with yield performance of wheat genotypes under drought stress. Ind. J. Plant Physiol., 7: 333-337.

Stanhill, G., 1987. Water use efficiency. Adv. Agron., 39: 53-85.

Tomos, A.D., 1985. The physical limitations of leaf cell expansion. SEB. Symposium.

Yongin, K., L.G. Seob, C. Sang, H.Y. Eak and G. Jaock, 2003. Effects of 5-aminolevulinic acid on growth and inhibition of various plant species. Korean J. Crop Sci., 48: 127-133.

Yongın, K., L.G. Seob, C. Sang, H. Tayeak and G. Jaock, 2003. Effects of 5-aminolevulinic acid on growth and inhibition of various plant species. Kor. J. Crop Sci., 48: 127-133.

Waller, R.A. and D.B. Duncan, 1969. A bays rule for symmetric multiple comparison problem. Am. Stat. Assoc. J., pp: 1485-1503.