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EFFECT OF P AND ZN FERTILIZATION ON WHEAT YIELD AND NUTRIENT UPTAKE IN CALCAREOUS SOIL

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ABSTRACT

Field experiments were conducted for two seasons in the calcareous soil located at the experimental farm, of Al-Galaa location, West of Nubaria, Alexandria Governorate, Egypt. Wheat (*Triticum aestivum* L.) was used as an experimental plant. The current work aims to evaluate the effect of P and Zn fertilization and their interaction on the soil chemical properties *i.e.*, pH, EC, organic matter content, availability of P, Zn, Fe, Mn, and Cu as well as translocation and agronomic Efficiency (AE). Apparent nutrient recovery (ANR) for phosphorus and zinc, marketable wheat yield, crop index and harvest index were also determined. On the other hand, soil zinc behavior was evaluated by sequential extraction and the interactions between Zn and Fe as well as Mn and Cu in calcareous soil was considered. Significant differences were found between all parameters investigated.

Application of rock phosphate enriched with humic acid and inoculated with phosphorous dissolved bacteria as P-humate was more effective on soil chemical characteristics especially when combined with Zn-humate. Application of rock phosphate was of lower effect on all parameters studied than superphosphate. These beneficial effects were positively reflected on each of the studied plant parameters of wheat grown on calcareous soils under consideration.

Keywords: Phosphorus fertilization, Zinc fertilization, Wheat plants, Calcareous soils

INTRODUCTION

Wheat is the dominant grain crop of the world commerce. It is occupying an important part of the daily diet of millions of people. In Egypt, increasing productivity of wheat becomes an important factor to overcome unusual increases in population. Approximately 60% of the world arable land is considered to be difficult for the plant production due to mineral stress caused by the deficiency, unavailability, or toxicity of some essential nutritive elements (Foy, 1983). Calcareous soils (pH >7) with moderate to high organic matter content (>1.5% organic C) are likely to be Zn deficient due to high HCO_3^- in the soil solution. A ratio of more than 1 for exchangeable Mg:Ca in soil may also indicate Zn deficiency. Although relatively large amounts of phosphate (P) are essential to plant growth, forms that can be taken up directly by plants are only found in low concentrations (0.01-3.0 µM) in most soil solutions (Barber, 1995). Low availability of P in soils limits crop yields. Under normal growing conditions the uptake of P by plants is tightly controlled. Plants normally moderate their capacity to take up P to maintain the P concentration in their tissues within physiological limits (Mimura, 1999).

Micronutrient deficiency is widespread in plants, animals and humans, especially in many arid countries, due to the calcareous nature of soils, high pH, low organic matter, salt stress, continual drought, high bicarbonate content in irrigation water and imbalanced application of fertilizers (Malakouti, 2008). Zinc is a structural component of several enzymes and it is required for enzyme activation; thus, Zn deficiency also affects carbohydrate metabolism, damages pollen structure and decreases the yield (Fang *et al*., 2008). Humic acid increases the permeability of plant membranes and enhances the uptake of nutrients. Moreover, it (humic acid) is also considered to improve soil nitrogen uptake and encourages the uptake of potassium, calcium, magnesium and phosphorus, making them more mobile and available to plant root system (Singer *et al*., 1998 and Pascual *et al*., 1999). Similarly, Zn is more efficiently used by plant if applied before and during leaf growth stage and before the appearance of inflorescence (Brohi *et al*., 2000). This not only results in higher yield but also affects product quality. Obviously, micro elements are added to macro nutrient fertilizers during the manufacture. However, microelements as Fe, Zn, Mn and Cu are also added to foliar fertilizers used throughout the world as effective, preventive and curative measure to compensate their deficiency. This has special importance in arid and semi arid regions where osmotic pressure promotes the absorption and activity of these elements influenced by the behavior of plant and the timing of foliar application (Chapagain and Wiesman, 2004). Zinc uptake can depend on different factors, for example, the application of potassium humate. The positive effect of humate on the decrease of Zn content in barley and oats was confirmed but in maize and poppy Zn content increased (Pavliková *et al*., 1997).

The objective of this study was to evaluate:1. The effect of P-fertilization on available P and Zn in calcareous soil, 2. The effect of Zn-fertilization on the availability of Fe, Mn and Cu in soil, and 3. Study the interaction between P and Zn on the uptake of P and Zn by wheat and yield characteristics of wheat growing on calcareous soil.

MATERIALS AND METHODS

Two field experiments were established in winter seasons of 2007/2008 and 2008/2009 at the experimental farm, of Al-Galaa location, West of Nubaria, Alexandria Governorate, Egypt using wheat (*Triticum aestivum* L.) cv. Sakha 69. Sowing dates were 20^{th} and 25^{th} of November for the 1^{st} and 2^{nd} seasons, respectively. The experimental design was split plot with 4 replicates the plot area was 10.5 m^2 (1/400 from faddan). Plots received chemical fertilizers (exception the control treatment) as follows: ammonium sulfate (20% N) and potassium sulfate (40% K) a level of 100 and 40 kg fed^{-1} of N and K, respectively. Potassium fertilizers were added before planting, while ammonium sulfate was added in two equal doses. Main treatments were devoted to P-fertilization application using three phosphorus sources as follows: superphosphate as mineral fertilizer, rock phosphate (RP) individually, and RP after enrichment with potassium humate at a rate 1:3 w/v and inoculated with P-dissolved bacteria (*Bacillus megatherium* bacteria) provided by the Biofertilizers Unit (Cairo Mircen, Microbiological Resource Center) where it was used for 30 days under incubation process to release phosphorus from rock phosphate (P-humate). All these sources were applied at a rate of 30 kg P_2O_5 fed^{-1}. On the other hand, Zn-fertilization was presented in subplots as soil application at a rate of 5 kg fed^{-1} as $ZnSO_4$ and Zn-humate. Zn-humate was prepared after humic acids extraction from rice straw compost using 0.1 N KOH, then enriched by 5% Zn as zinc sulfate (Page *et al*., 1982). Zn-humate was added to the soil at a rate of 5 L fed^{-1} at three times. The first was after 45 days from sowing (at tillering stage), the 2 and third times were sprayed separately after 15 days for each. The treatments were as follows:-

1. Control (untreated soil)
2. Superphosphate (SP)
3. Rock phosphate (RP)
4. P-humate
5. $ZnSO_4$
6. Zn-humate
7. Superphosphate (SP) + $ZnSO_4$
8. Superphosphate (SP) + Zn-humate
9. Rock phosphate (RP) + $ZnSO_4$
10. Rock phosphate (RP) + Zn-humate
11. P-humate + $ZnSO_4$
12. P-humate + Zn- humate

At the beginning of the experiment, surface soil samples were collected and analyzed according to Black (1982). Some soil physical and chemical characteristics are shown in Table 1. Wheat plants were harvested after 6 months from sowing.

Table 1: Some soil physical and chemical properties of the experimental soil.

Particle size distribution %				T.C	$CaCO_3$ %	O.M %	pH	EC_e dS m^{-1}	Total		Available	
									mg kg^{-1}			
C.S	F.S	Silt	clay						P	Zn	P	Zn
9.7	57.5	15.7	17.1	S.L	21.3	0.51	7.43	7.37	184	85.7	8.63	0.65

C.S= Coarse sand, F.S= Fine sand, T.C= Texture class , S.L= Sandy Loam, pH "1:2.5 soil : water suspension" EC_e "soil paste extract"

Sequential extraction for Zn

The sequential extraction procedure was demonstrated by Tessier *et al*. (1979) for the partition of Zn in soil into six operationally defined fractions; water soluble, exchangeable, association with carbonate, association Fe and Mn oxides, association organic matter and residue fraction.

Soil and plant samples

Soil samples were taken at a depth of 0-15cm, air dried and sieved through a 2 mm sieve then analyzed for pH, organic matter content, available P, DTPA extractable Fe, Mn, Zn and Cu according to Black (1982). Wheat plants were harvested and the yield components, grain and straw of each plot were recorded and Harvest index and crop index (Şehirali, 1988) were determined using the formula:

Harvest index (HI) % = (grain / total yield) x 100

Crop index (CI) % = (grain /straw) x 100

The plant samples were collected at 70 days after planting, dried at 70 C° to a constant weight, ground in Wiley's mill and one gram of ground 3 material was digested in acid mixtures of H_2O_2 and H_2SO_4. P was determined using ascrobic acid method and measured by a spectrophotometer. Fe, Mn, Zn and Cu were determined using the atomic absorption (IL-157).

Translocation coefficient (TC) for P and Zn concentration in straw and grain was determined using the formula:

$$TC = \frac{\text{Content of metal in grain (mg kg plant}^{-1}\text{)}}{\text{Content of the same metal in straw (mg kg plant}^{-1}\text{)}} \times 100$$

Nutrient use efficiency

The nutrient use efficiencies (Franzini *et al*., 2009), agronomic efficiency (response ratio) and apparent nutrient recovery were calculated as follows;

Agronomic Efficiency (AE):

$$AE = \frac{\text{Yield in fertilized plot (kg fed}^{-1}\text{) - Yield in control plot (kg fed}^{-1}\text{)}}{\text{Quantity of fertilizer nutrient applied (kg fed}^{-1}\text{)}}$$

Apparent Nutrient Recovery (ANR):

$$ANR = \frac{\text{Uptake in fertilized plot (kg fed}^{-1}\text{) - Uptake in control plot (kg fed}^{-1}\text{)}}{\text{Quantity of fertilizer nutrient applied (kg fed}^{-1}\text{)}}$$

The obtained results were subjected to statistical analysis and the treatments were compared using least significant difference test (L.S.D) at 0.05 level of probability, according to Snedecor and Cochran (1981).

RESULTS AND DISCUSSION

Effect of phosphorus fertilization on some soil chemical properties:
Soil reaction (pH), EC and organic matter content

Data presented in Table 2 indicate that the application of phosphorus fertilization, generally, decreased pH values at harvest time of wheat. Values of pH were lower in case of applying rock phosphate enriched with humic acids and inoculated by phosphate dissolving bacteria (P-humate) followed by rock phosphate (RP) alone and superphosphate compared to control treatment. Inoculation with phosphate solubilising bacteria, (B. megaterium) results in the lowest pH values in soil which may be due to the production of organic acids (Cakmakci *et al.*, 2007). Generally, the application of phosphorus had a positive significant effect on pH values, similar results were obtained by Youssef *et al*. (2009). Moreover, during the decomposition of P-humate, organic acids are produced, which influence soil pH and phosphorus availability, or they form complexes or chelates with the other cations and thus releasing phosphorous, Similar results were obtained by El-Fayoumy and Ramadan (2002).

The application of P fertilization on calcareous soil was of the highest effect on decreasing EC soil values as compared to control treatment (6.13), especially, in case of P-humate treatment. Electrical conductivity in calcareous soil after plant growth and yield are reduced in salt-affected soil (from 7.37 to 6.13 dS m^{-1}) because of the excess uptake of potentially toxic ions (Grattan and Grieve, 1999).This finding is expected to be due to the beneficial effect of humic substances in improving physical and chemical soil properties particularly infiltration rate and consequently decreasing dissolved salts in soil solution. Decreased EC could be due to the increased permeability leading to leaching of salts **(**Deepa, 2001). On the other hand, the application of P-humate was more effective in increasing significantly the organic matter content in calcareous soil followed by RP alone and superphosphate compared by control treatment, where the increasing values are 9.20, 3.70 and 1.85 % respectively. Humic matter is the major component of soil organic matter, also, the addition of humate will begin the process of rebuilding soil humus then, increasing the organic matter content in soil (Chen and Aviad, 1990).

P and Zn availability

Lowering pH and EC values, in contrast of increasing organic matter due to application of P fertilization was reflected in increasing the availability of P in calcareous soil, especially when rock phosphate enriched with humic acid and combined with phosphorus dissolved bacteria (P-humate) was applied. Also, the inoculation with dissolving phosphate bacteria increased the available macronutrient values as compared to non-inoculation. These results are in harmony with the findings of Sundara *et al*. (2002) who found that the phosphate solubilizing bacteria (PSB) application increased available P in soil. Recently, Cakmakci *et al*. (2007) reported that the available P response to *Bacillus megaterium* was higher than other tested strains. As regard to available P increase percentages, values recorded were 75.73, 58.25 and 105 % due to application of superphosphate, rock phosphate and P-humate respectively. This means that applying 30 kg P_2O_5 fed^{-1} in combination with bacteria and organic acids is satisfactory from the economical view of point. The increase of available P could be explained by the production of CO_2 and forming H_2CO_3 during organic acid decomposition, which enhanced phosphate solubility. Humic materials, the breakdown products of the total biota in the environment, generally are not a major source of P, but they do have a mobilizing effect on it in the subsurface. The use of extrinsic humates, especially leonardite humic acid, for soil improvement has experienced an upswing in recent years (Kelling, 2004).

Table 2. Effect of P fertilization on soil pH, organic matter content, available P and Zn in the studied calcareous soil.

Treatments	pH 1:2.5	EC dS m^{-1}	Organic matter %	Available mg kg^{-1}	
				P	Zn
Control	7.41	6.13	0.54	10.3	0.67
Superphosphate (SP)	7.33`	5.48	0.55	18.1	0.75
Rock phosphate (RP)	7.27	5.23	0.56	16.3	0.77
*P- humate	7.24	4.92	0.59	21.2	1.04
L.S.D.at 0.05	0.15	0.34	0.05	0.45	0.07

***P-humate = Rock phosphate enriched with K-humate and bacteria dissolved of phosphore (*Bacillus megatherium* bacteria)**

Data in Table 2 indicate that the concentration of Zn was significantly increased in case of applying P fertilization. The percentages of increase reached 11.93, 14.92 and 55.22 % due to application of superphosphate, rock phosphate individually or enriched with humic acids and P dissolved bacteria as P-humate, respectively as compared to control treatment (0.67 mg kg $^{-1}$ soil). Increases in Zn concentration as a result of P applications in the form of superphosphate have been attributed to the depression of soil pH in the root environment (Terman *et al*., 1966) and/or addition of trace amounts of Zn in the superphosphate (Ozanne *et al*., 1965). It is possible that the superphosphate applications may have depressed soil pH in the root environment, thus increasing Zn availability in calcareous soils, the availability of Zn is largely governed by soil pH, type of soil minerals, kind and amount of anions in the soil solution, and Zn carriers (Thind *et al*., 1990).

The results obtained clearly show that the combined treatment of rock phosphate enriched with humic acids and phosphate dissolving bacteria (P-humate) significantly increased the released P and Zn in the soil. This may be due to lowering soil pH and favourable air-water balance, which considerably showed a positive reflect on yield. On the other word, organic acid as a result of nutrient deficiency (P deficiency) may lower rhizosphere pH, making P and micronutrients such as Mn, Fe, and Zn more available in calcareous soils (Jones and Darrah, 1994). However, the relationship between organic acid exudation and rhizosphere acidification is not that simple, as the extrusion of H^+ would depend on the amounts of anions absorbed by roots relative to cations (Dakora and Phillips, 2002). When organic acids are added to solution they bind cations (*e.g*. Ca), causing the release of $2H^+$ (in the case of dicarboxylates, for example) from the organic acid, which consequently lowers solution pH. In contrast, the addition of potassium salt of the organic acids tends to cause a rise in soil solution pH, presumably due to the release of CO_3^- from the $CaCO_3$ and the formation of HCO_3^-. Total Zn concentration is in sufficient level in many agricultural areas, but available Zn concentration is in deficient level because of different soil and climatic conditions. Soil pH, lime content, organic matter amount, clay type and amount and the amount of applied phosphorus fertilizer affect the available Zn concentration in soil (Adiloglu and Adiloglu, 2006).

Zn fertilization

Zinc soil behavior evaluated by sequential extraction

Sequential extraction is used to assess the potential mobility and bioavailability of nutritive and non-nutritive elements in soils. The chemical forms were water soluble (W.S), exchangeable (Ex), bound to carbonates (Carb), bound of Fe and Mn oxides (Ox), bound to organic matter (Org), residual (Res) and summation of the extracted fractions (Sum) . Table 3 show the distribution of Zn in calcareous soil as affected by added Zinc fertilization ($ZnSO_4$ and Zn-humate). Total Zn determined in the soil as a whole with no application of Zn (control) was 85.7 mg kg^{-1} (data in Table 1). After the ($ZnSO_4$ and Zn-humate) fertilizer treatments, the order of Zn distribution between fractions was: Res > Carb > Ex = Org > Ox > W.S due to application of $ZnSO_4$ fertilizer, while the order of fractions was: Res > Org > Ex > Carb > Ox > W.S due to application of Zn-humate. The results in Table 3 indicate that the application of Zn-humate increased the concentration of Zn in each form in soil, especially, bound to organic matter, while application of $ZnSO_4$ had the greatest effect on carbonate form than other forms except the residual form in both treatments which responded more to Zn fertilization.

In figure 1, results indicated that residual form of Zn fertilization was the most important fraction compared with other forms studied. Data show that about 26.81 and 24.54% of total Zn were in residual form in case of $ZnSO_4$ and Zn-humate treatments, respectively. In contrast, the water soluble form was lower as it reached 7.23 and 10.03 % due to application of $ZnSO_4$ and Zn-humate, respectively, than other chemically forms. Regarding the association of Zn with Fe-Mn oxides, the percent values of Zn ranged between 13 % of total in both treatments ($ZnSO_4$ and Zn-humate) respectively. The carbonate bound Zn in figure 1 was generally the highest fraction after application of $ZnSO_4$ (19 %) than W.S and Ex. These results are in agreement with Mahboub *et al*. (2009). McBride (1989) indicated that some metal-complexing ligands suppress metal adsorption and others enhance adsorption by forming stable surface metal-ligand complexes. On the other hand zinc applied with natural chelate seemed to be more effective than synthetic chelate according to Dhillon and Dhillon (1983).

Table 3. Zinc associated with different chemical fractions (mg k^{-1} soil) in calcareous soil under studied.

Treatments	W.S	Ex	Carb	Ox	Org	Res	Sum	Mobility index*
$ZnSO_4$	0.24	0.57	0.61	0.44	0.57	0.89	3.32	0.37
Zn-humate	0.38	0.63	0.52	0.49	0.84	0.93	3.79	0.40

W.S= water soluble; Ex= Exchangeable; Carb= Bound to carbonates; Ox= Bound of Fe and Mn oxides; Org= Bound to organic matter; Res= Residual; Sum= Summation of the extracted fractions

***Mobility index =(Soluble + Exchangeable + carbonate fractions) / Sum of the six fractions**

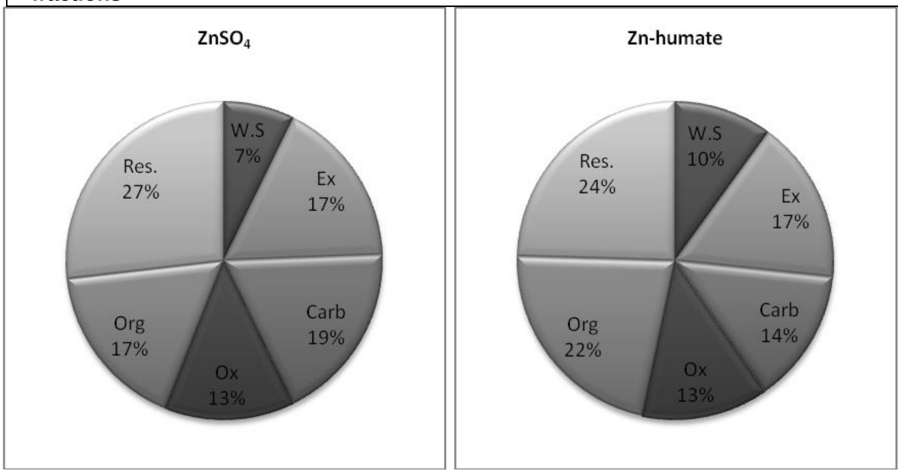

Fig. 1. The presence of Zn distribution in the studied samples soil

On the other hand, results in Table 3 show that the mobility index was the highest due to application of Zn-humate (0.40) than $ZnSO_4$ (0.37) fertilization in calcareous soil. It could be due to the more enhancing influence of natural chelate (humic acids) over other chemical form $ZnSO_4$ in terms of growth and Zn utilization by plant in calcareous soils might be due to less retention. Concerning the greater transport and movement of chelated Zn to plant roots, the applied Zn-humate can increase the concentration gradient of Zn toward the plant roots and Zn could be retained as a bioavailable Zn form in the soil solution which contributes considerably to the uptake of Zn by the plant, (Maftoun and Karimian, 1989). On the other hand, the mobility of Zn-humate in the soil changes in the most bioavailable forms of Zn in soil. Thus, the movement of Zn in the soil can produce a loss of Zn by leaching if excessive rainfall or irrigation occurs. In accordance with Prasad and Sinha (1981), the diffusion of Zn is the main mechanism that contributes to Zn nutrition of maize in calcareous soil, which quite frequently suffers from micronutrient deficiency.

Effect of P and Zn fertilization on concentrations of P, Zn, Fe, Mn and Cu in calcareous soil

The availability of soil phosphorus and micronutrients in the studied calcareous soil were greatly affected by humic acids enriched with nutrients particularly P and Zn (P-humate and Zn-humate), as shown in Table 4. The data obtained indicate that soil available P was significantly increased with P and Zn fertilizations especially in case of rock phosphate combined with humic acids and phosphorus dissolved bacteria (P-humate) as P fertilization applied with Zn-humate as Zn fertilization followed by P-humate combined with $ZnSO_4$. The increase percentage reached 97 and 121% due to application of P-humate combined with $ZnSO_4$ or Zn-humate, respectively. Soil available P and the DTPA extractable Fe, Mn, Zn and Cu were significantly increased by the application of P-humate incorporated with Zn-humate as compared to the control treatment. Both Fe and Mn were more affected by the different P applications, where their values reached the significance levels at the combined treatment of P-humate + Zn-humate. This could be due to the decrease of pH and EC and increase of organic matter content in calcareous soil (Table 2). These results agree with Zaki and Radwan (2006) who found that the applied P fertilizer and Phosphate dissolving Bacteria enhanced P and micronutrients availability in calcareous soil. Adriano (1986) reported that some cations, such as Zn^{+2}, could enter into the crystal lattice of layer silicates through isomorphous substitution or solid-state diffusion into the crystal structure. This process may be irreversible so that some applied metals may be irreversibly fixed by clay. The chelating agents are some of the strongest synthetic chelating agents and form much stronger chelates with Zn than naturally occurring organic ligands (Norvell and Welch, 1993). Application of Zn sulfate is resorted to overcome the problem, but the use efficiency of applied zinc is low (< 5-10%). Use of enriched organic manure helps to increase the use efficiency of nutrients. Furthermore, humic substances act as a natural soil conditioner which improved soil properties and consequently soil productivity. These results are in accordance with those obtained by More (1994).

Table 4. Effect of different P and Zn fertilization on concentrations of P, Zn, Fe, Mn and Cu in calcareous soil

Treatments	Available nutrients (mg kg^{-1})				
	P	Zn	Fe	Mn	Cu
Untreated soil (control)	10.28	0.67	3.45	0.85	0.43
Superphosphate					
$ZnSO_4$	18.45	0.81	3.64	0.87	0.44
Zn-humate	19.28	1.04	3.87	0.90	0.46
Rock phosphate					
$ZnSO_4$	16.02	1.06	3.75	0.89	0.45
Zn-humate	17.75	1.12	4.06	0.94	0.51
P-humate					
$ZnSO_4$	20.35	1.27	3.81	1.03	0.47
Zn-humate	22.78	1.34	4.12	1.18	0.53
L. S. D. at 0.05	1.04	0.67	0.54	0.32	0.23

The interaction between P and Zn fertilization treatments showed that the values of nutrients available were in ascending order of P > Zn > Fe > Mn > Cu. In other words, the availability of P and micronutrients responded more to P-humate + Zn-humate > P-humate + $ZnSO_4$ > rock phosphate + Zn humate > rock phosphate + $ZnSO_4$ > superphosphate + Zn-humate > superphosphate + $ZnSO_4$ > control treatments. The organic acids could potentially lower the pH of the rhizosphere and therefore increase the dissolution of metals and improve their availability for plant uptake (Van Hees *et al*., 2005). This is particularly apparent for metals that become more soluble with decreasing pH (*e.g*. Fe, Zn, Mn, etc.). Also, Sundara *et al*. (2002) reported that the phosphorus solubilizing bacteria (PSB), *Bacillus megatherium* application increased the plant available P status in the soil. It also enhanced tillering and stalks weight and led to cane yield increase (12.6%) over no application.

Effect of P and Zn fertilization on wheat production

The data in Table 5 indicate that P and Zn fertilization resulted in a significant increase in grain, straw weight and total yield compared to the control treatment, and consequently, the biological yield of wheat plant.

Data in Table 5 indicate that the application of all forms of P fertilizer *i.e.,* superphosphate, rock phosphate and P-humate had of a positive effect on grain and straw yield of wheat plant grown on calcareous soil, especially P-humate followed by superphosphate and rock phosphate as compared to the control (untreated soil). The increase percentages reached 222, 176 and 242 % for grain due to application of superphosphate, rock phosphate and P-humate respectively, while for wheat straw these increases were 129, 100 and 132, respectively, as compared to the control treatment. The application of rock phosphate individually decreased grain and straw yield compared to superphosphate and P-humate as P fertilization, but the application of rock phosphate enriched with humic acids and inoculated with phosphorus dissolved bacteria as P-humate was more effective on wheat yield than other treatments. Previously, Sundara *et al.* (2002) found that the sugarcane yield was increased by application of phosphorus solubilizing bacteria (PSB). This was due to increasing PSB activity in the rhizosphere and consequently enhancing the P solubilization. This leads to increase stalk number and stalk growth leading to higher cane yield. Recently, Cakmakci *et al*. (2007) obtained similar results.

Table 5. Effect of P and Zn fertilization on wheat yields

Treatments	Yield (kg fed^{-1})			Crop index % (CI)	Harvest index % (HI)
	Grain	Straw	Total		
Untreated soil	554	1430	1984	38.74	27.92
Superphosphate	1786	3270	5056	54.62	35.32
Rock phosphate	1531	2860	4391	53.53	34.87
P-humate	1897	3320	5217	57.14	36.36
$ZnSO_4$	1657	2984	4641	55.53	35.70
Zn=humate	1820	3140	4960	57.96	36.69
Superphosphate					
$ZnSO_4$	1854	3285	5139	56.44	36.08
Zn-humate	1892	3282	5174	57.65	36.57
Rock phosphate					
$ZnSO^4$	1634	2833	4467	57.68	36.58
Zn-humate	1678	2895	4573	57.96	36.69
P-humate					
$ZnSO^4$	1931	3075	5006	62.80	38.57
Zn-humate	2312	2976	5288	77.69	43.72
L.S.D. 0.05	75.07	82.12	-	-	-

On the other side, the application of Zn-fertilization individually was of the highest effect on wheat yield in case of both forms *i.e.,* $ZnSO_4$ and Zn-humate than the control. The results in Table 5 show that the increase percentage reached, 199 and 229 % for grain and 109 and 120 % for straw due to application of $ZnSO_4$ and Zn humate respectively. Concerning the effect of P and Zn fertilization together on wheat yield, data in Table 5 show that there exists significant increase in grain, straw and total yield in all case of treatments compared with control (untreated soil). In the same time, data show that, applying P-humate and Zn-humate were more effective in producing grain, straw and biological yield than P-humate or Zn-humate individually. Relative increase was 317 % for grain and 108 % for straw due to P-humate application associated with Zn-humate compared to the control. Data showed that P or Zn fertilization increased crop index and harvest index compared with the control treatment, however, it has been noticed that P-humate combined with Zn-humate increased markedly the crop index and harvest index in calcareous soil.

Translocation of nutrient (TC), agronomic efficiency (AE) and apparent nutrient recovery (ANR) for wheat plants

The calculated values of translocation of nutrient (TC), agronomic efficiency (AE) and apparent nutrient recovery (ANR) for wheat plants receiving different forms of phosphorus and zinc are shown in Table 6. In calcareous soils there are many factors that affect P and Zn availability, such as high pH, high $CaCO_3$ and low organic matter (Alloway, 2008). The lower bioavailability of P and Zn in soil directly affects grain Zn concentration. Low P and Zn concentration in wheat tissues was due to the low P and Zn bioavailability in soil with extreme Zn deficiency (Cakmak, 2002). However, the translocations values of P and Zn under P interaction with Zn fertilization increased due to application of P-humate especially when combined with Zn-humate followed by P-humate and $ZnSO_4$. Lowest values exist in case of rock phosphate with both $ZnSO_4$ and Zn-humate compared to untreated soil. The addition of humic acid with half dose of NPK produced significant and economical wheat yield with maximum nutrient accumulation and increased crop productivity by increased nutrient uptake. However, HA was better when applied singly, (Kaya *et al*, 2005). Phosphorus is of high mobility in plants and when deficient it may be translocated from old plant tissue to young active growing areas. On the other hand, Zinc absorption by plants involves a number of steps (Lasat *et al.*, 1998). First, adequate Zn bioavailability was necessary in the rhizoshpere. There are two pathways for Zn to move from the soil solution to the rhizosphere, mass flow and diffusion. In calcareous soils, diffusion is the dominant pathway for Zn to reach root zones. However, diffusion of Zn in calcareous soils is low due to low soil moisture, low organic matter and high pH (Alloway, 2008). Consequently, there is not sufficient available Zn reaching the rhizosphere.

Agronomic efficiency (AE) and apparent nutrient recovery (ANR) for wheat plants were greater due to the application of P and Zn fertilization. Also, inoculation with phosphate dissolving bacteria increased P availability to wheat indicated by higher P recovery percent as compared to other treatments. P recovery percent was superior for wheat plants receiving rock phosphate enriched with humic acid and inoculated with phosphate dissolved bacteria as P-humate especially when mixed with Zn-humate (16.52% for P and 66.81% for Zn), but superphosphate and rock-phosphate combined with Zn-humate were significantly similar in their effect (13.29 and 15.78% for P, 53.01 and 66.81 for Zn, respectively. These results agree with those reported by Youssef *et al*., (2009). Wheat P recovery from superphosphate mixed with $ZnSO_4$ reached (12.95% for P and 49.17 % for Zn) whereas rock-phosphate-P recovery combined with $ZnSO_4$ were (14.88% for P and 59.35% for Zn) which are much higher from untreated soil. The interaction between fertilizations treatments showed that the values of P and Zn recovery percent for wheat yields were in ascending order of P-humate +Zn humate > P-humate + $ZnSO_4$ > superphosphate + Zn-humate > superphosphate + $ZnSO_4$ > rock-phosphate + Zn humate > rock-phosphate + $ZnSO_4$. Apparent nutrient recovery (ANR) took the same trend in apparent nutrient recovery (ANR) for P and Zn due to application of P interaction with Zn fertilization for wheat plant grown on calcareous soil. The obtained data show that such treatments enhanced the grain yield, P-uptake and P-recovery significantly over the phosphorus dissolved bacteria or organic matter. This may be explained that a long time interaction (aging) of soluble P with soil leads to a positive effect on its reaction with solid phase of soil (Paramasivam *et al*., 2005). Also, such condition may be due to the presence of calcium carbonate and the formation of relatively insoluble reaction products with Ca, Fe and Al leading to P fixation. Combined of humic acids with P or Zn were more effective on translocation, agronomic efficiency (AE) and apparent nutrient recovery

(ANR) for wheat plants which might be due to the availability of soil microorganisms to convert the unavailable forms of nutrients elements to available forms.

Table 6. Effect of P and Zn fertilization on translocationof nutrient (TC), agronomic efficiency (AE) and apparent nutrient recovery (ANR) for wheat plants

Treatment	TC %		AE (kg fed^{-1})		ANR(kg fed^{-1})	
	P	Zn	P	Zn	P	Zn
Untreated soil (control)	39.45	11.87	12.04	48.21	0.24	23.90
Superphosphate						
$ZnSO_4$	48.34	31.40	12.95	49.17	2.85	24.29
Zn-humate	59.86	26.52	13.29	53.01	2.91	25.54
Rock phosphate (RP)						
$ZnSO_4$	45.75	28.04	14.88	59.35	3.14	42.41
Zn-humate	58.43	23.18	15.78	60.24	3.83	47.80
P-humate						
$ZnSO_4$	59.23	49.41	15.11	64.57	3.98	80.24
Zn-humate	65.19	53.45	16.52	66.81	4.10	96.80

Conclusion and Recommendation

Use of natural materials such as rock phosphate enriched with humic acids and inoculated with bacteria-dissolving phosphorus, maximizes the benefit from it and increases the released of phosphorus. Use of zinc-humate was more effective in bioavailability than use of $ZnSO_4$. Enrichment of humic substances with the macro or micronutrients was more economic and secure not only a waste of money, but also keep the environment clean.

REFERENCES

Adiloglu, A. and S. Adiloglu (2006). The Effect of Boron application on the growth and nutrient contents of maize in zinc (Zn) deficient soils. Research Journal of Agriculture and Biological Sciences. 2(1):1-4.

Adriano, D.C. (1986). Trace elements in the terrestrial environment. Springer-Verlag, New York, U.S.A.

Alloway, B. J. (2008). Zinc in soils and crop nutrition. Second edition, published by IZA and IFA Brussels,Belgium and Paris, France.

Barber, S.A. (1995). Soil nutrient bioavailability: A Mechanistic Approach, Ed 2. John Wiley & Sons, New York, pp 202-230

Black, C.A. (1982). Methods of soil analysis. Part 182, Soil Sci. Soc. And Am. Jne. Pub., Madison, Wisc., U.S.A.

Brohi, A.R.; H. Karaata; S. Ozcan; and M. Demir (2000). Factors effecting yield and nutrition of zinc fertilization through soil and foliar sprays. J. Fac. Agric*.,* Univ. of GOP, Tokat, Turkey, 17:123-128

Cakmakci, R.; M.F. Donmez; and O. Erdogan (2007). The effect of plant growth promoting rhizobacteria on barley seedling growth, nutrient uptake, some soil properties, and bacterial counts. Turk. J. Agric., 31:189-199.

Cakmak, I. (2002). Plant nutrition research: Priorities to meet human needs for food in sustainable ways. Plant Soil, 247:3-24.

Chapagain, B.P. and Z. Wiesman (2004). Effect of Nutri–Vant–PeaK foliar spray on plant development, yield, and fruit quality in greenhouse tomatoes. Science Horticulturae, 102:177-188

Chen, Y. and T. Aviad, (1990). Effect of humic substances on plant growth. In: Humic substances in soil and crop sciences: Selected Reading, MacCarthy, P., C.E. Clapp, R.L. Malcolm and P.R. Bloom (Eds). Soil Science Society America, Madison, WI., pp: 161-187.

Dakora, F.D. and D.A. Phillips (2002). Root exudates as mediators of mineral acquisition in low-nutrient environments. Plant and Soil 245:35-47.

Deepa, M. (2001). Effect of lignite humic acid on soil microorganisms. M.Sc.(Agric.) Thesis, TNAU, Coimbatore.

Dhillon, K.S. and S.K. Dhillon (1983). Relative efficiency of different chelates in the supply of applied zinc to maize and wheat. J. Nucl. Agric. Biol. 12:93-96.

El-Fayoumy, M.E. and H.M.Ramadan (2002). Effect of bio-organic manures on sandy soils amelioration and peanut productivity under sprinkler irrigation system. Egypt. J. Soil Sci. 42(3):383-394

Fang, Y.L.; Z. Wang; L. Xin; X. Zhao and Q. Hu (2008). Effect of foliar application of zinc, selenium and iron fertilizers on nutrients concentration and yield of rice grain in China. J. Agric. Food Chem., 56: 2079-2084.

Foy, C.D. (1983). Plant adaptation to mineral stress in problem soils. Iowa St. J. Res., 57:339-354.

Franzini, V.I.; T. Muraoka and F.L. Mendes (2009). Ratio and rate effects of 32 Ptriplesuperphosphate and phosphate rock mixtures on corn growth. Scientia Agricola. 66:71-76.

Grattan, S.R. and C.M. Grieve (1999). Salinity mineral nutrient relations in horticultural crops. Sci. Hortic., 78: 127-157

Jones, D.L. and P.R. Darrah (1994). Role of root derived organic-acids in the mobilization of nutrients from the rhizosphere. Plant and Soil 166:247-257

Kaya, C.; D. Higgs and A. Burton (2005). Foliar application of iron as a remedy for zinc toxic tomato plants. Journal of Plant Nutrition, 22:1829-1837.

Kelling, K.A. (2004).Staff nonconventional soil additives: Products, companies, ingredients, and claims. NCR-103 Committee on Nontraditional Soil Amendments and Growth Stimulants.

Lasat, M.M.; A.J.M. Baker and L.V. Kochian (1998). Altered Zn compartmentation in the root symplasm and stimulated Zn absorption into the leaf as mechanisms involved in Zn hyperaccumulation in Thlaspi caerulescens. Plant Physiology, 118:875-883.

Maftoun, M. and N. Karimian (1989). Relative efficiency of two zinc sources for maize (*Zea mays* L.) in two calcareous soils from an arid area of Iran. Agronomic 9:771-775.

Mahboub, S.; J.Yasrebi; N. Karimian and S. Xiao-Quan (2009). Effect of calcium carbonate removal on the chemical forms of zinc in calcareous soils by three sequential extraction methods. Research J. of Bio. Sci., 7: 858-865.

Malakouti, M.J. (2008). The effect of micronutrients in ensuring efficient use of macronutrients. Tur. J. Agric. For Micronutrients 32: 215-220.

McBride, M.B. (1989). Reactions controlling heavy metals solubility in J. soils. Adv. Soil Sci. 10:1-56.

Mimura, T. (1999). Regulation of phosphate transport and homeostasis in plant cells. Int Rev Cytol 191:149-200

More, S.D. (1994). Effect of farm wastes and organic irrigated manure on soil properties, nutrient availability and yields of rice and wheat grown on sodic Vertsoils. J. Ind. Soc. Sci., 46: 2253-2561.

Norvell, W.A. and R.M.Welch (1993). Growth and nutrient uptake by barley (*Hordeum vulgare* L. cv Herta): studies using an *N*-(2-hydroxyethyl) ethylenedinitrilotriacetic acid-buffered nutrient solution technique: I. Zinc ion requirements. Plant Physiology 101: 619-625

Ozanne, P.G; T.C. Shaw and D.C. Kirton (1965). Pasture responses to traces of zinc in phosphate fertilizers. Aust. J. Exp. Agric . Husb. 5: 29-33.

Page, A.L.; R.H. Miller and D.R. Keeny (1982). Methods of Soil Analysis, Part 2 Chemical and Microbiological Properties. (2nd Ed), Amer. Soc. Agron. Monograph No. 9, Madison., Wisconsin, U.S.A.

Paramasivam, S.; K.S. Sajwan and A.K. Alva (2005). Organic amendments to improve soil productivity and nutrient cycling. C.J. Li et al., (eds), Plant nutrition for food security, human health and environmental protection 1090-1091.

Pascual, J.A.; C. Garcia and T. Hernandez (1999). Comparison of fresh and composted organic waste in their efficacy for the improvement of arid soil quality. Bioresources Technol., 68: 255-264.

Pavlíková, D.; P. Tlustos; J. Száková; and J. Balík, J. (1997). The effect of application of potassium humate on the content of cadmium, zinc and arsenic in plants. Rostl. Výr., 43:481-486.

Prasad, B. and M.K. Sinha (1981). The relative efficiency of zinc carriers on growth and zinc nutrition of corn. Plant Soil 62:45-52.

Şehirali, S. (1988). Yemeklik tane baklagiller Ders Kitabı. (Seed Legumes, Lecture Notes), Publication No. 1089 pp. 314-335 Fac. of Agric., Univ. of Ankara, Turkey (In Turkish).

Singer, S.M.; O.M. Sawan; M.M. Abdel-Mouty and S.R Salman (1998). Study of the effects of the Delta mixTM and organic matter on growth and productivity of bean plants grown under calcareous soil conditions. Egypt. J. of Hortic., 25:335-347.

Snedecor, G. W. and W.G.Cochran (1981). Statistical Methodes 7th. Ed, Iowa State Univ. lowa, USA.

Sundara, B.; V. Natarajn; and K. Hari (2002).Influence of phosphorus solubilizing bacteria on the changes in soil available phosphorus and sugarcane and sugar yields. Field Crops Research. 77: 43-49.

Terman, G.; S.E. Allen and B.N. Bradford (1966). Response of corn to zinc as affected by nitrogen and phosphorus fertilizers. Soil Sci., Proc. 30:119-124.

Tessier, A.; P.G.C. Campbell and M. Bisson (1979). Sequential extraction procedure for the speciation of particulate trace metals. Anal. Chem. 51:844-851.

Thind, S.S.; P.N. Takkar and R.L. Bansal (1990). Chemical pools of zinc and the critical deficiency level for predicting response of corn to zinc application in alluvium derived alkaline soils. Acta Agron. Hung. 39:219-226.

Van Hees, P.A.W.; D.L. Jones; L. Nyberg; S.J.M. Holmstrom; D.L. Godbold and U.S. Lundström (2005). Modeling low molecular weight organic acid dynamic in forest soils. Soil Biology and Biochemistry 37:517-531.

Youssef, G.H.; M.A. Osman and W.M.A. Seddik (2009). A comparison of phosphate forms and rates as affected by inoculation with phosphate dissolving bacteria in sandy soil4th Conference on Recent Technologies in Agriculture Fac., Cairo university.

Zaki, R.N. and T.E.E. Radwan (2006). Impact of microorganisms activity on phosphorus availability and its uptake by Faba Bean plants grown on some Newly Reclaimed Soils in Egypt. Inter. J. of Agric. and Biology 8: 221-225.

تأثير التسميد بالفوسفور والزنك على محصول القمح والمحتوي العنصري للنبات في الاراضي الجيرية

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أجريت تجربة حقلية على موسمين بأرض جيرية تقع في المزرعة التجريبية ، منطقة الجلاء، غرب النوبارية بمحافظة الإسكندرية واستخدم فيها نبات القمح كمدلول للدراسة.

تهدف الدراسة الى تقييم تأثير التسميد بالفوسفور والزنك والتفاعل معا على بعض الخصائص الكيميائية للتربة مثل درجة الحموضة، EC، والمحتوى العضوي للتربة وكذلك تيسر كل من الفوسفور و الزنك، وبعض العناصر الغذائية (مثل الحديد والمنجنيز، والنحاس) ، كما قدر كل من انتقال العناصر (الفوسفور والزنك) خلال النبات والكفاءة الزراعية واسترداد المغذيات للفوسفور والزنك، بالإضافة إلى ذلك ، تم تحديد محصول القمح التسويقى كما قدر كل من مؤشر المحصول والحصاد.

من ناحية أخرى، تم تقييم سلوك الزنك بالأراضى من خلال تقدير الأستخلاص المتتابع و التفاعل بين الزنك والحديد والمنجنيز ، والنحاس في التربة الجيرية.

تبين من النتائج وجود اختلافات كبيرة بين جميع المعاملات تحت الدراسة. كما افادت النتائج الى ان صخر الفوسفات المخصب بحامض الهيوميك وملقح بالبكتريا المذيبة للفوسفور فى صورة P-humate أكثر فعالية على الخصائص الكيميائية في التربة الجيرية مجتمعة خصوصا عند اضافة مع Zn-humate.

كما لوحظ من النتائج ان استخدام صخر الفوسفات بمفرده اعطى أقل تأثير على جميع الخواص المدروسة مقارنة بالسوبر فوسفات. وقد انعكست هذه الآثار المفيدة إيجابا على كل من محصول القمح النامى فى الأرض الجيرية ومدلولاتة.

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