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Can humic acid replace part of the applied mineral fertilizers? A study on two wheat cultivars grown under calcareous soil conditions

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Abstract: Two field experiments were carried out during the two winter seasons of 2012/2013 and 2013/2014 in the experimental farm of City of Scientific Research and Technological Applications**,** Borg El-Arab City, Alexandria Governorate, Egypt, to study the effect of different combinations of mineral fertilizers and humic acid (100 % mineral fertilizers of NPK, the recommended doses of NPK), (75 % mineral fertilizers of NPK + 1 Kg humic acid/fed.), (50 % mineral fertilizers NPK + 2 Kg humic acid/fed.), (25 % mineral fertilizers NPK + 3 Kg humic acid/fed.), and (3 Kg humic acid/fed.) on two cultivars of wheat (Misr - 1 and Gemmiza-11) under calcareous Soil Conditions. The obtained results indicated that Gemmiza -11cultivar surpassed Misr-1 in plant height; spike length (cm); number of spikelets/spike, number of grain/spike and weight of grain/spike. Whereas Misr-1 cultivar surpassed Gemmiza-11 in number of spikes/m^2, weight of 100 grains(g) as well as grain, straw and biological yields (tons/fed), protein % and protein yield (kg/fed).

The interaction between Misr-1 and 75% NPK+ 1 kg humic acid produced the highest values of biological yield (11.57 tons/fed.) and number of spikes/m^2 (573). However, the interaction between Gemmiza-11 and 75% NPK+1 kg humic acid produced the highest values of weight of 100 grain (5.73 g), number of grain/spike (80.8) and weight of grain/spike (4.39 g).

It can be concluded that humic acid can replace 25 % of mineral fertilizers and produce insignificant increase in grain yield of wheat under calcareous soil conditions.

Key Words: wheat – mineral fertilizers- Humic acid- calcareous soils.

Introduction

Wheat (*Triticum aestivum* L.) is the most important cereal and forage crop all over the world and it is considered the main food crop in Egypt as in many other countries of the world. Furthermore wheat is considered the most important winter crop, because its grains are the main food for the urban and rural societies and its straw is a very important fodder for animal feed, especially during summer. The domestic wheat production in 2013 season was estimated by 8.7 million tones, whereas the Egyptian national consumption of

wheat is about 17.7 million tons in 2013; there is a great gab between the consumption and production[1]. Egypt imports above five million tons of wheat grains. Unless domestic wheat production increases annually, the deficit will increase, due to the increase birth rate (2%) and present per capita consumption estimated by about 200 kg/year[1]. Increasing wheat production could be possible via two ways: horizontal expansion through increasing the cultivated area with wheat and vertical expansion through the development of new cultivars having the high potentiality and subsequently implementing the proper cultural practices[2]. Egypt utilizes fertilizers at an accelerating rate, due to various factors such as the increase in the cropped area. Consequently, Egypt is considered to be a heavy use of chemical fertilizers, especially N fertilizers then P and K fertilizers. Soil fertility continues to decline because of combined effects of increasing pressure for land use for crop production, inadequate compensation of nutrients exported and lack of nutrients management. Humic acid is one of the major components of humic substances. Humic matter is formed through the chemical and biological humification of plant and animal matter and through the biological activities of microorganisms[3]. The effects of humic substances on plant growth depend on the source and concentration, as well as on the molecular fraction weight of humus. Lower molecular size fraction easily reaches the plasma lemma of plant cells, determining a positive effect on plant growth, that is, the nutrient uptake, especially nitrate. The effects seen on the intermediary metabolism are less understood, but it seems that humic substances may influence both respiration and photosynthesis[4]. Humic substances have a very strong influence on the growth of plant roots. When humic and fulvic acids are applied on the soil, enhancement of root initiation and increased root growth may be observed[5]. The stimulatory effects of humic substances have been directly correlated with the enhanced uptake of macronutrients, such as nitrogen, phosphorus and sulfur[6]. and micronutrients, such as Fe, Zn, Cu and Mn[7]. Humic substances have been reported to influence plant growth both directly and indirectly. The indirect effects of humic compounds on soil fertility include: (i) Increase in the soil microbial population including beneficial microorganisms, (ii) Improved soil structure and (iii) Increase in the cation exchange capacity and the pH buffering capacity of the soil. Directly, humic acid compounds may have various biochemical effects either at cell wall, membrane level or in the cytoplasm, including increased photosynthesis and respiration rates in plants, enhanced protein synthesis and plant hormone-like activity[6]. Humic substances may possibly enhance the uptake of minerals through the stimulation of the microbiological activity. When adequate humic substances are present within the soil, the requirement for nitrogen, phosphorus and potassium fertilizer applications may be reduced[5]. Humic substances are major components of organic matter, often constituting 60 to 70% of the total organic matter[8].

Materials and Methods

Two field experiments were carried out during winter seasons of 2012/2013 and 2013/2014 in the experimental farm of City of Scientific Research and Technological Applications**,** Borg El-Arab City, Alexandria Governorate, Egypt. to study the effect of different combinations of mineral fertilizers and humic acid (100 % mineral fertilizers of NPK, the recommended doses of NPK), (75 % mineral fertilizers NPK + 1 Kg humic acid/fed.), (50 % mineral fertilizers NPK + 2 Kg humic acid/fed.), (25 % mineral fertilizers NPK +3 Kg humic acid/fed.) and (3 Kg humic acid/fed.) on two cultivars of wheat (Misr - 1 and Gemmiza -11) under calcareous soil conditions.

Chemical properties of the soil (Table 1) were analyzed according to (page, *et al.*, 1982). The experimental design was split plot in three replicates and the sub plot area was 10.5 m^2 (1/400 feddan , one feddan = 4200 m^2) it includes 15 rows, 20 cm apart and each of 3.5 m in length. The main plots were devoted to wheat cultivars (Misr - 1 and Gemmiza -11), where mineral fertilizer NPK and humic acid were randomly distributed in sub-plots. Sowing dates of experiments were on late November in both seasons and harvested early May. Grain of the two wheat varieties (Misr - 1 and Gemmiza -11) were obtained from The Ministry of Agriculture, Egypt and were sown at the rate of 75 kg/fed. The humic acid was applied at 30 and 45 days after sowing. N fertilizer was added in the form of ammonium nitrate (33.5% N). Super phosphate fertilizer (15.5 % P_2O_5) was applied before sowing at the rate of 150kg/fed. Potassium fertilizer was applied before sowing (during seedbed preparation) at the rate of 50 kg/fed. in the form of potassium sulphate (48% K_2O). At harvest one square meter of each sub plots was harvested for determining the following:

Plant height (cm), number of spikes/m^2 ,spike length (cm), number of spikelets/spike, number of grain/spike, weight of grain/spike(g), grain yield (tons/fed.), straw yield (tons/fed.), biological yield (tons/fed.) and grain index (100 grains weight).

Crude protein content was determined as the total nitrogen following the micro kjieldhl method according to[9] and then total N content was multiplied by 6.25 to obtain the protein content in grain. Protein yield (kg/fed) = protein % × grain yield/fed.

Statistical analysis

Data were statistically analyzed according to[10]. The combined analysis was conducted for the data of the two seasons according to[11]. The least significant difference (LSD at 5%) was used to compare the means of the treatments.

Table (1): Mechanical and chemical analyses of experimental soil

Sand%	Silt %	Clay %	Soil texture	pH	O.M. %	$CaCO_3$ %	E.C. dS/m	Available nutrients ppm		
								N	P	K
63.05	14.22	20.64	Sandy clay loam	8.24	0.69	30.64	2.2	119	5.1	420

Results and Discussion

Effect of wheat cultivars

Data presented in Tables (2 and 3) indicated that Gemmiza-11 cultivar surpassed Misr-1 in plant height, spike length (cm), number of spikelets/spike, number of grain/spike and weight of grain/spike (g). Whereas Misr-1 significantly surpassed Gemmiza-11 in number of spikes/m^2, grain yield (tons/fed.), straw yield (tons/fed.), weight of 100 grain (g) and biological yield (tons/fed.). The superiority of Misr-1 in number of spikes/m^2, weight of 100 grain (g), grain, straw and biological yields (tons/fed.), protein % and protein yield (kg/fed.), may be due to the difference in the response to the applied treatments between the two cultivars. Previous results reported by[12] and[13] found highest grain yield at optimum fertilizers and attributed more tillers, greatest spike length, grains per spike and heavier grain weight.

Effect of different combinations of mineral fertilizers and humic acid

Data in Tables (2 and 3) indicated that (75% NPK+1 kg humic acid) increased spike length, number of spikelets/spike, number of grain/spike number of spike/m^2, 100 grain weight and weight of grain/spike (g), grain, straw and biological yields (tons/fed.), protein % and protein yield (kg/fed.) as compared to the other treatments. A distinction on the effects of humic acid should be made between indirect and direct effects on plants growth. Many researchers concluded the enhancing effect of humic acid on growth, yield, and nutrient uptake by many crops[14,15,16,17]. Indirect effects are mainly exerted through properties such as: enrichment in soil nutrients, increase of microbial population, higher cation exchange capacity (CEC), and improvement of soil structure; whereas direct effects are various biochemical actions exerted at the cell wall, membrane or cytoplasm and mainly of hormonal nature [18, 19]. The hormone like activities of humic acid is well documented in various papers, in particular auxin, cytokinin and gibberellins like effects[20,21,22,23,24]. These results are in accordance with[25, 26, 27] who concluded that grain yield of maize and cereal crops that increased with application of NPK fertilizer.

Table (2) Effect of varieties, different combinations of mineral fertilizers and humic acid on yield components of wheat (combined analysis of the two seasons).

Treatments varieties	Plant height (cm)	Spike length (cm)	Number of spikelets/ spike	Number of grain/ spike	Weight of grain/ Spike (g)	Number of spikes/m^2
Misr1	70.55	13.05	17.91	65.03	2.95	512.07
Gemmiza11	80.80	15.44	20.69	70.33	3.68	436.00
LSD (5%)	5.36	1.86	1.84	4.76	0.40	63.52
Combinations of mineral fertilizers						
100% NPK	77.38	15.20	19.83	70.43	3.30	476.83
75% NPK+1Kg Humic acid	79.03	16.01	20.27	72.61	3.75	559.83
50% NPK+2Kg Humic acid	77.36	13.8	19.20	67.90	3.22	469.17
25% NPK+3Kg Humic acid	73.68	12.96	19.13	67.52	3.42	421.50
3 Kg Humic acid	70.43	13.25	18.07	59.44	2.90	447.83
LSD (5%)	5.63	2.52	2.02	11.21	0.56	83.71

Table (3) Effect of varieties, different combinations of mineral fertilizers and humic acid on wheat yield (combined analysis of the two seasons).

Treatments varieties	Grain yield (tons/fed.)	Straw yield (tons/fed.)	Biological yield (tons/fed.)	100 grain weight (g)	Protein (%)	Protein Yield kg/fed.
Misr1	2.44	7.83	10.27	5.21	9.85	240.34
Gemmiza11	1.78	5.33	7.11	4.54	9.65	172.63
LSD (5%)	0.295	0.656	0.761	0.314	0.06	9.22
Combinations of mineral fertilizers						
100% NPK	2.13	6.53	8.66	4.69	9.96	201.49
75% NPK+1KgHumic acid	2.65	7.36	10.01	5.12	9.75	258.37
50% NPK+2Kg Humic acid	2.32	7.39	9.72	4.67	9.40	218.08
25% NPK+3KgHumic acid	1.96	6.13	8.11	5.07	9.33	182.87
3 Kg Humic acid	1.51	5.46	6.97	4.84	9.25	139.67
LSD (5%)	0.548	1.127	1.339	0.489	0.08	12.050

Interaction between wheat cultivars and the different combinations of mineral fertilizers and humic acid

Data presented in Tables (4 and 5) indicated that there were significant differences in all the studied characters due to the interaction between wheat cultivars and the combinations of mineral fertilizers and humic acid except for plant height , spikes length, and number of spikelets/spike which were not significantly affected. The interaction between Misr-1 and the combination of 75% NPK and 1 kg humic acid produced the highest number of spikes/m^2 (573), the highest values grain yield (2.96 tons/fed.), straw yield (8.78 tons/fed.), biological yield (11.57 tons/fed.), protein yield (290.17 kg/fed.) and protein (9.8%). The interaction between Gemmiza 11 and the combination of 75% NPK and 1 kg humic acid, produced the highest values of number of grain/spikes (80.8), weight of grain/spike (4.36 g) and 100 grain weight (5.72 g).The results of the current study are in general agreement with those obtained by [28] who pointed out that foliar spray of humic acid substances at 3 to 6 leaf stage significantly increased yield and yield components in common bean. Also, [29] reported significant differences between wheat genotypes in response to humic treatments in terms of economic yield and harvest index. [30] reported that different nitrogen fertilizer produced different responses of wheat which help in modeling grain yield and its components.

Conclusion:

The current study revealed that humic acid can replace 25% of the applied mineral fertilizers to wheat grown under calcareous soil conditions with insignificant increase in grain yield.

Table (4) Interaction effect of varieties and different combinations of mineral fertilizers and humic acid on yield components of wheat.

Treatments		Plant height (cm)	Spike length (cm)	Number of spikelets/ Spike	Number of grain/ spike	Weight of grain/ Spike (g)	Number of spikes/m^2
Misr1	100%NPK	69.37	14.07	19.07	67.80	3.133	453.66
	75%NPK+1KgHumic acid	75.13	13.97	18.80	64.42	3.19	573
	50%NPK+2Kg Humic acid	73.60	12.60	17.87	63	2.28	526.67
	25%NPK+3KgHumic acid	69.73	12.13	18.33	68.12	3.24	486
	3Kg Humic acid	63.93	12.50	15.47	61.82	3.04	521
Gemmiza 11	100%NPK	85.40	16.33	20.6	73.07	3.47	500
	75%NPK+1KgHumic acid	82.93	18.07	21.73	80.80	4.39	546.66
	50%NPK+2Kg Humic acid	81.13	15	20.53	72.80	4.15	401.66
	25%NPK+3KgHumic acid	77.63	13.8	19.93	66.93	3.59	357
	3Kg Humic acids	76.93	14	20.66	58.07	2.77	374.66
LSD (5%)		NS	NS	NS	16.54	0.834	123.44

Table (5) Interaction effect of varieties and different combinations of mineral fertilizers and humic acid on wheat yield.

Treatments		Grain yield (tons/fed.)	Straw yield (tons/fed.)	Biological yield (tons/fed.)	100 grain weight (g)	Protein (%)	Protein Yield kg/fed.
Misr1	100%NPK	2.35	7.73	10.09	4.62	8.72	205.09
	75%NPK+1Kg Humic acid	2.96	8.61	11.57	4.81	9.80	290.17
	50%NPK+2Kg Humic acid	2.56	8.78	11.35	3.63	9.43	242.25
	25%NPK+3Kg Humic acid	2.20	6.82	9.03	4.75	9.47	208.81
	3Kg Humic acid	2.13	7.18	9.32	4.91	9.35	199.62
Gemmiza 11	100%NPK	1.92	5.32	7.24	4.76	8.80	168.78
	75%NPK+1Kg Humic acid	2.34	6.11	8.46	5.73	9.75	228.63
	50%NPK+2Kg Humic acid	2.07	6.01	8.08	5.40	9.35	192.73
	25%NPK+3Kg Humic acid	1.72	5.45	7.17	5.39	9.40	161.86
	3Kg Humic acid	0.89	3.74	4.63	4.78	9.41	83.64
LSD (5%)		1.91	1.44	1.97	0.783	0.511	6.11

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