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Alleviation of the potential impact of climate change on wheat productivity using arginine under irrigated Egyptian agriculture

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Abstract. Agriculture is inherently sensitive to weather and climate. Adaptation of an appropriate management strategy is one of the likely decisions to cope with the impacts of changing climate. This study was designed to explore the role of arginine (0.0, 2.5 and 5.0 mM) in increasing the tolerance of wheat cultivar (Sakha-93) to two late sowing (23/12 and 23/1) dates, beside the normal sowing date (23/11) in Egypt. A field experiment was conducted in Agricultural Research Station of National Research Centre located in Shalkan Province, Kaluobia Governorate, Egypt. Delayed sowing caused marked reduction in biological and economic yield, through reduction in the spike length and weight, spike grain weight, spike no per square meter, and 1000-grains weight. The reduction in economic yield/fed reached to 10.39 and 41.22% when delay sowing wheat to 23/12 and 23/1 respectively. Foliar application of arginine with 2.5 and 5.0 mM on normal or delayed sowing wheat exhibited significant increment in yield and its components in comparison to untreated plants. The magnitude of increments was much more pronounced in response to 2.5 mM of arginine which induce 19.23, 20.53 and 25.51% increases in economic yield per feddan at normally, 30 and 60 days delay, respectively. As well as results show that, 2.5 mM arginine treatment induce 8.0% increase in grain yield over the plants sowing late at 23/12 and could reduce the reduction percent in grain yield from 41.22 to 26.22% at 23/1 sowing date. From this study it could be concluded that arginine could alleviate the adverse impact of climate change by late sowing of wheat and reduce the expected reduction of economic yield in semi-arid regions under irrigated agriculture.

Keywords. Wheat – Arginine – Delayed sowing – Climate change – Economic yield.

Atténuation de l'impact potentiel du changement climatique sur la productivité du blé en utilisant l'arginine en conditions irriguées en Égypte

Résumé. *L'agriculture, de façon inhérente, est sensible aux conditions météorologiques et au climat. L'adaptation d'une stratégie de gestion appropriée est une des décisions plausibles pour affronter les impacts d'un climat changeant. Cette étude a été conçue pour explorer le rôle de l'arginine (0,0, 2,5 et 5,0 mM) pour augmenter la tolérance d'un cultivar de blé (Sakha-93) à deux dates de semis tardif (23/12 et 23/1), en plus de la date normale de semis (23/11) en Égypte. Ainsi, une expérience a été menée aux champs à la Station de Recherche Agronomique du Centre National de la Recherche située dans la Province de Shalkan, Gouvernorat de Kaluobia, Égypte. Le semis tardif a provoqué une réduction marquée du rendement biologique et économique, à travers la réduction de la longueur et du poids des épis, du poids du grain de l'épi, du nombre d'épis par mètre carré, et du poids de 1000 grains. La réduction du rendement économique feddan-1 a atteint 10,39 et 41,22% pour le blé semé tardivement, les 23/12 et 23/1 respectivement. L'application foliaire d'arginine à 2,5 et 5,0 mM pour le semis normal ou tardif a montré une augmentation significative du rendement et de ses composantes en comparaison avec les plantes non traitées. L'ampleur de l'augmentation était bien plus prononcée en réponse à 2,5 mM d'arginine qui induit une augmentation de 19,23, 20,53 et 25,51% du rendement économique par feddan respectivement à la date normale, et avec un retard de 30 et 60 jours. Comme le montrent les résultats, le traitement à 2,5 mM d'arginine induit une augmentation de 8,0% du rendement en grain pour les plants semées tardivement le 23/12 et pourrait réduire la baisse de pourcentage de rendement en grain de 41,22 à 26,22% pour la date de semis du 23/1. À partir de cette étude il peut être conclu que l'arginine pourrait réduire l'impact adverse* *du changement climatique pour la date de semis tardive du blé et réduire la baisse attendue de rendement économique en région semi-aride sous agriculture irriguée.*

Mots-clés. *Blé – Arginine – Semis tardif – Changement climatique – Rendement économique.*

I – Introduction

Wheat is one of the very important crops in Egypt. Optimum sowing date plays an important role in yield production. Planting wheat in its optimum sowing date would realize optimum season length and achieve high grain yield as a result of suitable whether conditions prevailing through different wheat growth stages (Ouda *et al.*, 2005).

The impacts of climate change on agricultural activities in term of yield losses and increasing of water needs have been studied for the last decade in Egypt. The damage that climate change would do to agricultural productivity could be severe if no adaptation measures were taken (El-Shaer *et al.*, 1997). Previous research on the impact of climate change on agricultural sectors revealed that yields and water use efficiency will be decreased in comparison with current climate conditions. Whereas, climate change conditions could decrease water demand for winter crops by up to 2% by the year of 2050 (Eid and El-Mowelhi, 1998).

Delay of wheat sowing date reduced wheat yield as a result of exposure to high temperature, which reduce season length (Abd El-Monem, 2007; Mostafa *et al.*, 2009). Yield reduction in wheat under heat stress could be caused by accelerated phases development, accelerated senescence, increased respiration, reduced photosynthesis and inhibition of starch synthesis in developing kernels (Hamam and Khaled, 2009). Temperature fluctuations during grain filling were found to cause deviations from expected dough properties (Hamam and Khaled, 2009). The rise in daily average temperature up to 30°C or more during anthesis causes pollen sterility (Rayan *et al.*, 1999).

Furthermore, water stresses caused by high temperature as a result of climate change by delaying sowing date of wheat during different plant growth stages usually decreased final grain yield of wheat (Ouda *et al.*, 2005; Mostafa *et al.*, 2009). Also, a low soil moisture condition reduces the number of reproductive tillers which limit their contribution to grain yield (McMaste, 1997).

The stimulative effect of arginine as polyamine precursor on growth and yield component may act as protective agent in plants adapted to extreme environment (Kuhen *et al.*, 1990; Abd El-Monem, 2007). Paschalidis and Roubelakis-Angelakis (2005) reported that PAS, their precursor arginine and their biosynthetic enzymes are involved in stimulation of cell division, expansion and differentiation and vascular development in tobacco plant. Hassanein *et al.* (2008) found that arginine at 2.5 mM was the most effective in improving growth and yield of wheat plant exposed to high temperature stress. Moreover, Abd El-Monem (2007) and Mostafa *et al.* (2009) concluded that foliar application of arginine (1.25 and 2.5 mM) on normal or delayed sowing wheat exhibited significant increments in the growth and all yield parameters in comparison to the late sowing plants or the untreated control sown at normal date.

The objectives of this study were to determine the role of arginine in increasing yield of wheat at normal or delayed sowing dates under conditions of Egyptian irrigated agriculture.

II – Materials and methods

Field experiments were carried out at the Experimental Station of NRC (National Research Centre) in Shalakan Province, Kalubia Governorate, Egypt, to explore the role of arginine (0.0, 2.5 and 5.0 mM) in increasing the tolerance of wheat cultivar (Sakha-93) to two late sowing

(23/12 and 23/1) dates, beside the normal sowing date (23/11). Experiment was quadruplicated in split plot design with a net plot size of 3 × 3.5 meter. Sowing dates and arginine were allocated in main and sub plots, respectively. Arginine treatments were sprayed one month from sowing.

The soil was ploughed twice and divided into plots. Wheat grains sown by drilling seed manually in the rows at 15-cm apart at the rate of 60 kg/fed (1 fed = 4200 m^2). 100 kg calcium super phosphate (15.5 P_2O_5)/fed and 50 kg potassium sulphate (48% K_2O)/fed were added during seedbed preparation. Nitrogen fertilizer was applied at the rate of 40 kg N/fed as Urea (46% N) in two equal doses before the first and second irrigation. All agronomic practices for wheat cultivation were kept normal and uniform. Wheat plants were manually harvested on the last week of May.

At harvest, wheat plants in one square meter from each plot were cut and counted to determine number of spikes/m^2. Also, data on wheat plants i.e., plant height, number of spikelets and grain per spike, length and weight of spike, grains weight of spike and 1000-grains weight were determined from randomly selected 20 tillers. Wheat was threshed manually to determine grain, straw and biological yield per plot (3 × 3.5 m) to calculate grain, straw and biological yields per fed.

Analysis of variance (ANOVA) for split plot design and LSD to compare mean were used by M-STAT-C statistical analysis program (MSTAT-C, 1988).

Weakly maximum and minimum temperatures data were obtained for Shebeen El-Kanater region as representative of Shalakan region through the 2005/06 growing season (Fig. 1).

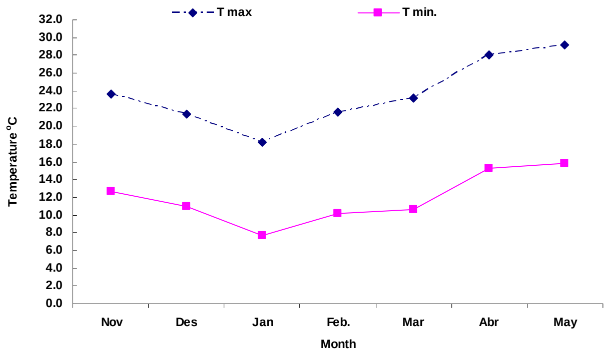

Fig. 1. Maximum and minimum temperature for Shebeen El-Kanater during growing season of 2005/06.

III – Results and discussion

1. Wheat yield components

Data in Table 1 showed that sowing wheat at the last week of November (23/11) is the optimum date for inducing the maximum yield traits at harvest i.e., plant height, spike length, weight, grain weight, spike number, spikelets number and grain spike ratio. These results could be attributed to the appropriate weather conditions prevailing during growth season, which in turn increased yield components. This result was in agreement with those obtained by Ouda *et al.* (2005). They reported that planting wheat in mid November or early December increased season length through increasing number of days to anthesis and consequently number of days to physiological maturity. Recently, Hamam and Khaled (2009) concluded that, sowing at favourable date where heat units and metabolites stored in favourable sowing date caused taller plants, vigorous growth and taller spikes.

Delaying the date of sowing for 30 and 60 days induced significant reduction in all components of yield (Table 1). These reduction reached to 4.05 and 19.94% for plant height, 6.48 and 21.33% for spikes number/0.25 m^2, 5.00 and 6.22% for spike length, 1.54 and 31.65% for spike weight, 4.48 and 33.73% for grain weight/spike, 4.05 and 18.92% for spikelets number/spike, 2.26 and 5.85% for grain spike ratio and 14.39 and 26.84% for 1000-grain weight, respectively compared with those of plants sown at suitable date. The decrease in these parameters can be attributed to the shortening in the total growth duration and exposing plant to high temperature stress in delaying sowing dates. The same results are obtained by several studies in Egypt (Ouda *et al.*, 2005; Abd El-Monem, 2007; Hamam and Khaled, 2009; Mostafa *et al.*, 2009) and abroad (Mohanty, 2003; Singh and Pal, 2003). Moreover, Menshawy (2007) reported that, high reduction in kernel weight was found under late planting, it could be fully accounted by the reduction in grain filling period. Delaying sowing date reduced kernel weight due to high temperatures affecting the grain maturity which resulted in shrinked kernels.

Table 1. Wheat yield and its components as affected by spraying with arginine at different sowing dates

Treatment		Plant height (cm)	Spike (s)				spikeletes noumber/ spike	Grain spike ratio	1000-grains wt. (g)	Yield (ton fed $^{-1}$)		
Sowing date	Arginine (mml)		No/ 0.25 m^2	Length (cm)	Weight (g)	Grains wt (g)				Grain	Straw	Biological
23-Nov-05.	**0.0**	86.50	108.00	10.00	3.35	2.26	18.50	0.67	49.21	2.51	4.51	7.02
	2.5	93.75	126.25	11.50	3.74	2.59	20.75	0.69	56.20	2.99	6.31	9.30
	5.0	87.50	118.00	11.50	3.58	2.36	18.75	0.66	52.12	2.84	5.69	8.53
23-Des-06.	**0.0**	83.00	101.00	9.50	3.20	2.11	17.75	0.66	42.13	2.25	4.32	6.57
	2.5	91.50	130.00	10.25	3.48	2.81	20.25	0.81	47.15	2.70	5.38	8.08
	5.0	86.60	120.00	9.88	3.36	2.26	18.75	0.67	45.14	2.69	5.31	8.00
23-Jan-06.	**0.0**	69.25	85.00	9.38	2.22	1.41	15.00	0.64	36.00	1.48	3.27	4.75
	2.5	72.00	116.75	10.25	2.37	2.11	17.00	0.89	40.02	1.85	4.36	6.21
	5.0	70.25	100.25	9.50	2.33	1.72	15.75	0.74	38.04	1.75	4.17	5.92
LSD $_{5\%}$		**1.17**	**15.56**	**1.00**	**0.37**	**0.33**	**1.53**	**0.14**	**1.49**	**0.41**	**0.35**	**0.68**

Foliar application of different arginine concentrations (2.5 and 5.0 mM) on wheat plants after one month from sowing exhibited significant increments in all yield parameters under normal or late dates of sowing. The maximum increase in all parameters was obtained by using 2.5 mM arginine. Spraying of 2.5 mM arginine treatment increased plant height by 10.24 and 3.97%, spikes number/0.25 m^2 by 10.24 and 3.97%, spike length by 7.89 and 9.28%, spike weight by 8.75 and 6.76%, spike grain weight 33.18 and 49.65%, spikelets number/spike by 14.08 and 13.33%, grain spike ratio by 22.46 and 40.17% and 1000 grain weight by 11.92 and 11.17% at sowing dates delayed for 30 and 60 days respectively, as compared with corresponding controls sown at delayed dates without treatment. The positive increase in the yield components of wheat in response to arginine is in agreement with those obtained by Iqbal and Ashraf (2005) and by El-Bassiouny *et al.* (2008). Moreover, Abd El-Monem (2007) and Mostafa *et al.* (2009) proved that, the positive increase in the yield components of wheat in response to arginine treatment may be due to the stimulatory effects of arginine in increasing vegetative growth, growth promoters, antioxidant enzymes, endogenous poly amines and endogenous amino acids under normal or high temperature stress.

2. Wheat yield (ton/fed)

Results in Table 1 indicated that sowing wheat at 23 November is the optimum date for inducing the maximum grain, straw and biological yields/fed as compared to the other sowing dates.

Similar results were reported by several investigations (Ouda *et al.*, 2005; Abd El-Monem, 2007; Hamam and Khaled, 2009; Mostafa *et al.*, 2009).

Sowing wheat in late dates (23/12 and 23/1) significantly decreased grain, straw and biological yields/fed as compared with plants sowing at suitable date (23/11). The reduction percentage reached to 10.39 and 41.22% for grain yield, 12.22 and 33.40% for straw and 11.59 and 35.98% for biological yield/fed when sowing date was delayed for 30 and 60 days, respectively (Table 1). The decrease in yields of wheat plant at late both sowing dates can be attributed to decline in spike weight, grain spike weight, 1000 grains weight and spike number/0.25 m^2 and other yield components (Table 1). These results are in good harmony with those obtained by Singh and Pal (2003), who found that late sowing caused shortening in the total growth duration and significant reduction in the biological and economic yields through reduction in the number of spikes per pot, number of grains per spike, weight of 1000 grain and grain dry weight per shoot. Ouda *et al.* (2005) reported that sowing wheat in late dates reduced season length, resulting in a reduction in grain, straw and biological yields. This could be attributed to reduction in the rate of leaf appearance as a result of water stress which reduces assimilate production by tillers and consequently reduce wheat grain and straw yields. Abd El-Monem (2007) and Mostafa *et al.* (2009) concluded that exposure of wheat plants to high temperature stress due to late cultivation (15/12) cold led to reducing the vegetative and reproductive phases in wheat, and consequently reduce grain, straw and biological yields compared to plants sown at normal date (15/11). Moreover, Hamam and Khaled (2009) reported that the wheat grain yield was greatly affected by the main yield components like kernel weight. Reducing flag leaf area, spike length and kernel weight caused great reduction in grain yield.

Foliar application of arginine with 2.5 and 5.0 mM on normal or delayed sowing wheat exhibited significant increment in wheat yield per fed in comparison to untreated plants. The magnitude of increments was much more pronounced in response to 2.5 mM of arginine which induce 19.23, 20.53 and 25.51% increases in grain yield/fed at normally, 30 and 60 days delay, respectively. As well as results show that, 2.5 mM arginine treatment induce 8.0% increase in grain yield over the plants sowing late at 23/12 and decrease the reduction percent in grain yield from 41.22 to 26.22%, straw yield from 33.40 to 11.41 and biological yield from 35.98 to 16.44% at 23/1 sowing date. At normal date the percent of increase due to application of 2.5 mM arginine in grain yield was 19.12%; straw yield was 28.31% and biological yield was 25.20% compared to untreated plant. These results may be due to the stimulatory effect of arginine in increasing yield components under normal or late sowing dates which serves as specific protective agent in plants exposed to extreme environment. The same results were obtained on wheat by Abd El-Monem (2007) and El-Bassiouny *et al.* (2008) under normal condition, Hassanein *et al.* (2008) under high temperature stress, and Mostafa *et al.* (2009) under late sowing conditions. They concluded that arginine stimulate the growth and yield of wheat through increasing vegetative growth, endogenous polyamines, endogenous amino acids and their translocation to the produced grains.

IV – Conclusion

From this study it could be concluded that arginine could alleviate the adverse impact of climate change by late sowing of wheat and reduce the expected reduction of economic yield in semi-arid regions under irrigated agriculture.

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