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Growth, yield and nutrient status of wheat plants as affected by potassium and iron foliar application in sandy soil

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Abstract: This study was carried out to determine the effects of potassium and different levels of iron foliar applications on growth, yield and nutrient statusof wheat plant grown in sandy soil. Two field experiments were conducted during two successive winter seasons of 2012/2013 and 2013/2014 in Research and Production Station, National Research Centre, Al-Nubaria District, Al Behaira Governorate, Egypt. The experimental design was split-plot in randomized complete block design with three replicates. This experiment includes six treatments in three replicates which were control (without K and Fe), foliar spraying with K (10000 ppm), Fe (500& 1000 ppm), K (10000 ppm) + Fe (500 ppm) and foliar spray with K (10000 ppm) + Fe(1000 ppm). The evidences provided by this experiment indicated that either potassium or iron applications lonely or combined had significant effects on growth , yield and nutrient concentration of wheat leaves, straw and grains and the highest record obtained by low level of Fe alone or combined with K.
Key words: wheat, potassium, iron,foliar spraying, nutrient status, yield and yield components.

Introduction

Wheat is considered as the major cereal crop in the world in respect of the cultivated area and total production. It provides an almost 20 % of food calories for people in the world as well as in Egypt. Increasing wheat production is the ultimate goal to reduce the wide gap between production and consumption**.**

Balanced nutrition of the plants is one of the main factors that affects the yield and quality of the plants. Potassium (K) is regarded as one of the major nutrient element which affects the yield and quality of grain and fruits. This nutrient plays an essential role in plant growth and metabolism[1,2]. It activates enzymes, serves as an osmoticum to maintain tissue turgor pressure, regulates the opening and closing of stomata, and balances the charge of anions[3,4].

Another essential nutrient is iron (Fe), it is required for a healthy growth and life cycle completion[5]. Fe plays a role in many plant functions in plant growth and development. This function includes chlorophyll synthesis, thylakoid synthesis and chloroplast development[6]. It also plays a role in energy transfer within the plant, it is a constituent of certain enzymes and proteins, it has an essential role in plant growth[5], and it enters root cells, involved in nitrogen fixation.Fe plays an active role in several enzymatic activities of photosynthesis as well as respiration.

According to the limitations of soil usage of micro-nutrients (such as consolidation and residual effects) foliar spraying or leaf feeding is one of the effective ways in resolve plants food requirement to micro-nutrients[7].Exogenous application through foliar spray of essential elements like K, Fe was found promising to enhance the growth at different parameters[8].In this respect, it was found that foliar application of nutrients on

wheat crop has had significant positive effects on plant growth and yield parameters[9,6,10].

It is evident from the above that use of both K and Fe nutrients is an important factor for wheat crop cultivation and these essential nutrients should be used in proper doses for increasing crop production. Thus, the present investigation was undertaken to study the effect of added potassium and iron on different growth parameters, nutrient status, grain and straw yields and quality.

Materials and Methods

Two field experiments were conducted during two successive winter seasons of 2012/2013 and 2013/2014 in Research and Production Station, National Research Centre, Al-Nubaria District, Al Behaira Governorate, Egypt.

This experiment include six treatments in three replicates which were control (without K and Fe), foliar spraying with potassium (K) (10000 ppm), as well as iron (Fe) (500 & 1000 ppm), K (10000 ppm) + Fe (500 ppm)and K (10000 ppm) + Fe(1000 ppm).

Wheat variety Masry 1 was sown during the winter seasons of 2012/2013 and 2013/2014 on 16th November in both seasons in sandy soil. The physico-chemical properties of the used soil are presented in Table (1) using the standard method described by[11]. The soil is sandy in texture and has pH 7.4, EC 0.3 dSm^{-1}, organic matter 0.3%, $CaCO_3$ 1.30%.

Table (1): Mechanical and physic-chemical propertiesof the experimental soil (average of 2008/2009 and 2009/2010 seasons)

Mechanical analysis %			Texture	Physical properties				Macronutrients (mg/100g)				Micronutrients (ppm)			
Sand	Silt	Clay		pH	E.C mS/m	$CaCO_3$	O.M %	P	K	Ca	Mg	Fe	Mn	Zn	Cu
92.3	3.1	4.6	Sandy	7.4	0.3	1.3	0.3	3.0	19.8	62	14.7	3.8	1.8	0.72	0.6

After 30 days from sowing each treatment were sprayed with water or one of the following aquas solutions containing 10000 ppm K as potassium sulphate, 500 and 1000 ppm Fe as ferrous sulphate, , mixture of K (10000 ppm) +Fe (500 ppm) and mixture ofK (10000 ppm) +Fe (1000 ppm).

Thirty days after foliar spraying (60days) from sowing, representative sample from three replicates was taken from every treatment to determine fresh and dry weight of leaves and stems and determine the following nutrient constituents N,P,K,Fe,Ca,Mg,Fe, Mn,Zn and Cu in the leaves.

At harvest time, wheat plants were collected and the following characters were determined, plant height, No of tillers,spike length, weight of one spike, weight of grains per one spike, No of spikes per m^2, weight of spikes per m^2, grain yield per m^2, biological yield per m^2, grain yield per feddan (feddan=4200m^2), biological yield per feddan , straw yield per feddanand weight of 1000 grains. Wheat plant shoots and grains after harvest were analyzed for macro and micronutrients. Plant samples were washed in sequence with tap water, 0.01 N Hcl- acidified bidistilled and bidistilled water, respectively, and then dried in a ventilated oven at 70 ^oC to constant weight. The plant samples were ground and representative samples from grains and straw were taken to determine the following nutrient constituents N,P,K,Fe,Ca,Mg,Mn and Zn.Macro and micronutrients were extracted using the dry ashing digestion method[12].

Total nitrogen content was determined using the method described by[13].Phosphorus was determined calorimetrically according to the method described by[14]. Micronutrients and Mg was measured using Atomic Absorption Spectrophotometer (PerkinElmer 100 B). Potassium and calcium were measured in the digested suspension using the Flame photometer, (Eppendorof, DR Lang) according to the methods described by[12].

Statistical analysis:

The experimental design was split-plot in randomized complete block design with three replicates. The results were submitted to analysis of variance according to[14]. Differences among treatment means were determined using the LSD test at a significance level of 0.05.

Results and Discusion

I-Effect of foliar application of potassium and iron on growth:

a- Plant height:

Data presented in Table (2) show that foliar spraying of K has promoting effect on plant height. These results confirmed by the findings of[16] who reported that application of K fertilization affected maize development, the plants became taller and greener, also[8] reported that height of tomato plant is significantly increased by the application of K. The promoting effect of K on plant height may be attributed tothe direct effect of K on plant growth and development[17].

Table 2: Effect of foliar application of potassium and iron on growth of wheat plants.

Treatments	Plant height cm/plant	Leaves		Stems	
		fresh wt.	dry wt.	fresh wt.	dry wt.
		(g/plant)		(g/plant)	
Control	68.00	22.67	7.56	2.52	0.84
Fe (500 ppm)	85.67	28.56	9.52	3.17	1.06
Fe (1000 ppm)	81.00	27.00	9.00	3.00	1.00
K (10000 ppm)	88.17	29.39	9.80	3.27	1.09
K+ Fe (500 ppm)	88.33	29.44	9.81	3.27	1.09
K+ Fe (1000 ppm)	86.83	28.94	9.65	3.22	1.07
LSD 5%	**0.41**	**0.45**	**0.04**	**0.43**	**0.16**

Data in table (2) also shows that foliar spraying of Fe increased plant height while the least values were observed with unsprayed wheat plants. These results were supported by[16,8,18]Such effect of iron on plant height may be attributed to the role ofFe in energy transfer within the plant, component of enzymes and proteins, and involved in nitrogen fixation and enters in root cells these reasons may be leads to an increase in plant height[19,5,20,16] reported that the positive effect of iron could be explained on a basis that Fe had optimistic effect on wheat growth parameters like plant height .

As regards the effect of foliar spraying with mixture of K and Fe on plant height, results clearly indicate that treatments receiving both K and Fe showed their significance over control, theseresults were confirmed with that obtained by[8] who reported that height of tomato plant is significantly increased by the application of K and Fe individually or in mixture and the maximum shoot length was observed in plants sprayed with mixture (K+Fe).

b- Fresh and dry weight of leaves and stem:

The same table (Table 2) show that both of K or Fe individually significantly increased fresh and dry weight of leaves and stem, these results was supported with the findings obtained by[16] who reported that K levels had positive effects on the dry weight of maize leaves.Also,[8]recorded that application of either K or Fe on tomato plants induce significant increase in vegetative biomass of shoot, and they added that the dry biomass of shoot followed same trend as shown by fresh shoot biomass, also, concluded that foliar application of potassium and iron alone contributed towards increase all the studied growth parameters.

The effect of the interaction between foliar spray with K and Fe on fresh and dry weights as indicated in Table (2) revealed that more fresh and dry weights were detected with the dual application as compared with the individual spray ones. The results also indicated that foliar spray with K (10000 ppm) + Fe (500 ppm) surpassed of all other treatments .The fresh and dry weight was (29.4 and 9.81 g/plant, respectively) for the leaves and (3.27 and 1.09 g/plant) for the stem. Similar results were obtained by[21,22]. In this respect[8] reported thatthe combined treatment of K and Fe is more effective than individual application.

It can be concluded that such enhancement effect of foliar spraying with K and Fe especially under low level of Fe might be attributed to the favorable influence of these nutrient on metabolism and biological activity and its stimulating effect on photosynthetic pigments and enzyme activity which in turn encourage vegetative growth of plants[23].

c- Nutrient contents of the leaves:

According to the data presented in Table (3) results indicate that K effect surpassed the effect of iron spraying on most nutrients uptake as compared with un-sprayed plants Such pronounced effect of K on nutrients uptake was reported by[24,25] who reported that K has direct synergistic relationships with iron and manganese.

Table 3 : Chemical composition of leaves as affected by foliar application of Fe and K

Treatments	N	P	K	Ca	Mg	Fe	Zn	Mn	Cu
	%					(ppm)			
Control	1.350	0.138	1.475	0.185	0.240	65.250	34.500	12.175	2.125
Fe (500 ppm)	2.063	0.188	2.690	0.293	0.320	112.500	33.500	8.975	2.650
Fe (1000 ppm)	1.278	0.220	1.845	0.185	0.205	80.750	39.250	10.050	4.225
K (10000 ppm)	2.473	0.278	3.540	0.293	0.345	161.250	54.250	12.175	14.275
K+ Fe (500 ppm)	1.680	0.233	2.210	0.203	0.233	78.750	37.500	13.750	8.450
K+ Fe (1000 ppm)	0.943	0.230	2.345	0.145	0.193	95.750	33.500	10.575	11.625
LSD 5%	**0.291**	**0.002**	**0.194**	**0.001**	**0.003**	**0.694**	**1.105**	**0.058**	**0.099**

Also data in Table (3) indicate that response to foliar spraying of Fe on nutrient contentsof wheat leaves differ according to its concentrations. The data show that foliar spraying with Fe (500 ppm) significantly increased macro nutrient contents in the leaves (N,P,K,Ca, Mg, Fe, Mn, Znand Cu). Under high concentration of Fe spraying (1000 ppm) N, Ca,Mg, Fe and Mn decreased as compared with control. The same table also show that N, K, Ca,Mg and Fe concentration decreased with high level of Fe foliar spraying as compared with low level .These results were confirmed by the finding obtained by [16,26] who reported that the high dose of iron decreased the K, N and P contents in maize leaves.

Table (3) also show that K and Fe interaction increased most macro and micro-nutrients concentration as compared with control treatment. The same table also shows K and Fe interaction decreased most macro and micro- nutrients concentration as compared with foliar spray with K only. These results were in the same line with those obtained by [16] who mentioned that addition of increasing levels of K and Feaffected the N, P, Mg and Ca concentrations negatively in maize leaves.

II-Effect of foliar application of potassium and iron on wheat yield:

a- Yield and yield components:

Regarding the effect of Potassium on yield and yield components the data presented in Table (4) revealed that foliar spraying with K significantly increased most yield and yield components i.e plant height, No. of tillers, spikes character and yield of straw, grain and biological yield as well as 1000-grain weight as compared with un-sprayed plants. These results are in harmony with those obtained by[27] on mungbean and[24]on wheat who recordedthat application of potassium increased dry matter, 1000-grain weight and number of tillers. Also,[22] reported that using Kcauses increase of grain yield, 1000-grain weight and number grain as compared with control treatment.

Data presented in Table (4) indicate that foliar application of Fe increased plant height,number of tillers/ plant. The same Table also show that spike length /plant, spikes weight/ plant, number of grain/spike, spike weight and grain weight/spike also increased by foliar application of Fe under both levels but such effect was more pronounced under low level (500 ppm). Similar results were obtained by[10]. Also, [6] reported that application of Fe significantly increased number of spikes /plant, number of grain /spike and 1000 grain weight, and wheat plants treated with low level of Fe gave the highest number of spikes /plant as compared with the other treatments.Also,[19] indicate that application of Fe also showed a significant response of wheat at lower rates but high rates of Fe reduced/ did not affect the growth and yield contributing parameters of crop. In this respect,[18]added that plant height, number of leaves and number of tillers were significantly increased through application of iron.

Table 4: Effect of foliar application of potassium and iron on yield of wheat plants.

Treatments	Plant height (cm)	No. of tillers (No./ m^2)	Spike length (cm)	Spike weight (g/spike)	Grains weight (g/spike)	Spikes No. (No./ m2)	Spikes wt. (kg /m^2)	Grain yield (kg /m^2)	Bio. yield (kg/m^2)	Grain yield (kg/fed	Bio. Yield (kg/fed)	Straw yield (kg/fed)	1000-grain weight (g)
Control	78.33	570.67	8.00	2.51	1.32	536.00	1.12	0.54	1.99	2287.6	8344.0	6056.4	44.2
Fe (500 ppm)	84.67	688.00	10.00	3.22	2.53	721.33	1.51	0.87	2.55	3635.8	10724.0	7088.2	46.0
Fe (1000 ppm)	87.00	576.00	7.67	2.21	1.53	598.00	1.18	0.65	2.05	2748.2	8596.0	5847.8	46.4
K (10000 ppm)	94.33	645.33	10.17	2.84	2.13	712.00	1.40	0.83	2.42	3470.6	10150.0	6679.4	46.5
K+ Fe (500 ppm)	96.33	736.00	10.17	2.94	2.64	764.00	1.54	0.93	2.65	3887.8	11116.0	7228.2	46.9
K+ Fe (1000 ppm)	93.33	564.67	8.33	2.52	1.94	556.67	1.20	0.72	2.38	3015.6	9982.0	6966.4	47.6
LSD 5%	**2.45**	**52.75**	**2.47**	**0.18**	**0.09**	**30.32**	**0.06**	**0.03**	**0.15**	**145.67**	**616.80**	**641.00**	**0.40**

The experimental results presented in Table (4) also revealed that foliar spraying with Fe resulted in significant increase in number of spikes/m^2, spikes weight kg/m^2, grain yield kg/m^2 and biological yield kg/m^2.Consequently these results reflected in high records in grain yield, straw yield and biological yield kg/feddan,the same trend was observed for 1000-grain weight. These results were in agreement with the findings obtained by[19,22] who reported that iron increased the grains yield. In general, there are various evidences that Fe foliar application increases fruit quality and yield in many crops[28].

Interaction of potassium and iron spray on yield components was illustrated in Table (4).The obtained results obliviously indicate that applying potassium and iron increased most of the studied characters as compared with control . Such effect was more pronounced for weight of spikes, grain yield and biological yield/m^2 and consequently reflected on the weight /feddan. Such effect was pronounced with the interaction of K and the lower level of Fe (500 ppm).The obtained results greatly indicated that the maximum grain , straw yield and biological yield /feddan (3887.8, 11116.0 and 7228.2 kg / feddan, respectively) recorded by wheat plants sprayed with both K and Fe at concentration of 500 ppm . Such promoting effect of the dual application of K and Fe demonstrated by[8]. In this respect,[22] reported that the most level of seed yield, biological yield,weight of thousand kernels, and number of seeds per ear has been earned from the use of potassium and iron together.

Such pronouncing effect of K and Fe on wheat yield may be attributed to the effect of Iron in formation of chlorophyll, and increasing photosynthetic products rate, photosynthetic material devoted to grain and the grain weight[29]. Also,[6] also added that this element can be easily sprayed on leaf, thus, leaves chlorophyll concentration increased which in turn, lead to an increase in plant height and yield. Potassium function also on increasing division and growth cell and increasing on photosynthesis process and transferring photosynthesis material, wasting store decreasing some deal and transferring photosynthesis material to grains was causing filling grain and increasing size grain and resultant is increase of 1000-grain weight.[30,24]

b-Effect on nutrient contents:

Nutrient contents of straw:

Effect of potassium spray on the nutrient contents of wheat straw as indicated in Table (5) show that spraying of K has pronounced effect on uptake of most studied nutrients. These results coincide by those obtained by[24,31] who reported that increase in K application increased K and Zn content of plants. However, [16]reported thatadequate K may be required for the efficient use of both Fe and other macronutrients.

Table 5 :Nutrientcontentsof straw as affected by foliar application of K and Fe

Treatments	N	P	K	Ca	Mg	Fe	Zn	Mn
	%					(ppm)		
control	0.760	0.180	2.055	3.048	0.320	65.500	50.250	12.175
Fe (500 ppm)	0.795	0.275	2.068	5.040	0.423	95.250	69.750	11.100
Fe (1000 ppm)	0.750	0.258	2.173	5.090	0.463	99.250	71.750	12.175
K (10000 ppm)	0.835	0.373	2.365	4.923	0.433	127.750	82.750	13.200
K+ Fe (500 ppm)	0.770	0.308	2.015	3.763	0.295	97.250	66.500	14.800
K+ Fe (1000 ppm)	0.855	0.373	2.083	3.475	0.270	92.000	68.250	13.750
LSD 5%	**0.002**	**0.006**	**0.003**	**0.099**	**0.002**	**0.399**	**1.205**	**0.282**

Nutrients concentration of wheat straw as indicated in Table (5) show that iron foliar application under both level significantly increased most of studied nutrients (N,P,K,Ca,Mg,Fe, Mn and Zn) as compared by control. These results confirmed by many investigators[32,33]. In This respect,[33] reported that with increase the Fe levels, Fe concentration in corn plants has increased significantly**.** Also,[34] added that Fe increased Fe, Cu, Mn and Zn in straw.The results by[35]also indicate that the treatments of Fe application had a significant effect on the absorption of potassium.

The data presented in Table (5) also indicate that interaction effects between K and Fe applications on nutrient concentrations was found to be statistically important.The obtained results revealed that N, P and Mn increased by the dual application of K and Fe but K, Ca, Mg , Fe and Zn decreased as compared with foliar spraying with either K or Fe alone. These results are in full agreement with those obtained by[36].

Nutrient contents of grains:

As for the effect of foliar application of potassium on mineral concentration of wheat grains the data indicate that foliar spray of potassium increased most of the nutrients but with less effect as compared with those sprayed with Fe (Table 6). On the other hand, potassium spraying increased Fe uptake more than Fe sprayed plants. It is worthy to note that the highest K concentration recorded by wheat plants sprayed with K only. The obtained results confirmed with those findings obtained by[24]who reported that application of potassium increased seed K, Zn, Fe, and protein contents. They also reported that grains K content is significantly correlated with leaf K, Zn grain and Fe contents. Thus, Adequate K may be required for the efficient use of both Fe and other macronutrients[16].

Table 6: Nutrient contents of grains as affected by foliar application of Fe and K

Treatment	N	P	K	Ca	Mg	Fe	Zn	Mn
	%					(ppm)		
control	1.808	0.180	0.128	0.393	0.275	22.000	52.250	15.325
Fe (500 ppm)	2.133	0.338	0.403	0.730	0.113	61.750	55.500	18.500
Fe (1000 ppm)	2.473	0.328	0.518	0.315	0.423	102.000	66.500	20.075
K (10000 ppm)	2.293	0.373	2.365	0.290	0.433	127.750	82.750	13.200
K+ Fe (500 ppm)	2.525	0.335	0.443	0.160	0.330	32.000	54.500	20.625
K+ Fe (1000 ppm)	2.313	0.340	0.535	0.223	0.403	71.500	66.250	21.125
LSD 5%	**0.042**	**0.006**	**0.020**	**0.006**	**0.007**	**1.922**	**1.054**	**0.346**

Iron foliar application has significant effects on the concentration of most studied nutrients(N,P,K,Ca,Mg,Fe,Mn and Zn)in the grains of wheat plants (Table 6). In general, such effect was more obvious under high level of Fe spray (1000 ppm) as compared with un-sprayed plants (Table 6). These results are in harmony with those obtained by[34,33,37].In this respect,[38] stated that use of Fe has an interaction effects on the absorption of other nutrients in the plant tissue.

The results of the study on the effect of foliar application of both potassium and iron on chemical composition of wheat grain indicate that dual application of K and Fe increased most of the studied nutrients as compared with un-sprayed plants (table 6). The data also indicate that there was slight effect of K and Fe foliar application on most nutrient concentration of wheat grain except Mn which increased by dual application more than single application of K and Fe. Similar results obtained by[16].

Conclusion

From the obtained results it can be concluded that the dual foliar application of potassium andiron had a positive effect on growth and yield parameters of wheat crop.It is evident also from the above that use of both K and Fe is an important factor for wheat crop cultivation than individual use and these essential nutrients should be used in proper doses for increasing crop production. From these results it can be assumed that K nutrient interaction improves iron nutrition without directly iron application[36].

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