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Effect of Soaking Seeds in Some Growth Regulators on Wheat Grown in Sandy Soil

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A RESEARCH field experiment was carried out to study the effect of soaking wheat seeds before sowing in aqueous solutions of gibberellic acid GA3 (2 g L^{-1}), Salicylic acid SA, humic acid HA and potassium humate K-H (6 g L^{-1} each) on wheat productivity under sandy soil conditions. Wheat yield (t ha^{-1}) increased maximally by 4.57% for GA3 treatment while decreased by 7.65% for the HA treatment compared with the control. Seed yield (t ha^{-1}) increased by 8.01% for K-H but decreased by 3.77% for HA. Shelling (%) increased significantly by 6.29% for K-H only, while decreased by 3.73% for GA3. Treatments significantly affected soil available Si and its uptake by growing plants. Available Si in soil (mg kg^{-1}) decreased significantly (as %) in a descending order GA3 (23.39%) > HA (20.71%) > K-H (13.4%) > SA (7.55%), which may be due to significant consumption of Si from soil as uptake by plant. Total Si content (g kg^{-1}) in wheat seeds increased significantly (as %) in the order GA3 (700%) > SA (672.73%) > HA (386.36%) but decreased by 22.73% for K-H for which Si-uptake decreased significantly by 16.54%. The studied plant growth regulators (PGRs) perhaaps affect the soaked wheat seeds physiologically and disrupt nutrient uptake from soil including N, P, K and Si. Pre-soaking in K-H can be recommended and preferable more than GA3, HA, and SA for health aspects and to avoid luxury consumption of Si by plant.

Keywords: Growth regulators; Organic solutions; Sandy soil; Soaking seeds; Wheat.

Introduction

Countries in North Africa and Middle East face insufficient water supply for irrigation due to the depletion of water sources (Ibrahim et al., 2015). The growing plants in sand soils suffer from several environmental stresses such as water stress that decreases the germination rate and percentage as well as seedling growth. Seed germination of winter wheat affects harvested seed yield, which is often hindered by dry soil conditions. Poor germination of wheat is a major limitation to crop yield in many arable areas of the world (Fateh et al., 2012 and El-Basioni et al., 2015).

Wheat (*Triticum aestivum* L.) is the highest ranking cereal crop globally. The establishment stage of wheat consists of three sensitive parts: germination, emergence and early seedling growth. Germination is a crucial stage for plant establishment. Osmotic stress at the initial stage may cause various physiological changes, such as interruption of membranes, nutrient imbalance and impairment of the ability to detoxify reactive oxygen species (ROS), differences in the antioxidant enzymes, decreased photosynthetic activity and a decrease in stomatal aperture. The uptake of K^+ ions essential for growth may be inhibited in some plants when they are susceptible to ion stress during germination or seedling growth, which leads to lower productivity (Alom et al., 2016).

Pre-soaking treatment could be used to mitigate the effects of many stresses on the seed germination. During germination of cereal seeds, the storage material accumulated in the starchy endosperm is mobilized by hydrolytic enzymes. The most

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abundant is α-amylase, which hydrolyzes starch to produce mono- and oligo-saccharides (Ashford and Gubler, 1984). Expression of cereal α- amylase is regulated by plant hormones GA and ABA and influenced by environmental factors. Proline acts in osmo-regulation and biotic and abiotic stresses cause free proline accumulation in many plants that is a defense mechanism under unfavorable environmental conditions (Sultana et al., 2000).

The effect of seed soaking on wheat was studied using distilled water and other dilute solutions such as solutions of $CaCl_2$, $ZnSO_4$, $Fe_2(SO_4)_3$, adenine, gibberellic acid, vitamin K_3, 2,4-D, garlic extract and nano-particles' suspensions of TiO_2, ZnO, nickel and chitosan (Salim and Todd, 1967, Li et al., 2013 and Rawat et al., 2018).

Seed treatment with plant growth regulators (PGRs) is sometimes an easy and low cost technique to overcome agricultural problems. It improves seed germination under unfavorable environmental conditions. Studies indicated that seed pre-soaking in water beyond 12 hr does not improve germination further, and beyond 21 hr, germination rate is drastically reduced. Probably the germinating embryo was suffocated due to excess water. Wheat seed attains 50% moisture content in 12 hr if soaked in free tap water. Water is a prerequisite to start the process of germination and soaking wheat seed in water before sowing increased harvested seed yield by 21.2% (Ahmad et al., 1998). A positive relationship have been reported between seedling vigor, improved stand establishment and higher productivity of cereal crops with plants originating from large seed compared to those grown from smaller seed. In wheat, increased seed size influences germination percentage and emergence as well as affects yield components and grain yield (Fateh et al., 2012; Hussain et al., 2013).

Many molecules such as polyethylene glycol (PEG) compounds have been used to induce water stress and simulate osmotic stress effects in petri dish (*in vitro*) for plants. It is a non-ionic water polymer not expected to penetrate into plant tissue rapidly. Salicylic acid (SA) and polyamines may have profound effects on plant growth and development. In some studies, seeds of winter wheat were separately pre-soaked with sodium nitro-prusside (SNP, as nitric oxide donor) and gibberellic acid (GA3) before germination under low temperature. Pre- soaking increased seed germination rate, germination index, decreased mean germination time and weight of seeds germinating under low temperature. Exogenous NO and GA3 increased seed respiration rate and promoted starch degradation along with increased amylase activities. Seedling growth and germination was also enhanced as a result of better reactive oxygen species (ROS) homeostasis under chilling temperatures by enhancing the ROS activity scavenging system in wheat (Sultana et al., 2000 and Li et al., 2013).

Alternate wetting and drying pre-planting treatments of seeds have shown to accelerate seedling emergence and growth activity in several grasses. The beneficial effect of such treatments is more pronounced as the soil moisture content is reduced. The response of seeds to an alternate wetting and drying treatment varies with the species (Walter et al., 1981).

The seeds of two wheat genotypes were soaked in humic acid (HA) solution to study the effects on the seedlings antioxidant system under NaCl and Na_2CO_3 stresses. Under the salt and alkali stresses, the seedlings leaf proline (Pro) content increased, membrane permeability enhanced, and aboveground fresh mass decreased. Seeds soaked in HA have an increased content of the seedlings leaf glutathione (GSH) that effectively relieved the damage of salt-alkali stress on the seedlings growth (Wei and Qing-xiang, 2011).

Therefore, if seed germination could be accelerated following broadcast seeding, the probability of successful establishment could be enhanced. The present study aims to indicate the effect of pre-soaking wheat seeds before sowing in aqueous solutions of gibberellic acid GA3, Salicylic acid SA, commercial humic acid HA and potassium humate K-H on wheat productivity under sandy soil conditions.

Materials and Methods

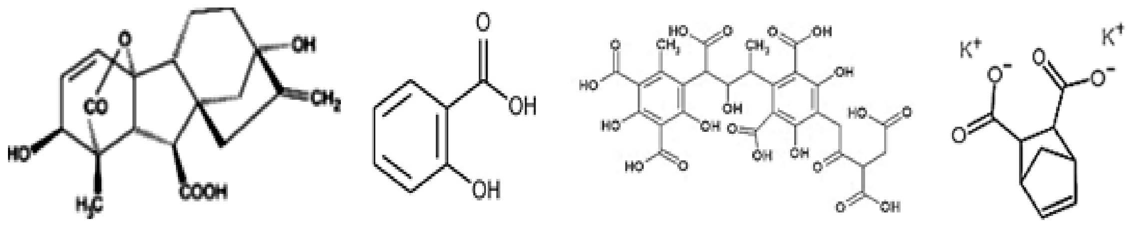
A field experiment was carried out during the winter seasons of 2017/2018 – 2018/2019 at the Ismailia Agricultural Research Station, (30° 35' 30" N 32° 14' 50" E elevation 3 m) Agricultural Research Center (ARC). Some properties of the studied sandy soil (*Typic Torripsamment; Entisol* [Arenosol AR] (FAO, 2014) are presented in Table 1.

Materials used (Fig. 1) were solid powder gibberellic acid GA3 ($C_{19}H_{22}O_6$ – Berelex, VALENT Bio-Science co.), Salicylic acid SA ($C_7H_6O_3$ – El Nasr pharmaceutical chemicals Co., Egypt.), commercial humic acid HA and potassium humate K-H ($C_9H_8K_2O_4$, 11.2 % K_2O).

TABLE 1. Some characteristics of the experiment soil before cultivation

Particle size distribution (%)				
	Coarse sand	**Fine sand**	**Silt**	**Clay**
	70.12	14.32	6.22	9.34
Texture class	**$CaCO_3$ (g kg^{-1})**	**Organic Matter OM (g kg^{-1})**	**pH†**	**Soil salinity, EC (dS m^{-1})‡**
Sandy	3.8	2.6	7.90	0.40
Available nutrients (mg/kg)				
	N	**P**	**K**	
	25.50	2.20	55.16	

† (1:2.5 soil : water suspension) ‡ (1:5 soil : water extract)



GA3 SA HA K-H

Fig. 1. Chemical structure of GA3, SA, HA and K-H used in the study.

Aqueous solutions were prepared separately by dissolving the desired weight of solid powder for each material in tap water (GA3, 2 g L^{-1} – HA, SA and K-H, 6 g L^{-1}). Doses were suggested by the author to study the extreme effect of high concentration of the studied materials. Seeds of wheat (*Triticum aestivum* L. *cv.* “Misr 1”) were soaked in different solutions in a ratio 300 g seeds in 500 mL for 12 hr. A previous study indicated that soaking beyond 12 hr does not improve germination (Ahmad et al., 1998). After that, soaked seeds were separated from solution, spread over a sieve tell air-dried. About 1 g of soaked seeds was weighed after swelling in solution then placed on wet filter paper for 6 days to observe preliminary germination. Moisture percent (%) was calculated for different soaking solutions in addition to a control sample soaked in tap water.

Planting and sampling

Seeds of wheat soaked in different treatments were sown in a complete randomized blocks distribution with three replicates. Agronomic practices were applied as recommendations of the Ministry of Agriculture, *i.e.* recommended mineral fertilization rates of super phosphate (15.5% P_2O_5, 31 kg P ha^{-1}) and potassium sulphate (48% K_2O, 95 kg ha^{-1}) were applied to soil before planting. Recommended ammonium sulphate (20.5 % N, 238 kg N ha^{-1}) was added in three equal doses during the growing season 15, 40 and 60 days from planting (Merwad, 2017). At harvest time, plant samples from each plot (4 m^2 area) were randomly selected and air-dried. Yield (t ha^{-1}) and some yield components such as seed yield (t ha^{-1}), 1000-seeds weight (g) and shelling (%) have been calculated based on the seed yield per plot area and the mean of the two seasons was recorded.

Analysis of soil and plant samples

The soil available N, P, K and Si were extracted by 1% K_2SO_4, 0.5 N $NaHCO_3$, 1 N NH_4OAc (pH 7.0) and 0.5 N CH_3COOH, respectively (Black, 1965; Jackson, 1973; Heckman and Wolf, 2009). Wheat seeds were dried at 70ºC for 48 h and ground. A half gram of the ground seeds was wet digested using the acid mixture (1:1 $H_2SO_4/HClO_4$) (Chapman and Pratt, 1961). Total concentrations of N, P, and K in plant and soil extracts were estimated by distillation using Kjeldahl glass apparatus, colorimetrically by the UV-Vis. Spectrophotometer (JENWAY UV/

Vis. Spectrophotometer 6405, UK) and by flame photometer (JENWAY PFP7 Flame photometer, UK), respectively. Soluble concentrations of Si in the plant and soil extracts were measured by the ICP Spectrometry (ICP-OES Ultima 2 JY Plasma, HORIBA, France).

Statistical Analysis

The statistical significance (LSD) of the treatments effect was estimated by the one-way analysis of variance (ANOVA) (Gomez and Gomez, 1964). Calculations were carried out at a significance level $P = .05$ using the Co-State software Package (Ver. 6.311), a product of Cohort software Inc., Berkley, California.

Results and Discussion

Germination of wheat seeds after soaking in the studied solutions

Table 2 indicates that soaking of wheat seeds in the studied solutions increased their moisture content (%) in the order GA3 (56.71) > K-H (51.35) > HA (50.28) compared to the control distilled water (46.88). Soaking in SA decreased the seed moisture (%) to 42.77% with no germination on filter paper. The most enhanced germination could be observed for HA followed by K-H then the GA3 compared to the control (Farid et al., 2018).

Yield and yield components

Soaking wheat seeds in aqueous solution of GA3, HA, K-H and SA affected the estimated yield and yield components but variation was almost non-significant. Table 3 indicates that the wheat yield (t ha^{-1}) increased by 4.57% for GA3 treatment and by 1.58% for K-H and SA while decreased by 7.65% for the HA treatment compared with the control. In addition, the seed yield (t ha^{-1}) increased by 8.01, 0.7 and 0.28% for K-H, GA3 and SA, respectively, but decreased by 3.77% for HA compared with control. The 1000-seed weight (g) increased by 3.36% for GA3, 0.99% for HA and SA, and 0.4% for K-H. Shelling percentage increased significantly by 6.29 for K-H only and increased non-significantly by 4.18% for HA while decreased by 3.73 and 1.3% for GA3 and SA, respectively. Previous studies indicated that treatment of wheat plants by some solutions like 0.05 mM SA or 0.8% $ZnSO_4$ affects wheat shelling percentage. This may be due to changes phytohormones levels in wheat seedlings that increase cell division within the apical meristem of seedling roots (Shakirova et al., 2003 and Hassanein et al., 2019).

Effect of different treatments on the soil available

TABLE 2. Swelling and germination of wheat seeds after soaking in treatments

Treatment					
	C	***GA3***	***HA***	***K-H***	***SA***
Swelled wt., g	1.60	1.64	1.77	1.85	1.66
Dry biomass, g	0.85	0.71	0.88	0.90	0.95
Moisture, %	46.88	56.71	50.28	51.35	42.77

TABLE 3. Yield and some yield components

Treatment	Yield, t ha^{-1}	Seed yield, t ha^{-1}	1000-seed wt., g	Shelling, %
C	12.03a	5.355a	50.6 a	44.52bc
GA3	12.58 a	5.393 a	52.3 a	42.86c
HA	11.11 a	5.153 a	51.1 a	46.38ab
K-H	12.22 a	5.784 a	50.8 a	47.32a
SA	12.22 a	5.370 a	51.1 a	43.94c
L.S.D $_{5\%}$	2.06	1.68	2.06	2.06
Significance of factor	ns	ns	ns	**

N, P and K (mg kg-1) and their content in seeds (g kg-1)

The obtained results of N, P and K contents in soil and seeds showed significant variation compared to the control treatment. Data presented in Table 4 shows the available N, P and K contents (mg kg^{-1}) in the studied soil due to soaking seeds before cultivation in studied solutions. Available N increased by 4.17% for HA and SA and significantly by 7.5% for GA3 but decreased significantly by 12.5% for K-H. Available P increased by 3.89% for GA3 but decreased by 1.56% for HA and significantly decreased by 17.12 and 11.67% for K-H and SA, respectively. Available K increased significantly by 26.32% and 5.27% for SA and K-H, respectively, which may be due to added K from humates. It decreased significantly by 10.52% for HA and by 51.05% for GA3.

Since all treatments received equal rates of applied N, P and K fertilizers, differences in the soil available nutrients may be attributed to the uptake by plant from soil affected by soaking wheat seeds in different solutions. Physiological processes in plant, which control nutrient uptake, are affected by variable levels of phytohormones in wheat seedling induced by soaking in aqueous solutions of GA3, HA, K-H and SA (Shakirova et al., 2003). Decreased available N (mg kg^{-1}**)** observed for the K-H treatment is accompanied by increased total content of N (g kg^{-1}) in seeds. Oppositely, increased available N (mg kg^{-1}**)** observed for GA3 and HA treatments, is accompanied by decreased total content of N (g kg^{-1}) in seeds. Table 4 shows an additional increase in the available-N more than the control as well as decreased available P and/or K that is not accompanied by increase in the total P or K in seeds. This may be caused by interaction between applied N, P or K nutrients with functional –OH groups of GA3, HA or SA particles coating the sown seeds (Fig. 1) and formation of organic compounds not absorbed by plant.

Data presented in Table 4 showed that there were no significant differences between total P and K contents. However, N showed a different trend, total seed N contents (mg kg^{-1}) decreased significantly by 14.7% for HA treatment. The total seed N (mg kg^{-1}) increased by 7.32% for SA. The decrease in total P (as %) was in the order of GA3 (11.96) > SA (7.98) > K-H (7.06) > HA (4.29). Additionally, the decrease in total K recorded the highest reduction value by 4.85% for GA3 followed by 3.3, 1.76 and 1.32% for HA, SA, and K-H treatments, respectively.

Soil available Si and its uptake as affected by different treatments

Soaking wheat seeds in the studied organic solutions before cultivation significantly affected the Si-status in both soil and plant, in terms of soil available, seed total and Si-uptake by wheat

TABLE 4. Soil available and seed total contents of N, P and K as affected by different solutions treatments

Treatment	Soil available nutrients, mg kg^{-1}			Nutrients content in seeds, g kg^{-1}		
	N	P	K	N	P	K
C	39.6b	2.57a	88.41c	15.71ab	3.26a	4.54a
GA3	42.57a	2.67a	69.8e	14.79bc	2.87a	4.32a
HA	41.25ab	2.53a	79.11d	13.40c	3.12a	4.39a
K-H	34.65c	2.13b	93.07b	15.71ab	3.03a	4.48a
SA	41.25ab	2.27b	111.68a	16.86a	3.00a	4.46a
L.S.D $_{5\%}$	2.06	0.17	1.68	1.68	1.68	2.06
Significance	***	***	***	*	ns	ns

TABLE 5. Soil available Si (mg kg^{-1}), seed total Si (g kg^{-1}) and Si uptake from soil (g kg^{-1} soil) affected by different treatments

Treatment	Soil available Si, mg kg^{-1}	Total Si in seeds, g kg^{-1}	Si uptake by plants, g kg^{-1} soil
C	8.21a	22c	4.95c
GA3	6.29c	176a	39.87a
HA	6.51c	107b	23.16b
K-H	7.11bc	17c	4.13c
SA	7.59ab	170a	38.35a
L.S.D 5%	1.03	21	1.68
Significance	*	***	***

seed as shown in Table 5. Compared to the control, available Si in soil (mg kg^{-1}) significantly decreased (as %) in the order GA3 by 23.39 > HA by 20.71 > K-H by 13.4 > SA by 7.55 (non-significant).

Total Si (g kg^{-1}) content in wheat seeds increased significantly (as %) in the order of GA3 (700) > SA (672.73)> HA (386.36); whilst Si contents in the seeds of K-H treatment decreased by 22.73%. Also, seed Si uptake (g kg^{-1} soil) increased significantly by 705.78% for GA3, 675.03% for SA and 368.1% for HA, while decreased significantly by 16.54% for K-H treatment. Data indicate luxury Si consumption by seeds due to seed soaking in the studied PGRs solutions including GA3, SA and HA. The increase/decrease in the available Si in soil is accompanied by similar variation in the total Si in seeds. This behavior may be caused by the physiological effect of growth regulators on soaked seeds that induces nutrient uptake from soil solution. It is more pronounced for Si due to its role in the plant physiology so that it is more affected by soaking seeds in PGRs. The K-H solution may exhibit a limited abnormal effect on soaked seeds and more controlled uptake of nutrients by plant.

Effect of soaking treatments on Si, N, P and K in soil (mg kg-1) and in seeds (g kg-1)

The C/N ratio of soil may indicate its need to add organic matter (OM) and/or nitrogen (N). Also, some authors referred to that Si-rich species generally have low calcium concentrations and mentioned proposed criteria to differentiate plants. “Accumulators” have a Si concentration over 1% and a [Si]/[Ca] ratio >1, “Excluders” have a Si concentration below 0.5% and a [Si]/[Ca] ratio <0.5 while plants that do not meet these criteria are called “intermediates.” (Guntzer et al., 2012). In the same manner, the ratio between available Si, N, P and K can be suggested to define their equilibrium in soil and uptake by plant affected by different treatments taking into consideration the improved quality parameters. Table 6 presents the values of Si/N, Si/P, and Si/K ratios that may be used as guide for specifying optimum nutrient ratio in both soil and plant to compare the studied treatments.

Maximum seed yield (t ha^{-1}) and the most significant shelling (%) in the present study were obtained by soaking wheat seeds in K-H solution (Table 3). Otherwise, soaking seeds in GA3, HA and SA solutions can be considered less efficient for the estimated yield parameters of wheat. Optimal nutrient uptake by plant was less deteriorated by soaking in K-H than in GA3, HA and SA solutions. Table 6 indicates a distinguishable ratio between both available and total Si and N, P and/or K for the K-H treatment compared with other treatments. They are 0.205, 3.34, 0.076 and 1.08, 5.61, 3.79 for available and total Si/N, Si/P and Si/K, respectively.

On the other hand, the GA3 treatment that exhibited the minimum shelling (%) compared to the K-H in the present study (Table 3), showed the minimum value of the available Si/N (0.148) and Si/P (2.36) ratio. It showed also the maximum value of total Si/N (11.90), Si/P (61.32) and Si/K (40.74) ratio compared to the K-H. It can be concluded that further decrease in the available ratios and/or further increase in the total ratios than the mentioned values may adversely affect wheat yield and yield parameters. Imbalanced nutrients result in an inhibition of yield and quality of cultivated wheat as mentioned in some studies on the effect of Si availability on biomass production, grain yield, nutrient status and nutrient use efficiency for wheat. It was found that Si improves N use efficiency and is involved in C and P metabolism with subsequent effects on nutrient stoichiometry of wheat as a major staple crop (Neu et al., 2017 and Greger et al., 2018).

TABLE 6. Ratio between available and total nutrient (Si, N, P and K) content as affected by different soaking solutions

Treatment	Ratio between available nutrient in seeds			Ratio between total nutrient in seeds		
	Si/N	Si/P	Si/K	Si/N	Si/P	Si/K
C	0.207	3.19	0.093	1.40	6.75	4.85
GA3	0.148	2.36	0.090	11.90	61.32	40.74
HA	0.158	2.57	0.082	7.99	34.29	24.37
K-H	0.205	3.34	0.076	1.08	5.61	3.79
SA	0.184	3.34	0.068	10.08	56.67	38.12

The present work studies the response of one wheat variety to soaking in aqueous solution of GA3, HA, K-H and SA. Many differences between treatments can be related to their effect on the early germination of wheat. Some studies have suggested that soaking of different wheat varieties in water indicated variable behavior for water imbibitions during the first 12 hr of soaking. Germination potential improved by drying the soaked seed may be attributed to the hydrolytic processes during presoaking. Simple sugars were released and utilized immediately for synthesis, upon germination (Ahmad *et al.,* 1998). Differences in the chemical structure in Fig. 1 for GA3, HA, K-H and SA showed different osmotic effects on wheat seeds when soaked in their aqueous solutions.

Additionally, the PGRs of GA3, HA, K-H and SA are expected to simulate some hormonal moieties in wheat seeds during soaking and before sowing (Shakirova et al., 2003). Compared with the control, SA showed decreased moisture content of seeds 42.77% and suppressed early germination. Gibberellic acid maximally increased seed moisture up to 56.71% but showed weak germination. This may be caused by suffocated germinating embryo due to excess water as mentioned by Ahmad *et al.* (1998). Humic acid and K-H strongly improved seed germination. Ionization degree in aqueous solution produces chargeable species from different acids: GA3, HA and SA while K-H is the water soluble potassium salt of humic acid dissociates into K^+ and humate. Wheat seeds are surrounded by a thin layer of the electrolyte and swell due to the osmotic pressure around it. It is believed that it influences the proline accumulation that is thought to be an osmo-regulator in germinating wheat seeds. The seeds coat may be ruptured so that allows oxygen or some other requisite for germination to flow (Shull, 1913 and Sharon et al., 2016).

It is not likely that bulky gibberellate, humate or salicylate can penetrate soaked seeds. It was previously stated that pre-soaking in GA3 and proline was effective in promoting germination and increasing α-amylase expression. Wetting accelerates some of the early metabolic processes such as synthesis of adenosine triphosphate, uridine diphosphate hexose, hexose phosphate, uridine triphosphate and α-amylase (Sultana et al., 2000). Plants treated by poly ethylene glycol (PEG) had early senescence processes for synthesis of ethylene, ROS, per-oxidation of membrane lipids and decrease in chlorophyll content are induced (Abbas et al., 2014). Germination and root growth may be preceded at a reduced rate under decreasing water potential. This was likely due to an inhibition of gibberellic acid-induced α-amylase synthesis similar to that noted in barley aleurone layers (Walter et al., 1981 and Cairns & de Villiers, 2019).

Salicylic acid (SA) may have profound effects on plant growth and development play a role in regulating a number of physiological processes in plants. In this study, although SA showed no early germination compared to GA3, HA and SA, no significant variation observed in the estimated yield (t ha^{-1}) or yield components. Studies have defined that pretreatment of seeds with dilute solutions of SA under drought stress caused an increase in germination percentage (Fateh et al., 2012).

The most pronounced effect of the studied treatments can be observed for the Si-status. Table 5 showed that harvested wheat seeds of some treatments obtained extremely high Si-content Si (g kg^{-1}) compared to the control and K-H treatment. Soaking seeds in GA3, HA or SA significantly raised absorbed Si in the harvested seeds by 700%, 672.73% and 386.36%, respectively, compared to control. Silicon plays a physiological role in cereals generally and in Si-accumulators like wheat especially. Since PGRs like GA3, HA and SA affect the plant physiologically, they may highly accelerate Si uptake by wheat seeds to the luxury consumption levels or even above three-fold maximum limit of Si content. High Si-accumulators like wheat often contain 1 to 3% Si and contain 10 to 100 g Si kg^{-1} dry weight (Walsh et al., 2018). Dissociation of the mentioned acids may enhance the dissolution of Si from different sources within soil matrix to form plant available Si species which are highly absorbed by wheat. Additionally, pre-soaking in such acid solution may promote Si-transporters or Si-gene responsible so that activate Si-uptake mechanism (Mayland et al., 1991 and Liang et al., 2013).

A promising effect was observed in the present study for K-H being more environment and health friendly. Pre-soaking seeds in the K-H salt solution enhanced seed germination maximum increase in the seed yield (t ha^{-1}) by 8.01%, and significant increase in shelling by 6.29%. This can attributed to a more balanced effect on nutrient availability and controlled uptake of N, P, K and Si (Selim et al., 2010). Potassium humate can be recommended for soaking wheat seeds before cultivation and more preferable than GA3, HA, and SA for health aspects (Wang et al., 2011).

Conclusion

Soaking of wheat seeds before cultivation in aqueous solutions of GA3, HA, K-H and SA affected the wheat yield (t ha^{-1}) and the estimated yield components but not significantly. Significant effect was found on soil available N, P, K and Si-status may be due to significant variation in nutrient uptake from soil. The studied PGRs may affect the wheat seed physiologically and result in a disrupted nutrient uptake including N, P, K and Si. Pre-soaking in K-H solution can be recommended as it enhanced wheat seed germination, showed maximum increase in the seed yield (t ha^{-1}) by 8.01%, and significant increase in shelling by 6.29%. This can attributed to a more balanced and controlled effect on the uptake of N, P, K and Si.

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Compete of Interest

The authors declare no compete of interest.

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تأثير نقع البذور فى بعض منظمات النمو على القمح النامى فى التربة الرملية

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أجريت تجربة حقلية بحثية لدراسة تأثير نقع حبوب القمح قبل الزراعة فى محاليل مائية من : حمض الجبريليك GA3 (٢ جم/لتر) - حمض الساليساليك SA– حمض الهيوميك HA– هيومات البوتاسيوم K-H (٦ جم/لتر لكل منهم) على إنتاجية القمح تحت ظروف التربة الرملية . أقصى زيادة فى إنتاجية القمح (طن/هكتار) كانت لمعاملة GA3 بنسبة ٤,٥٧٪ بينما إنخفضت بنسبة ٧,٦٥٪ لمعاملة HA بالمقارنة مع الكنترول. وقد زادت إنتاجية الحبوب (طن/هكتار) بنسبة ٨,٠١٪ لمعاملة K-H لكنها إنخفضت بنسبة ٣,٧٧٪ لمعاملة HA . وكانت هناك زيادة معنوية فى نسبة الإمتلاء (Shelling, %) بنسبة ٦,٢٩٪ لمعاملة K-H فقط لكنها إنخفضت بنسبة ٣,٧٣٪ لمعاملة GA3 . وقد أثرت المعاملات تأثيرا معنويا على تركيز كل من السيليكون Si الميسر فى التربة والكلى فى حبوب القمح والممتص بواسطة حبوب القمح , حيث إنخفض Si الميسر فى التربة (مج/كجم) معنويا بالترتيب : GA3 بنسبة ٢٣,٣٩٪ > HA بنسبة ٢٠,٧١٪ > K-H بنسبة ١٣,٤٪ > SA بنسبة ٧,٥٥٪ . محتوى السيليكون Si الكلى (جم/كجم) فى حبوب القمح بلغ زيادة معنوية بالترتيب GA3 بنسبة ٧٠٠٪ > SA بنسبة ٦٧٢,٧٣٪ > HA بنسبة ٣٨٦,٣٦٪ لكنه إنخفض ب K-H بنسبة ٢٢,٧٣٪ والتى إظهرت إنخفاضا معنويا فى إمتصاص السيليكون Si-uptake بنسبة ١٦,٥٤٪ . تبين أن محاليل منظمات النمو قيد الدراسة ربما تؤثر فيسيولوجيا على حبوب القمح التى تم نقعها وربما أدت إلى إضطراب فى إمتصاص المغذيات شاملة النيتروجين والفوسفور والبوتاسيوم (N,P,K) والسيليكون (Si) , ومع ذلك فإن نقع حبوب القمح فى محلول K-H يمكن أن يوصى به ويكون مفضلا على GA3 و HA وSA وذلك للإعتبارت الصحية ولتجنب الإمتصاص المفرط لعنصر السيليكون Si .