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Effect of P Mineral Fertilization Combined with Compost and Phosphate Solubilizing Bacteria on Wheat Yield and Its Components in Calcareous Soil

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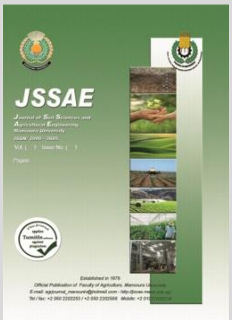

ABSTRACT

The current work aimed to evaluate the effect of P mineral fertilization, compost source and phosphate solubilizing bacteria (PSB) on wheat yield *Triticum aestivum, L. (var. Msr$_1$)* and its components in calcareous soil. A pot experiment was conducted inside a greenhouse at the Faculty of Technology and Development, Zagazig University, Sharkia Governorate, Egypt during 2019/2020 winter season. The experiment was laid out in split split plot design with three replications. The main and sub plots were 0, 15 ، 30 kg P fed^{-1} and 15 m^3 fed^{-1} compost (C$_1$, C$_2$) respectively. Sub sub-plots were three rates of 0, 1 and 2 L fed^{-1} PSB. The results indicated that the values of grain yield (GY), straw yield (SY), biological yield (BY), harvest index (HI), crude protein (CP), N,P and K uptakes, agronomical N use efficiency (ANUE), N recovery efficiency (NRE), agronomical K use efficiency (AKUE), K recovery efficiency (KRE), and physiological K use efficiency (Ph.KUE), increased significantly with increasing P fertilizer level as well as with rising (PSB) rate from 0.0 to 2 L fed^{-1}. Compost$_1$ (C$_1$) was superior to compost$_2$ (C$_2$) in relation to its impact on all studied agronomic traits, (CP), N uptake, (ANUE), (NRE), agronomical P use efficiency (APUE), physiological P use efficiency (Ph.PUE), (AKUE) and (Ph.KUE). The best interaction treatment that achieved the highest values of most studied parameters was (30 kg P fed^{-1}+ C$_1$ + 2 L bio-fertilizer fed^{-1}) flowed by (15 kg P fed^{-1} + C$_1$ + 2 L) without any significant differences.

Keywords*:* P mineral fertilizer, compost, phosphate solubilizing bacteria and nutrient use efficiencies.

INTRODUCTION

Calcareous soils widespread in the Arab Republic of Egypt, especially in the northwestern sector region, and the plants growing in these soils suffer from a lack of phosphorus element. Phosphorus is the second most widely occurring nutrient deficiency in agriculture system. Unfortunately, under semiarid conditions plants are not able to get the required P due to high soil pH and low organic matter (Aziz *et al.*, 2005.and Amanullah *et al.*, 2014). Therefore, adsorption of phosphorus in calcareous soils decreases availability of P for the crop plants causing P-deficiency in these soils (Aziz *et al.*, 2005 and Amanullah *et al.*, 2009, 2010). Consequently, phosphorus fertilizer efficiency remains low in calcareous soil (Delgado *et al*., 2002). When calcium super phosphate is added as a source of phosphor in calcareous soil the availability of P for utilization and uptake by crops decreased due to reversion of applied phosphates to less available forms such as octacalcium phosphate by reacting with calcium compounds leading to decline the solubility of calcium phosphate minerals (Al Harbi *et al*., 2013).

Phosphorus and nitrogen elements are considered the most important nutrients for root development, seed formation, growth and yield. (Beigzade *et al*., 2013).

Precipitation of phosphorus compounds due to soil chemical reactions limit the plant available P and decreased phosphate fertilization use efficiency by crops. Sushanta *et al.*, (2014) reported that reaction of phosphate in the soil has an important contribution to crop growth and fertilizer use efficiency. Thus phosphorus fertilization are important for all cultivated crops and necessary for obtaining best yield. Many researches demonstrated that crops yields improved by added P-fertilizers (Zahir *et al.*, 2000 and Memon *et al.*, 2011). Adding organic matter to the soil not only improve soil physical, chemical and biological properties, but also had a big role for increasing the solubility of some nutrients and subsequently its availability to plant uptake (Abedi *et al*., 2010; Ahmed *et al*., 2011; Genaidy 2011). In addition, the supply of nutrients to be fully compatible with the natural power of plants help to biodiversity, intensification of vital activities, improve the quality and keeping health of the environment which is one of the most important biological advantages (Novell leyva *et al.*, 2003). Bio fertilizers are one of biological way to increase the productivity in the agricultural sector. Using the beneficial microorganisms in the soil such as phosphorus dissolving bacteria is able to change insoluble phosphorus in soil into the soluble form as well as increased the amount its available nutrients, ability to enhance plant growth and yield increase.

Generally, P deficiency is invariably a common crop growth and yield-limiting factor, especially in soils high in calcium carbonate, which reduces P solubility (Ibrikci *et al.* 2005). Therefore, the goal of the present

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study is to investigate the effect of phosphate fertilizer rate, compost source and P- solubilizing bacteria rate on wheat productivity in calcareous soil.

MATERIALS AND METHODS

The present experiment was carried out in a greenhouse at Faculty of Technology and Development, Zagazig University, Sharkia Governorate, Egypt during 2019/2020 winter season, using closed bottom plastic pots (32 cm in diameter and 27 cm deep) filled with 20 kg dry calcareous soil which was transferred from the Noubaria Research Station farm in the northern coast of the Tahrir District, Egypt. Soil samples were taken from the surface layer (0 -30 cm). Table 1 shows the main properties of the soil under study. The experiment was laid out in randomized complete block design with split split plot arrangement using three replications in addition to control treatment (non-use P-fertilizer, compost and phosphate solubilizing bacteria). Main plots occupied by three different phosphorus fertilizer rates (0, 15 and 30 kg P fed^{-1}) i.e. 0.0, 0.375 and 0.750 g P pot^{-1} as Ca – superphosphate (68 g P kg $^{-1}$). The sub plots were dedicated to the compost source C_1 and C_2 at rate of 15 m^3 fed^{-1}. The compost was obtained from two different factories in the Sharkia Governorate. The physical and chemical properties of the tested composts have been presented in Table 2. The sub-sub plots were assigned to three levels of Phosphorus solubilizing bacteria (PSB) (0.0, 1 and 2 L fed^{-1}). PSB *(Bacillus megatherium*) was obtained from Egyptian Ministry of Agriculture (Department of Soil Microbiology Research, Agricultural Research Center). Bio-fertilizer was added twice the first with sowing and the second was added after 30 days from sowing. On 15th/11/2019, ten cleaned wheat seeds *Triticum aestivum, L. (var. Msr$_1$)* were sown in each pot with soil moisture at saturation by using tap water. For other irrigations, water was added when soil moisture had depleted to 50% of the total available water.

Five plants were left in each pot after thinning. The recommended rates of potassium (20 kg K fed^{-1} i.e. 0.5 g K pot^{-1}) as potassium sulphate (400 g K kg^{-1}) were added during soil preparation. Nitrogen (100 kg N fed^{-1} i.e. 2.5 g N pot^{-1}) as ammonium sulphate (205g N kg^{-1}). Nitrogen fertilizer applied in three equal splitting doses; the first was at planting; and the other doses were added every 30 day from each. After harvest on 5th /5/2020, all plants of each pot taken and separated into grains and straw. The biological yield (BY), straw yield (SY) and grain yield (GY) were recorded (g pot^{-1}) as well as plant samples were taken and oven dried at 70 ºC to a constant weight and conserved for analysis. The N, P and K contents of the plants were determined by wet digestion using the standard methods as reported by Westerman (1990). Crude protein (CP) content was calculated by multiplying N content × 5.83 according to Ronald *et al.* (2005). Harvest index (HI) was calculated as a percent [(grain yield ÷ total biological yield) × 100]. Agronomical N, P and K-use efficiencies (AUE); N, P and K- recovery efficiencies (RE) as well as physiological N, P and K- use efficiencies (Ph.UE) were calculated as the following equations according to Naeem *et.al.* (2017).

$$\text{- AUE} = \frac{\text{Grain yield of treated - Grain yield of control (g pot}^{-1})}{\text{Element applied (g pot}^{-1})}$$

$$\text{- RE} = \frac{\text{Total element uptake of treated - Total element uptake of control (g pot}^{-1})}{\text{Element applied (g pot}^{-1})}$$

$$\text{- Ph. UE} = \frac{\text{Grain yield of treated - Grain yield of control (g pot}^{-1})}{\text{Total element uptake of treated - Total element uptake of control (g pot}^{-1})}$$

Soil samples taken before planting, air – dried, ground to pass through a 2- mm sieve for analysis of some physical and chemical properties according to Sparks (1996).

Table 1. Some physical and chemical analyses for soil under study.

Soil fertility characteristic	Value
Mechanical analysis (%)	86.03 sand, 5.33 silt,8.64 clay
Soil texture class	Loamy Sand
Saturation percentage (SP) %	23.00
EC (Soil paste extract) dSm^{-1}	1.89
Soluble cations (mmole L^{-1})	Ca^{2+} = 4.11 ; Mg^{2+} = 3.78 Na^{+} = 2.61 ; K^{+} = 0.51
Soluble anions (mmole L^{-1})	CO_3^{2-} = 0.00 ; HCO_3^{-} = 7.93 SO_4^{2-} = 4.39 ; Cl^{-} = 2.19
Soil – pH (1:2.5)	8.12
$CaCO_3$ (g kg^{-1})	234.60
O.M (g kg^{-1})	11.20
Soil - CEC (cmol$_c$ kg $^{-1}$)	16.48
Total N (g kg $^{-1}$)	0.44
Available N, P and K (mg kg $^{-1}$)	
N	72.00
P	5.50
K	235.00

Notes: 1- Soil analyses were done using representative composite samples.
2- Extraction solution for available N (KCl), P (Na-bicarbonate), K (NH_4-acetate).

Table 2. Some physico-chemical characteristics of the tested compost

Compost characteristics	Compost$_1$ (C_1)	Compost$_2$ (C_2)
Moisture content (%)	27.52	29.85
Bulk density (g cm^{-3})	0.405	0.455
Organic matter (OM) %	39.55	40.82
Organic carbon (C) %	22.94	23.68
Total nitrogen (N) %	1.27	1.12
C/N ratio	18.06	21.14
pH (1 : 10 extract)	7.24	7.49
EC$_e$ (1 : 10 extract)	1.71	2.33
Total –P (%)	0.48	0.78
Total –K (%)	1.04	1.87

RESULTS AND DISCUSSION

1- Vegetative characters and yield:

a) Effect of phosphate fertilizer:

Data in Table 3 clearly demonstrated that increasing mineral phosphorus rate from zero up to 30 kg P fed^{-1} led to significant increases in wheat grain yield (GY), straw yield (SY) and biological yield (BY). As an average, the increments of (47.9& 53.2 %), (25.3 & 27.3 %) and (33.8 & 37 %) for grain, straw and biological yields were obtained due to application of 15 and 30 kg P fed^{-1}, respectively compared to 0.0 P fertilizer rate. These findings may be due to that balanced phosphorus fertilizer application stimulates root development, which might have resulted in better plant growth and more number of total tillers per plant. In addition, phosphorus contributes in numerous vital functions in plants as photosynthesis, respiration, energy transfer, cell division and seed formation (Mengel and Kirkby, 2001). These results are in line with those obtained by Pareek (2004); Memon *et al.* (2005)); Rahim *et al.* (2010) and Majeed *et al.* (2014) who reported that wheat plant height, number of fertile tillers, number of spikelets per spike and number of grains per spike increased significantly with increasing in phosphorus levels. Concerning harvest index (HI), the results in Table 3 indicate that phosphorus application at the highest rate of 30 kg fed^{-1} showed the better harvest index 41.97 % followed by 15 kg P kg fed^{-1} 41.49 % and the minimum harvest index of 37.52 % was recorded as a result of P non-application. This result probably may be due to the increased grain yield at a greater rate than straw yield.

Similar results are obtained by Amanullah *et al.* (2010) and Noonari *et al.* (2016).

Table 3. Effect of phosphate fertilizer rate, compost source and phosphate solubilizing bacteria rate on wheat yield and its quality.

Wheat characteristics	Grain yield	Straw yield	Biological yield	Harvest Index	Protein
Treatment		gram pot^{-1}			%
Control	13.43	35.54	48.97	27.42	10.42
P- fertilizer rate (kg P Fed^{-1})					
0	25.41	42.23	67.64	37.52	10.88
15	37.58	52.93	90.51	41.49	11.98
30	38.92	53.76	92.68	41.97	12.05
Organic fertilizer Source					
C_1	34.71	50.05	84.76	40.66	11.70
C_2	33.23	49.23	82.46	40.00	11.57
Bio - fertilizer rate (L Fed^{-1})					
0	31.74	48.07	79.81	39.47	11.38
1	33.78	49.55	83.33	40.24	11.56
2	36.39	51.30	87.68	41.27	11.96
$LSD_{5\%}$ a	0.34	0.48	0.64	0.27	0.09
$LSD_{5\%}$ b	0.24	0.34	0.46	0.20	0.07
$LSD_{5\%}$ c	0.24	0.36	0.34	0.28	0.13

b) Effect of compost:

Application of compost at rate of 15 m^3 fed^{-1} showed significant increase in (GY), (SY), (BY) and (HI) (Table 3). As an average, $compost_1$ (C_1) gave the best values with increments of 158, 41, 73 and 48 % for (GY), (SY), (BY) and (HI) respectively as compared to control treatment (zero compost). While the obtained increments with applying $compost_2$ (C_2) were 147, 39, 68 and 46 % respectively as compared to non-compost application treatment. These results may be attributed to that the compost not only acts as a source of plant nutrients and biological properties for microorganisms but also influence the availability of native nutrients in soil and improves soil physical properties as permeability and water holding capacity. These results are congruent with those obtained by Osman *et al*. (2013). With respect to organic manure source, the results reveal that $compost_1$ (C_1) was superior to $compost_2$ (C_2) in relation to its effect on all previous agronomic traits and the obtained increments were (4.5, 1.7 and 2.8 %) for (GY), (SY) and (BY) respectively with applying (C_1) as compared to (C_2). This result may be due to that C_1 contains the highest value of total nitrogen (1.27 %) compared to 1.12 % in C_2. Notwithstanding organic manure source have a little effect on harvest index.

c) Effect of bio- fertilizer:

Data illustrated in Table 3 suggested that grain, straw, biological yields and harvest index significantly increased gradually with increasing bio- fertilizer rate.

Application of 2 L fed^{-1} resulted in realizing maximum values of 36.39, 51.30, 87.68 g pot^{-1} and 41.27 % with increments of 14.65, 6.72, 9.86 and 4.56 % for (GY), (SY), (BY) and (HI) as compared to non-use phosphorous dissolving bacteria (PSB) treatment, respectively. These results may be due the promoting effect of bacteria on plant growth and productivity by improving photosynthetic activities, synthesizing phytohormones and enhance the general availability of nutrients. There are similar related results reported by Saber *et al.* (2012); Beigzade *et al.* (2013); Wali *et al.* (2018).

d) Interaction effect:

The statistical analysis of variance for data in Table 4 show different positive responses to interaction effect of phosphate fertilizer rate, compost source and bio-fertilizer rate on wheat yield and its components. Data indicate that the interaction between P levels and compost source had no significant effect on values of (SY), (BY) and (HI). In addition, the values of (GY), (SY) and (HI) not affected significantly by interaction between compost source and bio-fertilizer rates. Meanwhile, the statistical analysis of variance for data illustrated that the values of studied agronomic traits significantly affected by interaction of both of (P levels × bio-fertilizer rates) and (P levels × compost source × bio-fertilizer rates). The best interaction treatment that achieved the highest values of 41.76, 55.53 and 97.29 g pot^{-1} and 42.93 % with increases of 211, 56 ,99 and 57 % for (GY), (SY) , (BY) and (HI), respectively was (30 kg P fed^{-1}+ C_1+2 L bio-fertilizer fed^{-1}) as compared to control treatment. At the same time, data also appeared that there is no significant difference between interaction treatment of (15 kg P fed^{-1} + C_1 + 2 L bio-fertilizer fed^{-1}) and (30 kg P fed^{-1} + C_1 + 2 L bio-fertilizer fed^{-1}).These results are in harmony with those obtained by Saber *et. al.* (2012); Beigzade *et. al.* (2013).

2- Chemical composition, nutrient uptake and nutrient use efficiencies:

a) Effect of phosphate fertilizer:

Data in Tables 3 and 5 emphasize that grains crude protein content (%), N-uptake (g pot^{-1}) by grains or straw and total N-uptake (grains + straw) significantly increased with increasing P-fertilizer rate up to 30 kg fed^{-1}. As an average, the increments were (10.1 & 10.8 %), (60 & 69 %), (52 & 88 %) and (61 & 76 %) for grains crude protein content (CP), N-uptake by grains, N-uptake by straw and total N-uptake due to raising of P-fertilizer rate from 15 to 30 kg fed^{-1} respectively compared to 0.0 P fertilizer rate treatment. This result may be explained on the basis that phosphorus improves root growth. Rahim *et al*. (2010) and Rasul (2016) demonstrated that nitrogen and protein content in wheat grains increased with increment of P fertilizer level. In addition, data show that agronomical N use efficiency (ANUE) and nitrogen recovery efficiency (NRE) significantly increased with increasing P-fertilizer rate. The highest values of (ANUE) and (NRE) were 10.20 and 0.34 (g g^{-1}) respectively with applying 30 kg P fed^{-1}.

These results mainly may be due to applying the recommended dose of N fertilizer (100 kg N fed^{-1}). On the other hand the maximum physiological N use efficiency (Ph.NUE) of 42.51 g g^{-1} was observed at 0.0 kg P fed^{-1}, and it decreased significantly with increasing levels of P-fertilizer up to 30 kg P fed^{-1}. This decreases probably due to increase the amount of total nitrogen uptake with increasing P- fertilizer rates and at the same time slight increase in grain yield.

Table 4. Interaction effect of phosphate fertilizer rate, compost source phosphate solubilizing bacteria rate on wheat yield and its quality.

Wheat characteristics / Treatment			Grain yield	Straw yield	Biological yield	Harvest Index	Protein
P- fert., rate (kg Fed^{-1})	Compost Source	Bio.fert., rate (L Fed^{-1})	gram pot^{-1}			%	
Zero	C_1	0	24.51	41.91	66.42	36.90	10.70
		1	25.57	42.95	68.52	37.32	10.94
		2	28.03	43.63	71.66	39.12	11.23
	Mean		26.04	42.83	68.87	37.78	10.96
	C_2	0	22.52	40.06	62.58	35.99	10.61
		1	24.84	42.41	67.25	36.94	10.80
		2	26.97	42.41	69.38	38.87	11.02
	Mean		24.78	41.63	66.40	37.27	10.81
15	C_1	0	35.70	50.87	86.57	41.24	11.76
		1	38.39	53.03	91.42	41.99	12.00
		2	41.50	55.43	96.93	42.81	12.36
	Mean		38.53	53.11	91.64	42.01	12.04
	C_2	0	33.99	50.79	84.78	40.09	11.66
		1	36.55	52.28	88.83	41.15	11.80
		2	39.37	55.16	94.53	41.65	12.29
	Mean		36.64	52.74	89.38	40.96	11.92
30	C_1	0	37.50	52.91	90.41	41.47	11.82
		1	39.44	54.19	93.63	42.12	11.97
		2	41.76	55.53	97.29	42.93	12.56
	Mean		39.57	54.21	93.78	42.17	12.12
	C_2	0	36.23	51.88	88.10	41.12	11.75
		1	37.89	52.46	90.35	41.94	11.85
		2	40.69	55.61	96.30	42.25	12.32
	Mean		38.27	53.32	91.58	41.77	11.97
0		0	23.52	40.99	64.50	36.45	10.66
		1	25.21	42.68	67.89	37.13	10.87
		2	27.50	43.02	70.52	39.00	11.13
15		0	34.85	50.83	85.68	40.67	11.71
		1	37.47	52.66	90.13	41.57	11.90
		2	40.44	55.30	95.73	42.23	12.33
30		0	36.86	52.40	89.26	41.30	11.79
		1	38.66	53.33	91.99	42.03	11.91
		2	41.22	55.57	96.80	42.59	12.44
C_1		0	32.57	48.56	81.13	39.87	11.43
		1	34.47	50.06	84.52	40.48	11.64
		2	37.10	51.53	88.63	41.62	12.05
C_2		0	30.91	47.58	78.49	39.07	11.34
		1	33.09	49.05	82.14	40.01	11.48
		2	35.68	51.06	86.74	40.92	11.88
$LSD_{5\%}$ a*b			0.34	NS	NS	NS	NS
$LSD_{5\%}$ a*c			0.41	0.62	0.60	0.49	NS
$LSD_{5\%}$ b*c			NS	NS	0.49	NS	NS
$LSD_{5\%}$ a*b*c			0.58	0.87	0.84	NS	NS

Table 5. Effect of phosphate fertilizer rate, compost source phosphate solubilizing bacteria rate on N-uptake and nitrogen use efficiencies by wheat yield

Wheat characteristics	N- Uptake g. pot^{-1}			Nitrogen Use Efficiencies g g $^{-1}$		
Treatment	**Grain**	**Straw**	**Total**	**ANUE**	**NRE**	**Ph.NUE**
Control	0.24	0.19	0.43	-	-	-
P- fertilizer rate (kg Fed^{-1})						
0	0.48	0.25	0.72	4.79	0.12	42.51
15	0.77	0.38	1.16	9.67	0.29	34.29
30	0.81	0.47	1.27	10.20	0.34	31.23
Organic fertilizer Source						
C_1	0.70	0.39	1.10	8.52	0.27	34.60
C_2	0.67	0.33	1.00	7.92	0.23	37.42
Bio - fertilizer rate (L Fed^{-1})						
0	0.63	0.28	0.91	7.33	0.19	40.51
1	0.68	0.34	1.02	8.15	0.24	36.64
2	0.75	0.47	1.22	9.19	0.32	30.87
$LSD_{5\%}$ a	0.006	0.004	0.011	0.13	0.003	0.25
$LSD_{5\%}$ b	0.005	0.003	0.008	0.09	0.002	0.18
$LSD_{5\%}$ c	0.009	0.004	0.011	0.10	0.004	0.57

Phosphorus uptake (g pot^{-1}) by grains, straw as well as total P-uptake (grains + straw) significantly increased in response to the raise in P-fertilizer rate from 15 to 30 kg P fed^{-1} pot^{-1} (Table 6). The increments were (388 , 638), (62 ,276) and (347 , 653) % for P-uptake by grains, straw and also total P-uptake respectively as compared to no-apply of P- fertilizer. This can be attributed to the fact that increasing the rate of phosphate fertilizer leads to enhancing soil to supply phosphorus to plants. These results are accordance with those recorded by Sushanta *et al*., (2014) and Ghafoor (2016) who stated that total P-uptake by wheat increased with the increase in the rate of addition P fertilizer to the soil.

Regarding to the effect of P-fertilizer levels on phosphorus use efficiencies, data presented in Table 6 indicate that (APUE), (PRE) and (Ph.PUE) showed decreasing trend to applied P-fertilizer rates. The lowest mean values of 33.98, 0.33 and 108.01 g g^{-1} for (APUE), (PRE) and (Ph.PUE) respectively were recorded with applying 30 kg P fed^{-1}. This reducing effect can be attributed to the decrease in the rate of increase in both the grain yield and the total P uptake with the increase in the rate of P fertilization. Similar results are obtained by (Rahim *et al.* 2010 and Ghafoor 2016) who stated that phosphorus use efficiency (PUE) and phosphorus physiological efficiency index decreased with increasing rate of phosphorus fertilizer application. Data analysis in Table 7 show that K- uptake (g pot^{-1}) by grains and straw, total K-uptake (grains + straw), (AKUE), (KRE) as well as (Ph.KUE) significantly increased with increasing P-fertilizer rate. By comparing the results obtained by applying 15 and 30 kg P fed^{-1} with those obtained without P-fertilizer use, the calculations demonstrated that the increments of averages for K- uptake by grains and straw, total K-uptake, AKUE, KRE and Ph.KUE were (56, 61%), (44, 46%), (47, 50%), (102, 113%),(91, 97%) and (6, 8%) respectively.

Table 6. Effect of phosphate fertilizer rate, compost source phosphate solubilizing bacteria rate on P-uptake and phosphorus use efficiencies by wheat yield.

Wheat characteristics	P- Uptake g. pot^{-1}			Phosphorus Use Efficiency g g $^{-1}$		
Treatment	**Grain**	**Straw**	**Total**	**APUE**	**PRE**	**Ph.PUE**
Control	0.008	0.003	0.011	-	-	-
P- fertilizer rate (kg P Fed^{-1})						
0	0.024	0.021	0.034	-	-	592.22
15	0.117	0.034	0.152	64.41	0.38	174.78
30	0.177	0.079	0.256	33.98	0.33	108.01
Organic fertilizer Source						
C_1	0.097	0.037	0.134	33.93	0.22	345.54
C_2	0.115	0.053	0.160	31.67	0.25	237.80
Bio - fertilizer rate (L Fed^{-1})						
0	0.087	0.033	0.119	29.45	0.19	352.32
1	0.104	0.039	0.142	32.58	0.23	302.27
2	0.127	0.052	0.180	36.36	0.29	220.41
$LSD_{5\%}$ a	0.001	0.001	0.006	0.55	0.003	11.19
$LSD_{5\%}$ b	0.001	0.001	0.005	0.40	0.002	8.05
$LSD_{5\%}$ c	0.001	0.001	0.003	0.47	0.003	4.25

These results may be due to application of the recommended dose of potassium fertilizer only or reduced rates of increase in total potassium uptake with an increase in grain yield.

b) Effect of compost:

The statistical analysis of variance for data in Tables 3, 5, 6 and 7 clearly indicate that compost had significant effect on grain protein content, N, P and K-uptakes by grains or straw as well as the nutrient use efficiencies. Concerning the effect of compost source, data reveal that C_1 was superior to C_2 with respect to the obtained values of (CP), N-uptake by grains, N-uptake by straw, total N-uptake, (ANUE), (NRE), (APUE), (Ph.PUE), (AKUE) and (Ph.KUE). Meanwhile, C_2 outperformed C_1 for values of (Ph.NUE), P-uptake by grain and straw, total P uptake, (PRE), K-uptake by grain and straw, total K-uptake and (KRE). These results could be due to the differences of the nutrient contents in the used two composts.

Table 7. Effect of phosphate fertilizer rate, compost source phosphate solubilizing bacteria rates on K-uptake and potassium use efficiencies by wheat yield.

Wheat characteristics	K- Uptake g. pot^{-1}			Potassium Use Efficiency g g $^{-1}$		
Treatment	**Grain**	**Straw**	**Total**	**AKUE**	**KRE**	**Ph.KUE**
Control	0.034	0.092	0.126	-	-	-
P- fertilizer rate (kg P Fed^{-1})						
0	0.066	0.193	0.259	23.95	0.266	89.78
15	0.103	0.277	0.380	48.31	0.508	94.96
30	0.106	0.282	0.388	50.97	0.523	97.35
Organic fertilizer Source						
C_1	0.091	0.250	0.340	42.56	0.428	98.64
C_2	0.093	0.252	0.344	39.60	0.437	89.42
Bio - fertilizer rate (L Fed^{-1})						
0	0.088	0.238	0.326	36.62	0.400	90.04
1	0.092	0.248	0.339	40.70	0.427	94.98
2	0.095	0.266	0.361	45.91	0.470	97.08
LSD $_{5\%}$ a	0.001	0.001	0.002	0.79	0.007	1.03
LSD $_{5\%}$ b	0.001	NS	0.001	0.56	0.005	0.74
LSD $_{5\%}$ c	0.001	0.002	0.001	0.47	0.004	1.46

d) Interaction effect:

In general, the results show that the interaction effect of phosphate fertilizer rate, compost source and bio-fertilizer rate on the chemical composition of the wheat plant, its uptake of nutrients and their utilization efficiencies gave different responses (Tables 4, 8, 9 & 10).

With regard to the effect on grain crude protein content, the interaction effect was positive and not significant, as it scored the best value (12.50%) using the treatment (P 30 × C_1 × 2 L fed^{-1}). Respect to nitrogen uptake by grains, the interaction effect was positive and not significant, while it was positive and significant for straw and total uptake, where the interaction treatment (P 30 × C_1 × 2 L feed-1) recorded the highest values of 0.90, 0.71 and 1.61 for grains, straw and total uptake, respectively.

Relating to P and K-uptakes, the interaction effects were positive and the best values obtained were (0.230, 0.114), (0.109, 0.297) and (0.339, 0.411) g pot^{-1} for the uptake by grains, straw and total uptake, respectively when using the interaction treatment (P 30 × C_2 × 2L fed^{-1}).

Table 8. N-uptake and nitrogen use efficiencies by wheat yield as affected by the interaction of phosphate fertilizer rate, compost source phosphate solubilizing bacteria rate.

Wheat characteristics / Treatment			N- Uptake g. pot^{-1}			Nitrogen Use Efficiency g. g $^{-1}$		
P- fert., rate (kg Fed^{-1})	**Compost Source**	**Bio.Fert., rate (L Fed^{-1})**	**Grain**	**Straw**	**Total**	**ANUE**	**NRE**	**Ph.NUE**
Zero	C_1	0	0.45	0.23	0.68	4.43	0.10	44.32
		1	0.48	0.24	0.72	4.86	0.12	41.86
		2	0.54	0.30	0.84	5.84	0.16	35.78
	Mean		0.49	0.26	0.75	5.04	0.13	40.65
	C_2	0	0.41	0.20	0.61	3.64	0.07	50.50
		1	0.46	0.23	0.69	4.57	0.10	43.88
		2	0.51	0.27	0.78	5.42	0.14	38.69
	Mean		0.46	0.23	0.69	4.54	0.10	44.36
15	C_1	0	0.72	0.29	1.01	8.91	0.23	38.40
		1	0.79	0.36	1.15	9.99	0.29	34.67
		2	0.88	0.58	1.46	11.24	0.41	27.25
	Mean		0.80	0.41	1.21	10.05	0.31	33.44
	C_2	0	0.68	0.28	0.96	8.23	0.21	38.79
		1	0.74	0.33	1.07	9.25	0.26	36.13
		2	0.83	0.45	1.28	10.38	0.34	30.52
	Mean		0.75	0.35	1.10	9.29	0.27	35.15
30	C_1	0	0.76	0.36	1.12	9.63	0.28	34.88
		1	0.81	0.48	1.29	10.41	0.34	30.24
		2	0.90	0.71	1.61	11.34	0.47	24.01
	Mean		0.82	0.52	1.34	10.46	0.36	29.71
	C_2	0	0.73	0.33	1.06	9.12	0.25	36.19
		1	0.77	0.40	1.17	9.79	0.30	33.05
		2	0.86	0.51	1.37	10.91	0.38	28.99
	Mean		0.79	0.41	1.20	9.94	0.31	32.74
0		0	0.43	0.22	0.65	4.04	0.09	47.41
		1	0.47	0.24	0.71	4.72	0.11	42.87
		2	0.53	0.29	0.81	5.63	0.15	37.24
15		0	0.70	0.29	0.99	8.57	0.22	38.60
		1	0.77	0.35	1.11	9.62	0.28	35.40
		2	0.86	0.52	1.37	10.81	0.38	28.89
30		0	0.75	0.35	1.09	9.38	0.27	35.54
		1	0.79	0.44	1.23	10.10	0.32	31.65
		2	0.88	0.61	1.49	11.13	0.43	26.50
C_1		0	0.64	0.29	0.94	7.66	0.20	39.20
		1	0.69	0.36	1.05	8.42	0.25	35.59
		2	0.77	0.53	1.30	9.47	0.35	29.01
C_2		0	0.61	0.27	0.88	7.00	0.18	41.83
		1	0.66	0.32	0.98	7.87	0.22	37.69
		2	0.73	0.41	1.14	8.90	0.29	32.73
LSD $_{5\%}$ a*b			NS	0.006	0.016	0.14	0.006	NS
LSD $_{5\%}$ a*c			0.01	0.007	0.019	0.18	0.007	NS
LSD $_{5\%}$ b*c			NS	0.006	0.016	NS	0.006	0.81
LSD $_{5\%}$ a*b*c			NS	0.010	0.027	0.25	0.011	1.40

As for the nutrient use efficiencies by the wheat plant, the research results indicate that the effect of the interaction treatment on the values of APUE, PRE and Ph.PUE did not show a specific trend. On the other hand, the treatment (P 30 × C_1 × 2L fed^{-1}) gave the best values for ANUE, NRE, AKUE & Ph. KUE, whilst the height value for KRE was optioned with treatment (P 30 × C_2 × 2L fed^{-1}), while treatment (P 0.0 rate × C_2× 0.0 bio-fertilizer level) gave the largest value (50.5) of Ph. NUE.

Table 9. P-uptake and phosphorus use efficiencies by wheat yield as affected by the interaction of P- fertilizer rate, compost source phosphate solubilizing bacteria rates.

Wheat characteristics / Treatment			P- Uptake g. pot^{-1}			Phosphorus Use Efficiency g g^{-1}		
P- fert., rate (kg Fed^{-1})	Compost Source	Bio.Fert., rate (L Fed^{-1})	Grain	Straw	Total	APUE	PRE	Ph.PUE
Zero	C_1	0	0.016	0.007	0.023	-	-	923.42
		1	0.019	0.008	0.027	-	-	758.75
		2	0.031	0.010	0.041	-	-	486.67
	Mean		0.022	0.008	0.030	-	-	722.95
	C_2	0	0.018	0.009	0.027	-	-	568.13
		1	0.024	0.010	0.034	-	-	486.09
		2	0.037	0.015	0.052	-	-	330.24
	Mean		0.026	0.033	0.038	-	-	461.49
15	C_1	0	0.090	0.027	0.117	59.38	0.28	210.08
		1	0.110	0.032	0.142	66.55	0.35	190.53
		2	0.135	0.042	0.177	74.86	0.44	169.10
	Mean		0.112	0.034	0.145	66.93	0.36	189.90
	C_2	0	0.102	0.028	0.130	54.84	0.32	172.80
		1	0.125	0.034	0.159	61.65	0.40	156.22
		2	0.141	0.043	0.184	69.18	0.46	149.94
	Mean		0.123	0.035	0.158	61.89	0.39	159.65
30	C_1	0	0.138	0.051	0.189	32.09	0.24	135.21
		1	0.148	0.059	0.207	34.68	0.26	132.68
		2	0.190	0.095	0.285	37.78	0.37	103.41
	Mean		0.159	0.068	0.227	34.85	0.29	123.77
	C_2	0	0.157	0.073	0.230	30.40	0.29	104.27
		1	0.197	0.088	0.285	32.61	0.37	89.37
		2	0.230	0.109	0.339	36.34	0.44	83.10
	Mean		0.195	0.090	0.285	33.12	0.37	92.25
0		0	0.017	0.008	0.025	-	-	745.78
		1	0.022	0.009	0.031	-	-	622.42
		2	0.034	0.013	0.047	-	-	408.46
15		0	0.096	0.028	0.124	57.11	0.30	191.44
		1	0.118	0.033	0.151	64.10	0.38	173.38
		2	0.138	0.043	0.181	72.02	0.45	159.52
30		0	0.148	0.062	0.210	31.25	0.27	119.74
		1	0.173	0.074	0.246	33.65	0.32	111.03
		2	0.210	0.102	0.312	37.06	0.41	93.26
C_1		0	0.081	0.028	0.110	30.49	0.17	422.90
		1	0.092	0.033	0.125	33.74	0.20	360.65
		2	0.119	0.049	0.168	37.55	0.27	253.06
C_2		0	0.092	0.037	0.129	28.41	0.20	281.73
		1	0.115	0.044	0.159	31.42	0.26	243.89
		2	0.136	0.056	0.192	35.17	0.30	187.76
$LSD_{5\%}$ a*b			0.001	0.001	0.005	0.67	0.004	6.01
$LSD_{5\%}$ a*c			0.002	0.002	0.006	0.82	0.005	7.36
$LSD_{5\%}$ b*c			0.001	0.001	0.005	NS	0.004	6.01
$LSD_{5\%}$ a*b*c			0.002	0.002	0.009	NS	0.007	10.41

Table 10. K-uptake and potassium use efficiencies by wheat yield as affected by the interaction of P- fertilizer rate, compost source phosphate solubilizing bacteria rates.

Wheat characteristics / Treatment			K- Uptake g. pot^{-1}			Potassium Use Efficiency g g^{-1}		
P- fert., rate (kg Fed^{-1})	Compost Source	Bio.Fert., rate (L Fed^{-1})	Grain	Straw	Total	AKUE	KRE	Ph.KUE
Zero	C_1	0	0.063	0.184	0.247	22.16	0.242	91.57
		1	0.066	0.185	0.251	24.28	0.251	97.12
		2	0.068	0.207	0.275	29.20	0.298	97.99
	Mean		0.066	0.192	0.258	25.21	0.264	95.56
	C_2	0	0.064	0.185	0.249	18.18	0.245	73.90
		1	0.067	0.188	0.255	22.82	0.259	88.45
		2	0.069	0.208	0.277	27.08	0.302	89.67
	Mean		0.067	0.194	0.260	22.69	0.269	84.01
15	C_1	0	0.099	0.259	0.358	44.54	0.464	95.99
		1	0.101	0.275	0.376	49.92	0.500	99.84
		2	0.105	0.294	0.399	56.14	0.546	102.82
	Mean		0.102	0.276	0.378	50.20	0.503	99.55
	C_2	0	0.101	0.260	0.361	41.13	0.469	87.49
		1	0.103	0.279	0.382	46.24	0.513	90.31
		2	0.108	0.296	0.404	51.88	0.556	93.31
	Mean		0.104	0.278	0.382	46.42	0.513	90.37
30	C_1	0	0.101	0.269	0.370	48.13	0.488	98.63
		1	0.105	0.279	0.384	52.01	0.516	100.80
		2	0.107	0.294	0.401	56.67	0.549	103.03
	Mean		0.104	0.281	0.385	52.27	0.518	100.82
	C_2	0	0.102	0.270	0.372	45.60	0.492	92.67
		1	0.107	0.281	0.388	48.92	0.525	93.36
		2	0.114	0.297	0.411	54.51	0.570	95.63
	Mean		0.108	0.283	0.390	49.68	0.529	93.89
0		0	0.064	0.185	0.248	20.17	0.244	82.74
		1	0.067	0.187	0.253	23.55	0.255	92.79
		2	0.069	0.208	0.276	28.14	0.300	93.83
15		0	0.100	0.260	0.360	42.84	0.467	91.74
		1	0.102	0.277	0.379	48.08	0.507	95.08
		2	0.107	0.295	0.402	54.01	0.551	98.07
30		0	0.102	0.270	0.371	46.87	0.490	95.65
		1	0.106	0.280	0.386	50.47	0.521	97.08
		2	0.111	0.296	0.406	55.59	0.560	99.33
C_1		0	0.088	0.237	0.325	38.28	0.398	95.40
		1	0.091	0.246	0.337	42.07	0.422	99.25
		2	0.093	0.265	0.358	47.34	0.464	101.28
C_2		0	0.089	0.238	0.327	34.97	0.402	84.69
		1	0.092	0.249	0.342	39.33	0.432	90.71
		2	0.097	0.267	0.364	44.49	0.476	92.87
$LSD_{5\%}$ a*b			0.001	NS	NS	0.66	NS	2.07
$LSD_{5\%}$ a*c			0.001	0.003	0.003	0.81	0.006	2.53
$LSD_{5\%}$ b*c			0.001	NS	0.002	NS	0.005	NS
$LSD_{5\%}$ a*b*c			0.002	NS	NS	1.14	NS	3.58

CONCLUSION

From the results of this research it can be concluded that:

1- Sandy calcareous soils suffer from poor physical, chemical and biological properties, and thus a decrease in their fertility, in addition to a high pH, which causes problems in the availability of nutrients, especially phosphorus. To treat these problems, it is through continuous organic and biological fertilization, in addition to mineral fertilization, to provide the plant's requirements of the nutrients necessary for its growth and to obtain the appropriate crop in terms of quantity and quality.

2- It is necessary to change the traditional agricultural based on the use of chemicals to the organic and bio-farming system as a sustainable one with the use of natural mineral fertilizers in order to improve and preserve the fertility of this type of soil in order to produce healthy and safe food and reduce environmental pollution.

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تأثير التسميد الفوسفاتي المعدني والسماد العضوي المصنع والبكتريا المذيبة للفوسفات على محصول القمح ومكوناته في التربة الجيرية.

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يهدف هذا العمل إلى تقييم تأثير التسميد الفوسفاتي المعدني ومصدر السماد العضوي المصنع والبكتيريا المذيبة للفوسفات (PSB) على محصول القمح ومكوناته *Triticum aestivum, L.* (صنف مصر 1) النامي في التربة الجيرية. أجريت تجربة أصص داخل صوبة كلية التكنولوجيا والتنمية -جامعة الزقازيق - محافظة الشرقية - مصر خلال الموسم الشتوي 2019 / 2020 . نفذت التجربة بتصميم القطع المنشقة مرتين بنظام القطاعات الكاملة العشوائية باستخدام ثلاثة مكررات. أشتملت القطع الرئيسية و الفرعية علي مستويات الفوسفور المعدني (0 و 15 و 30 كجم بو فدان $^{-1}$) و مصدر الكومبوست (C_1 و C_2) بمعدل (15 م ^{3} فدان $^{-1}$) على التوالي بينما تم تخصيص القطع التحت رئيسية لمستويات البكتريا المذيبة للفوسفات (0.0 و 1 و 2 لتر فدان $^{-1}$). أوضحت النتائج أن قيم محصول الحبوب (GY) و محصول القش (SY) و المحصول البيولوجي (BY) و دليل الحصاد (HI) و البروتين الخام (CP) و النيتروجين و الفوسفور و البوتاسيوم الممتص و كفاءة الاستخدام الزراعية للنيتروجين و البوتاسيوم (ANUE) و (AKUE) و كفاءة استرجاع النيتروجين و البوتاسيوم (NRE)- (KRE) و كفاءة الاستخدام الفسيولوجية للبوتاسيوم (Ph.KUE) زادت معنويا مع زيادة مستوى السماد الفوسفاتي و كذا مع زيادة معدل استخدام البكتيريا المذيبة للفوسفات من 0,0 إلى 2 لتر لكل فدان. تفوق الكومبوست رقم 1 على الكومبوست رقم 2 في تأثيره علي جميع الصفات الزراعية المدروسة و البروتين الخام (CP) و النيتروجين والفوسفور والبوتاسيوم الممتص و كفاءة الاستخدام الزراعية للنيتروجين (ANUE) وكفاءة استرجاع النيتروجين (NRE) وكفاءة الاستخدام الزراعية للفوسفور(APUE) و كفاءة الاستخدام الفسيولوجية للفوسفور (Ph.PUE) و كفاءة الاستخدام الزراعية للبوتاسيوم (AKUE) وكفاءة الاستخدام الفسيولوجية للبوتاسيوم (Ph.KUE) . أفضل معاملة تفاعل حققت أعلى قيم لمعظم الصفات المدروسة كانت (30 كجم فو فدان $^{-1}$ + C_1 + 2 لتر سماد حيوي فدان $^{-1}$) يليها معاملة (15 كجم فو فدان $^{-1}$ + $2C_1$ + لتر سماد حيوي فدان $^{-1}$) بدون أي فروق معنوية.