ENHANCEMENT OF ROCK PHOSPHATE APPLICABILTY BY COMPOST AND PHOSPHATE DISSOLVING BACTERIA AND ITS EFFECT ON QUALITY AND PRODUCTIVITY OF CANOLA PLANT GROWN IN SANDY SOILS

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ABSTRACT: *Two field experiments were conducted during the two early winter seasons of 2014/2015 and 2015/2016 at Ismailia Agricultural Research Station, Agricultural Research Center (ARC), Ismailia Governorate, Egypt. Aim was to evaluate enhancement of applicability of rock phosphate by addition of compost and inoculation with phosphate dissolving bacteria and its effect on quality and productivity of canola plant. The experiment included 3 factors as follows: (1) three rates of rock phosphate i.e. 0 (RP$_0$), 250 kg ha^{-1} (RP$_1$) and 500 kg ha^{-1} (RP$_2$, (2) two treatments of compost: without application C$_0$ and 24 Mg ha^{-1}(C$_1$) and (3) two P-dissolving bacteria (PDB): none (PDB$_0$) and inoculation (PDB$_1$). The highest values of plant growth characters, yield and its component, seed quality, nutrient content and their uptake of canola plant were obtained under treatment of RP$_2$ + C$_1$ + PDB$_1$. It could be concluded that, the combined use of rock phosphate at rate of 500 kg ha^{-1} and compost manure at rate of 24 Mg ha^{-1} plus seed inoculation with PDB was more economical due to reduce and costs of the used fertilizers with access to results would be an appropriate substitute for chemical phosphorous fertilizer in sustainable agriculture system.*

Key words: *Canola plant, Organic composts, Phosphate dissolving bacteria, Rock phosphate and Sandy soil,*

INTRODUCTION

Canola plants (*Brassica napus L.*) are an important oil crop that ranks only behind soybean and palm oil in global production. In Egypt canola has a bright future to contribute in reducing oil deficiency gaps between production and consumption of edible oil. Canola plant is considered one of the new crops with high water use efficiency or high drought tolerance that can be used for oil seed production in the arid regions of the world (Leilah and Al-Khateeb, 2003). In Egypt, more desert areas of sandy calcareous soils have to be put under cultivation. Thus, growing canola in these soils could be successful, because these soils are less fertile and could produce relatively high economic yield with low level inputs mainly NPK fertilizers as mixed with organic manure (Ahmed *et al.;* 2005).

Phosphorus (P) is a major key nutrient for plants and affects several characteristics of plant growth. Though P, both in organic and inorganic forms is abundant, but due to its ability to form complexes with other soil constituents, it is not easily available for uptake by the plants (Khan *et al.,* 2009). Therefore, frequent application of important amounts of chemical fertilizers containing soluble forms of P is needed to achieve maximum plant productivity (Gyaneshwar *et al.,* 2002). Production of chemical fertilizers is based on chemical processing of insoluble mineral phosphate (high-grade ore) by treating them with sulfuric acid at high

temperature. Thus, the process is environmentally undesirable and a costly affair (Vassilev *et al.,* 2006). Excessive and indiscriminate application of chemical fertilizers show adverse impact on the soils in that soil micro flora and fauna (which impart natural properties to the soils) are destroyed thereby resulting into decreased agricultural production after years of application. Rock phosphate (RP) is a natural phosphorus source which can be an alternative to chemical fertilizers; unfortunately, it is soluble in acidic soils only and is not applicable in alkaline soils. Canola crop requires a suitable amount of rock phosphate (RP) as phosphate fertilizers, for better crop production. The insoluble P content of RP may be converted to the soluble form by chemical acidulation and biological means.

Microbial solubilization of rock phosphate is gaining importance as microbes release organic acids to solubilize rock phosphate. Phosphate solubilizing bacteria having ability to solubilize rock phosphate (Yadav *et al.,* 2014). Phosphate solubilization by bacteria is more efficient than fungi and bacterial processes are much easier for industrial application. The microbial strain such as P-dissolving bacteria is one of the most important agents to sustain P availability in the treated soil. These strain agents are the primary substances controlling the enhanced plant growth, absorption nutrients and photosynthesis process (Makovacki and Milic, 2001). Moreover, seed inoculation with bio-fertilizer is economically important as it resulted in reducing the needs of N and P fertilizers and improving the crop yield. (Romano, *et al* 2017) found that bio-fertilization improved plant growth characters and seed yield of sunflower plants.

The application of compost to soil can improve the soil quality, supply nutrients to plants and soil microbes, and reduce environmental pollution (Yang, 2003). Organic composts contained macro nutrients, trace elements, organic substances like amino acids and plant growth regulators such as auxin, cytokinin. Organic composts are known to enhance seed germination and plant growth (Thirumaran *et al.;* 2009). They have been also shown to increase crop yield, improve growth and induce resistance to frost, fungal and insect attack and increase nutrient uptake from the soil. Further organic matter (that matrixed rock phosphate particles) complexes soil cations, thereby preventing fixation of P. Thus compost is an ideal medium to increase the efficacy of rock phosphate and appears to be the best medium for direct application of rock phosphate, compost charged by rock phosphate along with phosphate solubilizing bacteria can be used as an efficient P fertilizer.

The current work aims to evaluate the applying different rates of rock phosphate and addition of compost on canola plant (*Brassica napus L.*) inoculated with P-dissolving bacteria (PDB) grown on sandy soil in order to develop a cost effective, eco-friendly and sustainable system where the supply of phosphorus to plants can be ensured.

MATERIALS AND METHODS
Site description

the field experiments were conducted along two winter successive seasons of 2014/2015 and 2015/2016 at Ismailia Agricultural Experimental Station, Agricultural Research Center (ARC), Egypt located between Latitude 29° 21′ 48″ N and Longitude 30° 44′ 45″ E. Main properties of soil, and chemical composition of both compost and rock phosphate were carried out according to Klute *et al.*; (1986) and the obtained data are recorded in Tables 1, 2 and 3. Available N, P and K in soil were

extracted by 1% K$_2$SO$_4$, 0.5 M solution sodium bicarbonate and 1 <u>N</u> ammonium acetate respectively, and were determined according to Jackson, (1973) and determined using Atomic Absorption Spectrophotometer.

Experimental design

The experimental design was a randomized complete block including 16 treatments with three replicates. The experiment included 3 factors as follows: (1) three rates of rock phosphate i.e. 0 (RP$_0$), 250 kg ha^{-1} (RP$_1$) and 500 kg ha^{-1} (RP$_2$, (2) two application rates of compost: without application "C$_0$" and 24 Mg ha^{-1} "C$_1$" and (3) two P-dissolving bacteria (*Bacillus megaterium var.*) PDB: none "PDB$_0$" and inoculation "PDB$_1$". All treatments were replicated three times. The experimental unit area was 10.5 m^2 with dimensions 3 x 3.5 m, each plot included 4 ridges (3.5 m in length and 30 cm in width).

Crop management

Rock phosphate and applied compost were incorporated into the soil 21 days before sowing. Canola seeds (*Brassica napus L.*) were inoculated with P-dissolving bacteria (PDB) on the same day of sowing, where phosphate absorbed on peat-moss power as carrier and registered to bio-fertilizers unit, Ministry of Agric., Egypt from which it was obtained. Hill spacing was 10 cm within the row. Seeds were sown 3-5 seeds on each hill on the second half of November. Normal Irrigation water was used immediately after sowing, then every one week interval according to agronomic practices in the district. Thinning was carried out at 15 days after sowing to secure two plants per hill on both sides of the ridge. Nitrogen fertilizer was added as ammonium nitrate at rate of 0.34 kg N kg^{-1} in two equal doses, the first dose was carried out after thinning and the second one was carried out at flowering stage. Also potassium fertilizer was added in the form of potassium sulphate at rate of 0.398 kg K kg^{-1} in two equal doses. First dose was added after one month of planting and the second was carried out after 21 days of the first dose.

Table 1. Main characteristics of the studied soil.

(%) Particle size distribution				Texture class	CaCO$_3$ (g kg-1)	O.M (g kg-1)	pH	EC	SP (%)	CEC (cmolc kg^{-1}soil)
Coarse sand	Fine sand	Silt	Clay							
78.01	9.6	5.61	6.78	Sandy	2.1	3.6	7.43	0.93	14.4	3.16
Soil cations (mmolc L^{-1})				Soil anions (mmolc L^{-1})				Available macronutrient (mg kg^{-1})		
Ca^{+2}	Mg^{+2}	Na$^+$	K$^+$	CO3^{-2}	HCO$_3^-$	Cl$^-$	SO4^{-2}	N	P	K
3.1	3.8	2.25	0.15	0	4.68	3.89	0.73	16.53	6.33	29.31

pH of 1 : 2.5 soil : water suspension. EC: of soil past extract

Table 2. Main characteristics of applied compost.

O.M (g kg^{-1})	Total C (g kg^{-1})	Total N (g kg-1)	Total P (g kg-1)	Total K (g kg-1)	C/N ratio	EC (dSm^{-1})	pH	Bulk density (Mg m^{-3})
358.7	252.6	13.4	8.5	16.8	18.9	2.3	7.3	0.83

pH of 1 : 5 compost : water suspension. EC: of 1: 10 compost : water extract.

Table 3. Main characteristics of applied rock phosphate.

Character	P	Ca O	Fe$_2$O$_3$	SiO$_2$	Mg O	SO$_4$	CaCO$_3$
Value (%)	12.85	44.2	1.4	4.22	2.15	1.06	11.91

Plant analysis

At harvest plant samples of both seeds and straw were collected for determination of the growth parameter, yield and its components and uptake of macro nutrients. Nitrogen was determined with a micro-Kjeldahl (Chapman and Pratt, 1961). Phosphorus was determined calorimetrically, according to Watanabe and Olsen, (1965). Potassium was determined using a Flame photometer, according to Jackson, (1973). Phosphorous contents in plant were determined by using a standard turbidity method according to (Issam and Sayegh, 2007). Crude protein was calculated by multiplying total seed N-content by 6.25 (Deyoe and Shellenberger, 1965). The oil content of canola seeds was determined by using a soxchlet according to A.O.A.C. (1990) while, oil yield estimated by multiplying seed yield (kg ha^{-1}) by oil content. All collected data were statistically analyzed according to Sedecor and Cochron (1980), to define the values of L.S.D.

RESULTS AND DISCUSSION
Growth characters

Data in Table 4 show that plant growth characters of canola plants are significantly increased due to the all treatments. With respect to the effect of rock phosphate application of the growth of canola plant, the rock phosphate causes gradually increased with increasing the application rate. Increasing percentages for RP$_2$ treatments were 71.47, 57.22 and 126.70% for plant height, dry weight and number of branch/plant, respectively over control treatment. Such effect may be due to that phosphorous encourage the growth of root system and enhance the photosynthesis, carbohydrates metabolites synthesized by plants and consequently increase plant growth characters. These results are in same line with those obtained by Abo-Baker and Hassan (2017)

Table 4. Growth characters of canola plant as affected by rock phosphate, compost and phosphate dissolving bacteria treatments.

RP	Compost	PDB treatments								
		PDB$_0$	PDB$_1$	Mean	PDB$_0$	PDB$_1$	Mean	PDB$_0$	PDB$_1$	Mean
		Plant height (cm)			Dry weight plant^{-1} (g)			No. of branches plant^{-1}		
RP0	C$_0$	78.13	81.35	79.74	70.26	73.68	71.97	5.29	6.47	5.88
	C$_1$	83.74	87.56	85.65	81.73	86.45	84.09	7.18	9.36	8.27
Mean		80.94	84.46	82.70	76.00	80.07	78.03	6.24	7.92	7.08
RP1	C$_0$	95.22	98.84	97.03	90.37	98.98	94.68	10.35	11.26	10.81
	C$_1$	112.86	119.42	116.14	101.25	110.74	106.00	12.83	14.46	13.65
Mean		104.04	109.13	106.59	95.81	104.86	100.34	11.59	12.86	12.23
RP2	C$_0$	131.29	140.97	136.13	113.43	120.81	117.12	15.12	15.81	15.47
	C$_1$	143.44	151.55	147.50	125.32	131.15	128.24	16.33	16.94	16.64
Mean		137.37	146.26	141.81	119.38	125.98	122.68	15.73	16.38	16.05
Grand mean		107.45	113.28	110.36	97.06	103.64	100.35	11.18	12.38	11.78
Means of compost										
	C$_0$	101.55	107.05	104.30	91.35	97.82	94.59	10.25	11.18	10.72
	C$_1$	113.35	119.51	116.43	102.77	109.45	106.11	12.11	13.59	12.85
LSD$_{0.05}$		RP=ns C=10.13 PDB=1.98 RPxC=34.46 RPxPDB=22.73 CxPDB=ns			RP=25.55 C=10.79 PDB=4.85 RPxC=33.77 RPxPDB=24.64 CxPDB=ns RxCXPDB=27.11			RP=ns C=1.76 PDB=0.98 RPxC=5.77 RPxPDB=3.88 CxPDB=ns RxCXPDB=6.89		

	RxCXPDB=18.57		

RP_0, RP_1 and RP_2: 0, 250 and 500 kg ha^{-1} of rock phosphate, C_0 and C_1: 0 and 24 Mg ha^{-1} of compost PDB$_0$ and PDB$_1$: none and inoculation with phosphate dissolving bacteria, n.s non-significant at the 5% levels of probability at L.S.D test.

Results also showed that application of compost manure had a significant increase effect on growth characters of canola plant (table 4). Increments due to C_1 were 11.62, 12.17 and 19.86 % for plant height, dry weight and number of branch/plant, respectively as compared with untreated plants (control). Same results were obtained by Awad *et al.* (2009).

Data resulted in Table (4) revealed that inoculation of canola seeds with phosphorous dissolving bacteria (PDB) significantly increases all of investigated plant growth characters. The corresponding relative increments due to PDB$_1$ were 5.42, 6.77 and 10.73 % for plant height, dry weight and number of branch/plant, respectively as compared with un-inoculated plants. These increases may be due to stimulation plant hormones production such as auxins, cytokines, gibberellins and also some volatile compounds. These results in accordance with those obtained by Abo-Baker and Hassan (2017)

Regarding to the interaction effect of the studied three factors, data in Table (4) reveal that different levels of RP combined with PDB inoculation led to a marked increase in plant growth characters. Percentages of RP$_2$ + PDB$_1$ treatment were 80.70, 65.76 and 162.5 % for plant height, dry weight and number of branch/plant, respectively as compared with RP$_0$ x PDB$_0$. Results also indicate that different rates of RP with compost application resulted significant increase in the studied plant growth characters as compared with RP0 + C0. These results are in agreement with those obtained by Awad *et al.* (2009) and El-Edfawy (2012). With respect to the interaction effect between RP application rates as combined with compost manure plus PDB seed inoculation, results indicated that the combined treatment of RP$_2$ + C$_1$ + PDB$_1$ proved to be even superior among other treatments in terms of plant growth characters of canola plant which produced 94.0, 86.6 and 220.23 % for plant height, dry weight and number of branch/plant, respectively as compared with unfertilized treatment. These increments might be due to the organic compounds which resulted during the decomposition of organic matter that can help to dissolution the fixed from of P in rock phosphate and increase the uptake of phosphorous by plant and also organic matter provide substrate for microbial growth which enhance plant growth characters. These results are in harmony with obtained by Abd El-Moneim *et al.* (2015).

Yield and yield component

Results in Table (5) indicated that, the application rates of RP gave markedly increase in all yield characters under study. The RP$_2$ treatment were enhanced No. of pods/plant by 75.12 %, 1000 seed weight by 12.33 %, seed yield by 42.18 % and straw yield by 32.21% as compared with RP0. Same results were obtained by Zapta and Roy (2004) and Abo-Baker and Hassan (2017).

As regard to the main effect of PDB inoculation on yield and yield components of canola plant, the obtained results in Table 5 showed that seed inoculation with PDB led to significant increase in all yield characters the percentages were 2.94, 1.73, 1.46 and 1.16 % for No. of pods/plant, 1000 seed weight, seed yield and straw yield,

respectively. These results are in the same line with those obtained by Abo-Baker and Hassan (2017).

Data also of this study, clear that using of compost manure at rate of 24 Mg ha^{-1} had a positive effect on the yield

characters of canola plant as compared to untreated plants (Table 5) El-Edfawy (2012) obtained the same results.

Table 5. Yield and its component of canola plant as affected by rock phosphate application, compost manure and phosphate dissolving bacteria treatments.

RP	Compost	PDB treatments								
		PDB_0	PDB_1	Mean	PDB_0	PDB_1	Mean	PDB_0	PDB_1	Mean
		No. of pods plant^{-1}			1000 seed weight (g)			Seed yield (kg ha^{-1})		
RP_0	C_0	186.86	193.17	190.02	2.13	2.16	2.15	710.33	719.21	714.77
	C_1	196.35	203.75	200.05	2.21	2.25	2.23	743.20	755.80	749.50
Mean		191.61	198.46	195.03	2.17	2.21	2.19	726.77	737.51	732.14
RP_1	C_0	253.11	261.42	257.27	2.29	2.32	2.31	851.43	868.90	860.17
	C_1	288.74	296.35	292.55	2.35	2.39	2.37	885.12	896.31	890.72
Mean		270.93	278.89	274.91	2.32	2.36	2.34	868.28	882.61	875.44
RP_2	C_0	328.25	336.82	332.54	2.41	2.45	2.43	963.20	975.04	969.12
	C_1	346.16	354.94	350.55	2.48	2.51	2.50	1105.28	1120.30	1112.79
Mean		337.21	345.88	341.54	2.45	2.48	2.46	1034.24	1047.67	1040.96
Grand mean		266.58	274.41	270.49	2.31	2.35	2.33	876.43	889.26	882.84
Means of compost										
	C_0	256.07	263.80	259.94	2.28	2.31	2.29	841.65	854.38	848.02
	C_1	277.08	285.01	281.05	2.35	2.38	2.37	911.20	924.14	917.67
$LSD_{0.05}$		RP=83.56 C=20.69 PDB=6.12 RPxC=ns RPxPDB=90.45 CxPDB=89.67 RxCXPDB=55.79			RP=0.15 C=0.04 PDB=0.03 RPxC=0.14 RPxPDB=0.12 CxPDB=0.07 RxCXPDB=0.22			RP=222.64 C=65.66 PDB=10.39 RPxC=255.48 RPxPDB=97.96 CxPDB=66.59 RxCXPDB=98.92		
		Straw yield (kg ha^{-1})			Harvest index (%)			Crop index (%)		
RP_0	C_0	903.41	915.90	909.66	44.02	43.99	44.00	78.63	78.52	78.58
	C_1	934.23	946.48	940.36	44.31	44.40	44.35	79.55	79.85	79.70
Mean		918.82	931.19	925.01	44.16	44.19	44.18	79.09	79.19	79.14
RP_1	C_0	1026.81	1035.40	1031.11	45.33	45.63	45.48	82.92	83.92	83.42
	C_1	1069.63	1082.91	1076.27	45.28	45.29	45.28	82.75	82.77	82.76
Mean		1048.22	1059.16	1053.69	45.31	45.46	45.38	82.84	83.34	83.09
RP_2	C_0	1180.58	1196.40	1188.49	44.93	44.90	44.92	81.59	81.50	81.54
	C_1	1251.93	1263.10	1257.52	46.89	47.00	46.95	88.29	88.69	88.49
Mean		1216.26	1229.75	1223.00	45.91	45.95	45.93	84.94	85.10	85.02
Grand mean		1061.10	1073.37	1067.23	45.13	45.20	45.16	82.29	82.54	82.42
Means of compost										
	C_0	1036.93	1049.23	1043.08	44.76	44.84	44.80	81.04	81.31	81.18
	C_1	1085.26	1097.50	1091.38	45.49	45.56	45.53	83.53	83.77	83.65

LSD$_{0.05}$	RP=131.46 C=38.38 PDB=10.11 RPxC=ns RPxPDB=122.62 CxPDB=ns RxCXPDB=111.56	RP=0.77 C=0.56 PDB=0.03 RPxC= 1.33 RPxPDB=1.05 CxPDB=n.s RxCXPDB=1.11	RP=1.66 C=1.39 PDB=0.11 RPxC=2.21 RPxPDB=2.18 CxPDB=n.s RxCXPDB=2.31

RP$_0$, RP$_1$ and RP$_2$: 0, 250 and 500 kg ha^{-1} of rock phosphate, C$_0$ and C$_1$: 0 and 24 Mg ha^{-1} of compost PDB$_0$ and PDB$_1$: none and inoculation with phosphate dissolving bacteria, n.s non-significant at the 5% levels of probability at L.S.D test.

Concerning to the interaction effect of the studied three factors, results in Table (5) indicate that the combined application of RP + PDB particularly treatment of RP$_2$ + PDB$_1$ gave significant increase in all yield characters i.e. No. of pods/plant, 1000 seed weight, seed yield, straw yield, harvest index and crop index. These results are in harmony with obtained by Abo-Baker and Hassan (2017). Also the obtained results clear that the combined effect of the RP$_2$ treatment with application of compost manure at rate of 24 Mg ha^{-1} significantly increased all yield characters at maturity stage of canola plant. The respective increase were 84.48, 16.28, 55.69 and 38.24 % for No. of pods/plant, 1000 seed weight, seed yield and straw yield, respectively over control treatment. These results might be due to the compost manure could produce organic acid which lowered pH nearer plant roots which increased the availability of P from RP and improved its efficiency that promote growth and yield of canola plant (Awad *et al*. 2009). Also results in Table (5) reveal that, the highest values were obtained under combined treatment of RP$_2$ + C$_1$ + PDB$_1$ which led to positive and significant increase in all yield characters. These increases were 89.94, 17.84, 57.72, 39.81, 6.77 and 12.80 % for No. of pods/plant, 1000 seed weight, seed yield straw yield, harvest index and crop index, respectively over control treatment. These increase may be due to compost manure stimulating and increase the activity of PDB that can in turn producing the organic acids that may help acidify

and dissolve RP and thus increasing P-uptake by plant which ultimately reflected it increased growth and yield for canola plant. (Awad *et al*. 2009).

Seed quality
Results in Table (6) reveal that oil and protein contents of canola plant were not responded significantly by the tested treatments. However, the combined treatment of RP$_2$ + C$_1$ + PDB$_1$ led to significant increase in oil and protein content. Increments were 3.38 and 3.54 % for oil and protein content, respectively compared with the control. Also data in the same Table clear that the oil yield of canola plant was affected significantly by all treatments in this study. The greatest value of oil yield in canola seeds was associated with the combined treatment of RP$_2$ + C$_1$ + PDB$_1$ which produced 62.73% relative to unfertilized plants. This might be due to that P is required for production of high quality of seeds. Since it occurs as co-enzymes involved in energy transfer reactions, energy tapped in photosynthesis in form of adenosine triphosphate (ATP) and nicotinamide adenine-dinucleotide phosphate (NADP), this energy is then used in photosynthesis of lipids and other essential organic compounds. Also phosphorous is considered as a component of nucleic acids, which necessary for protein synthesis. Similar results observed by Awad *et al.;* (2009) Abd El-Moneim *et al.*; (2015) and Abo-Baker and Hassan (2017).

Nutrients concentration and uptake

In general, results in Tables (7) and (8) show that N and K concentration in canola seeds and straw were not affected significantly by applied treatments. The results in the same tables reveal that P concentration and NPK- uptake were significantly increased by the studied treatments. It worthy to mention that the

highest values were obtained under combined treatment of $RP_2 + C_1 + PDB_1$ followed by treatment of $RP_1 + C_1 + PDB_1$. Increment values of $RP_2 + C_1 + PDB_1$

relative to the control were 186.67, 63.29, 352.11 and 69.48 for P content, N-uptake, P-uptake, K-uptake, respectively in seeds whereas, in straw were, 155.56, 56.41, 259.2 and 68.79%, respectively. These increases due to increase in P availability as a result of organic acids produced during organic matter decomposition as well as the chelating effect of organic complexes with P. these results are in accordance with those obtained by Abd El-Moneim *et al.* (2015) and Abo-Baker and Hassan (2017).

Table 6. Seed quality of canola plant as affected by rock phosphate application, compost manure and phosphate dissolving bacteria treatments.

RP	Compost	PDB treatments								
		PDB_0	PDB_1	Mean	PDB_0	PDB_1	Mean	PDB_0	PDB_1	Mean
		Oil content (g kg^{-1})			Oil yield kg ha^{-1}			Protein content (g kg^{-1})		
RP0	C_0	43.82	44.00	43.91	311.86	316.45	314.16	21.18	21.25	21.22
	C_1	43.90	44.09	44.00	326.20	333.20	329.70	21.37	21.56	21.47
Mean		43.86	44.05	43.95	319.03	324.83	321.93	21.28	21.41	21.34
RP1	C_0	44.23	44.29	44.26	376.60	384.80	380.70	21.43	21.50	21.47
	C_1	44.59	44.70	44.65	394.60	400.60	397.60	21.56	21.68	21.62
Mean		44.41	44.50	44.45	385.60	392.70	389.15	21.50	21.59	21.54
RP2	C_0	44.91	45.08	45.00	432.50	439.54	436.02	21.62	21.75	21.69
	C_1	45.21	45.30	45.26	499.70	507.50	503.60	21.90	21.93	21.92
Mean		45.06	45.19	45.13	466.10	473.52	469.81	21.76	21.84	21.80
Grand mean		44.44	44.58	44.51	390.24	397.02	393.63	21.51	21.61	21.56
Means of compost										
	C_0	44.32	44.46	44.39	373.65	380.26	376.96	21.41	21.50	21.46
	C_1	44.57	44.70	44.63	406.83	413.77	410.30	21.61	21.72	21.67

| LSD$_{0.05}$ | RP=n.s C=n.s PDB=n.s RPxC=0.57 RPxPDB=0.64 CxPDB=ns RxCXPDB=0.22 | RP=81.66 C=29.67 PDB=4.12 RPxC=89.65 RPxPDB=89.51 CxPDB=34.62 RxCXPDB=79.98 | RP=ns C=0.19 PDB=0.07 RPxC=ns RPxPDB=ns CxPDB=0.11 RxCXPDB=0.35 |

RP$_0$, RP$_1$ and RP$_2$: 0, 250 and 500 kg ha^{-1} of rock phosphate, C$_0$ and C$_1$: 0 and 24 Mg ha^{-1} of compost PDB$_0$ and PDB$_1$: none and inoculation with phosphate dissolving bacteria, n.s non-significant at the 5% levels of probability at L.S.D test.

Table 7. Nitrogen, P and K content and their uptake in seeds of canola plant as affected by rock phosphate application, compost manure and phosphate dissolving bacteria treatments.

RP	Compost	PDB treatments								
		PDB$_0$	PDB$_1$	Mean	PDB$_0$	PDB$_1$	Mean	PDB$_0$	PDB$_1$	Mean
		N			P			K		
concentration (g kg^{-1})										
RP0	C$_0$	3.39	3.40	3.40	0.30	0.31	0.31	1.60	1.61	1.61
	C$_1$	3.42	3.45	3.44	0.33	0.36	0.35	1.64	1.66	1.65
Mean		3.41	3.43	3.42	0.32	0.34	0.33	1.62	1.64	1.63
RP1	C$_0$	3.43	3.44	3.44	0.54	0.58	0.56	1.65	1.67	1.66
	C$_1$	3.45	3.47	3.46	0.62	0.64	0.63	1.68	1.69	1.69
Mean		3.44	3.46	3.45	0.58	0.61	0.60	1.67	1.68	1.67
RP2	C$_0$	3.46	3.48	3.47	0.65	0.70	0.68	1.69	1.70	1.70
	C$_1$	3.50	3.51	3.51	0.82	0.86	0.84	1.71	1.72	1.72
Mean		3.48	3.50	3.49	0.74	0.78	0.76	1.70	1.71	1.71
Grand mean		3.44	3.46	3.45	0.54	0.58	0.56	1.66	1.68	1.67
Means of compost										
	C$_0$	3.43	3.44	3.43	0.50	0.53	0.51	1.65	1.66	1.65
	C$_1$	3.46	3.48	3.47	0.59	0.62	0.61	1.68	1.69	1.68
LSD$_{0.05}$		RP=ns C=0.02 PDB=ns RPxC=ns RPxPDB=ns CxPDB=ns RxCXPDB=ns			RP=0.29 C=0.07 PDB=0.01 RPxC=0.22 RPxPDB=0.28 CxPDB=0.09 RxCXPDB=0.24			RP=ns C=0.02 PDB=ns RPxC=ns RPxPDB=ns CxPDB=0.03 RxCXPDB=ns		
Uptake (kg ha^{-1})										
RP0	C$_0$	24.08	24.45	24.27	2.13	2.23	2.18	11.37	11.58	11.47
	C$_1$	25.42	26.08	25.75	2.45	2.72	2.59	12.19	12.55	12.37
Mean		24.75	25.26	25.01	2.29	2.48	2.38	11.78	12.06	11.92
RP1	C$_0$	29.20	29.89	29.55	4.60	5.04	4.82	14.05	14.51	14.28
	C$_1$	30.54	31.10	30.82	5.49	5.74	5.61	14.87	15.15	15.01
Mean		29.87	30.50	30.18	5.04	5.39	5.22	14.46	14.83	14.64
RP2	C$_0$	33.33	33.93	33.63	6.26	6.83	6.54	16.28	16.58	16.43
	C$_1$	38.68	39.32	39.00	9.06	9.63	9.35	18.90	19.27	19.08
Mean		36.01	36.63	36.32	7.66	8.23	7.95	17.59	17.92	17.76
Grand mean		30.21	30.80	30.50	5.00	5.36	5.18	14.61	14.94	14.77
Means of compost										
	C$_0$	28.87	29.42	29.15	4.33	4.70	4.51	13.90	14.22	14.06
	C$_1$	31.55	32.17	31.86	5.67	6.03	5.85	15.32	15.65	15.49

LSD$_{0.05}$	RP=5.22 C=1.79 PDB=0.39 RPxC=5.25 RPxPDB=ns CxPDB=ns RxCXPDB=ns	RP=2.66 C=1.12 PDB=0.29 RPxC=2.33 RPxPDB=2.55 CxPDB=1.28 RxCXPDB=3.36	RP=2.79 C=1.28 PDB=0.31 RPxC=ns RPxPDB=ns CxPDB=1.37 RxCXPDB=ns

RP$_0$, RP$_1$ and RP$_2$: 0, 250 and 500 kg ha^{-1} of rock phosphate, C$_0$ and C$_1$: 0 and 24 Mg ha^{-1} of compost PDB$_0$ and PDB$_1$: none and inoculation with phosphate dissolving bacteria, n.s non-significant at the 5% levels of probability at L.S.D test.

Table 8. Nitrogen, P and K concentration and uptake in straw of canola plant as affected by rock phosphate application, compost manure and phosphate dissolving bacteria treatments.

RP	Compost	PDB treatments								
		PDB$_0$	PDB$_1$	Mean	PDB$_0$	PDB$_1$	Mean	PDB$_0$	PDB$_1$	Mean
		N			**P**			**K**		
concentration (g kg^{-1})										
RP0	C$_0$	1.27	1.29	1.28	0.09	0.11	0.10	1.06	1.07	1.07
	C$_1$	1.28	1.31	1.30	0.10	0.12	0.11	1.15	1.18	1.17
Mean		1.28	1.30	1.29	0.10	0.12	0.11	1.11	1.13	1.12
RP1	C$_0$	1.31	1.32	1.32	0.12	0.15	0.14	1.18	1.20	1.19
	C$_1$	1.34	1.35	1.35	0.16	0.19	0.18	1.21	1.23	1.22
Mean		1.33	1.34	1.33	0.14	0.17	0.16	1.20	1.22	1.21
RP2	C$_0$	1.37	1.40	1.39	0.16	0.19	0.18	1.24	1.25	1.25
	C$_1$	1.41	1.42	1.42	0.20	0.23	0.22	1.27	1.28	1.28
Mean		1.39	1.41	1.40	0.18	0.21	0.20	1.26	1.27	1.26
Grand mean		1.33	1.35	1.34	0.14	0.17	0.15	1.19	1.20	1.19
Means of compost										
	C$_0$	1.32	1.34	1.33	0.12	0.15	0.14	1.16	1.17	1.17
	C$_1$	1.34	1.36	1.35	0.15	0.18	0.17	1.21	1.23	1.22
LSD$_{0.05}$		RP=ns C=0.02 PDB=ns RPxC=0.05 RPxPDB=ns CxPDB=0.02 RxCXPDB=ns			RP=0.08 C=0.01 PDB=0.02 RPxC=ns RPxPDB=0.03 CxPDB=0.03 RxCXPDB=ns			RP=ns C=0.04 PDB=ns RPxC=ns RPxPDB=ns CxPDB=0.03 RxCXPDB=ns		
Uptake (kg ha^{-1})										
RP0	C$_0$	11.47	11.82	11.64	0.81	1.01	0.91	9.58	9.80	9.69
	C$_1$	11.96	12.40	12.18	0.93	1.14	1.04	10.74	11.17	10.96
Mean		11.72	12.11	11.91	0.87	1.07	0.97	10.16	10.48	10.32
RP1	C$_0$	13.45	13.67	13.56	1.23	1.55	1.39	12.12	12.42	12.27
	C$_1$	14.33	14.62	14.48	1.71	2.06	1.88	12.94	13.32	13.13
Mean		13.89	14.14	14.02	1.47	1.81	1.64	12.53	12.87	12.70
RP2	C$_0$	16.17	16.75	16.46	1.89	2.27	2.08	14.64	14.96	14.80
	C$_1$	17.65	17.94	17.79	2.50	2.91	2.70	15.90	16.17	16.03
Mean		16.91	17.34	17.13	2.20	2.59	2.39	15.27	15.56	15.42
Grand mean		14.17	14.53	14.35	1.51	1.82	1.67	12.65	12.97	12.81
Means of compost										
	C$_0$	13.70	14.08	13.89	1.31	1.61	1.46	12.11	12.39	12.25

C_1	14.65	14.98	14.82	1.72	2.03	1.87	13.20	13.55	13.37
$LSD_{0.05}$	RP=ns C=0.77 PDB=0.27 RPxC=ns RPxPDB=ns CxPDB=0.88 RxCXPDB=ns			RP=0.69 C=0.36 PDB=0.22 RPxC=0.51 RPxPDB=0.88 CxPDB=ns RxCXPDB=ns			RP=ns C=1.03 PDB=0.25 RPxC=ns RPxPDB=ns CxPDB=1.06 RxCXPDB=ns		

RP_0, RP_1 and RP_2: 0, 250 and 500 kg ha^{-1} of rock phosphate, C_0 and C_1: 0 and 24 Mg ha^{-1} of compost PDB_0 and PDB_1: none and inoculation with phosphate dissolving bacteria, n.s non-significant at the 5% levels of probability at L.S.D test.

CONCLUSION

From these above mentioned results it could be concluded that, the combined use the combination of rock phosphate at rate of 500 kg ha^{-1} and compost manure at rate of 24 Mg ha^{-1} plus seed inoculation with PDB was a good economic return due to the reduction in the mounted mineral fertilizers used and its costs. These results would be an appropriate substitute for chemical phosphorous fertilizer in sustainable agriculture system.

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زيادة فاعلية صخر الفوسفات بواسطة الكمبوست والبكتريا المذيبة للفوسفات وتأثيرها على جودة وإنتاجية نبات الكانولا النامى فى أرض رملية

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الملخص العربى

أقيمت تجربتان حقليتان فى الموسمين الشتويين 2014/2015 و 2015 / 2016 بمحطة بحوث الإسماعيلية التابعة لمركز البحوث الزراعية محافظة الإسماعيلية – مصر . تهدف الدرسة لتقييم زيادة فاعلية صخر الفوسفات بإضافة الكمبوست والتلقيح بالبكتيريا المذيبة للفوسفات وتأثيره على جودة وإنتاجية نبات الكانولا. اشتملت التجربة على ثلاثة عوامل: 1– ثلاثة معدلات من صخر الفوسفات صفر، 250 و 500 كجم/هكتار 2– معدلين لإضافة الكمبوست صفر و 24 ميجا جرام / فدان 3– معاملتان للبكتريا المذيبه للفوسفات بدون إضافة و بالتلقيح . كانت أعلى قيم لصفات النمو – المحصول – مكونات المحصول – جودة البذور – محتوى النبات والممتص من العناصر الغذائية لنبات الكانولا وجدت فى المعاملة معدل 500 كجم /هكتارمن صخر الفوسفات + إضافة الكمبوست + التلقيح بالبكتريا المذيبة للفوسفات . ويمكن التوصية بأن إضافة صخر الفوسفات بمعدل 500 كجم / هكتار مع إضافة الكمبوست بمعدل 24 ميجا جرام / هكتار مع تلقيح البذور بالبكتريا المذيبة للفوسفات تحقق أعلى عائد وأقل تكلفة إقتصادية بالمقارنة بالأسمدة الكيماوية ويمكن أن تحل محل الأسمدة الفوسفاتية الكيميائية لنظام الزراعة المستدامة.

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