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Using Compost Tea to Maximize Use Efficiency of Phosphatic Fertilizers and its Effect on Health and Productivity of Calcareous Soil

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A FIELD experiment was carried out during two successive seasons (2018 and 2019) to evaluate the efficiency of P fertilization alone, in alternative with non-enriched compost tea (NECT) and together with enriched compost tea (ECT) at two application rates. The studied treatments were arranged within the experimental units in completely randomized block design. The effect of phosphorus (P) treatments on soil chemical properties and its content of available nutrients, nodulation efficiency and soil productivity of common bean plants and its content of essential nutrients was studied. Increasing rate of added P as H_3PO_4 in the three forms resulted in a decrease of soil pH and its content of $CaCO_3$, slight increase of EC, and increase of soil CEC and its content of OM and available macro- (N, P, K and Ca) and micro-nutrients(Fe, Mn, Zn and Cu), where these changes were occurred with different rates. The high relative changes for the studied determinations were found with the treatment ECT P followed by those found in the soil fertigated by P+ NECT. Also, increasing rate of added P in the three forms resulted in increase in the formed root nodules, yield of common bean (straw and seeds) plants and its content of N, P, K, Ca, Fe, Mn, Zn, Cu and protein. As well as added P in ECTP followed by the applications of P+NECT increased the agronomical efficiency of P fertilizers under calcareous soil conditions.

Keywords: Calcareous soil, Phosphorus, Compost tea, Agronomical efficiency and Common bean.

Introduction

The horizontal expansion of agricultural soils in Egypt mainly depends on reclamation and cultivation of new soils especially in the Western Desert of Egypt. The soils of these regions characterized by an alkaline pH, high content of $CaCO_3$, coarse texture and low content of organic matter and available nutrient which adversely affect plant growth. Also, P forms in these soils are found in an insoluble compound with some cations such as calcium reduced its availability and uptake by plants (Cordell et al., 2011). Soil organic amendments such as compost tea and compost increased P availability as well as its uptake by plants (Hegazy et al., 2015; Emam et al., 2020;Taha et al., 2016; Abou Hussein et al., 2019).

Compost tea improves soil quality by altering its chemical, physical and biological properties as well as increase organic matter content water holding capacity and overall diversity of microbes. It also provides essential plant nutrients and suppressing diseases, which indirectly contributes to enhance plant growth (Heather et al., 2006).Hegazy et al. (2013) found that compost tea and compost can be used as an environment friendly alternative fungicide for reduction of damping-off disease.

Leguminous crops such as common bean (*Phaseolus vulgaris* L.) are not cultivated only as a human diet, but also for improving soil quality through biological nitrogen fixation. For millions of people in the world, these crops are an important source of calories, protein, dietary, fibers minerals and vitamins (Elkhatib, 2009). Bean consumption is high mostly because they are relatively cheap food.

This study aimed to examine the effect of compost tea on P fertilization efficiency and their effect on common bean productivity. In addition,

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individual and combined effect of P fertilization and compost tea on chemical indicator of calcareous soil health were studied.

Materials and Methods

This study was carried out as a field experiment to increase soil P availability and its fertilizer efficiency under calcareous soil conditions using compost tea through surface drip irrigation system and their effect on soil productivity of common bean plants.

The experimental soil

Before planting randomized five soil samples were taken at soil depth of 0-20 cm from the experimental calcareous soil of private farm at El-Nobaria, Al-Behaira Governorate, Egypt (30° 40′ 43″ N, 30° 08′ 43″ E). These samples were air-dried, mixed, ground, sieved through a 2 mm sieve and analyzed for its physical and chemical properties following the methods described by Klute (1986), Cottenie et al. (1982) and Page et al. (1982). These properties are shown in Table 1.

Compost tea preparation

The used compost tea was produced from compost prepared in the same farm.Compost was previously prepared from plant residues mixed with farmyard manure, $CaCO_3$, urea, superphosphate and elemental sulphur as activator. This mixture was composted in an aerobic heap up to maturity which obtained after about three months as described by Abou Hussein *et al*. (2016). Samples of prepared compost were taken for compost tea preparation following the method described by Ingham (2005) with the modifications pointed out by Hegazy et al. (2015) as follows:

A weight (5 kg) of prepared fresh compost were scaled in a column bag and submerged in 100 l of tap water in a 200 L plastic container. Water used was previously pump aeriated for 0.5 h to remove the present chlorine to avoid its harmful effects on the activity of compost microorganisms. Then, molasses was added to the mixture in the plastic container at mixed ratio of 0.5% (v/v). The soaking process of compost was carried out at room temperature (25 ± 2 °C) for 96 hr with continuous aeration (10ml/min and delivery per container through air source). All previous steps of compost tea preparation were done in separated three containers, where the first one represented the non-enriched compost tea (NECT), while the second and the third represented the enriched compost tea with phosphorus in the form of phosphoric acid (H_3PO_3) which characterized by specific gravity of 1.68, purity percent of 85 % and 61.5 % P_2O_5 (26.86 P)at application rate of 31.6 and 63.2 ml l^{-1} (3162 and 6325 ml / container) which equal 0.85 and 1.7 kg P per container "100 l" i.e. ECTP1 and ECTP2, respectively. Each type of compost tea types must be prepared few times to obtain the demanded amounts. The prepared three types of compost tea were chemically analyzed as described by Page *et al*. (1982) and AOAC (2002) and the found data are listed in Table 2.

TABLE 1. Some physical and chemical properties of the cultivated soil and its content of available nutrients

Particle size distribution (%)				Texture class	Water holding capacity (%)
Coarse sand	Fine sand	Silt	Clay		
22.3	55.6	11.4	10.5	Sandy	20.1

Chemical properties

pH (1:2.5) (soil: water susp.)	EC dS m^{-1} (1:5) soil: (water extract)	OM g kg^{-1}	$CaCO_3$ %	CEC c mole kg^{-1}
8.45	2.11	5.1	16.22	18.85

Available nutrients (mg kg^{-1})

N	P	K	Ca	Fe	Mn	Zn	Cu
31.11	3.15	75.5	17.50	2.22	2.93	1.25	0.52

TABLE 2. Some chemical properties of tested compost tea*

Parameter	Type of compost tea		
	NECT	ECTP1	ECTP2
pH	7.05	6.65	6.11
EC dSm^{-1}	2.11	2.20	2.43
Total N mg l^{-1}	1.85	1.90	1.96
Total P mg l^{-1}	15.2	8508	17005
Total K mg l^{-1}	350.65	354.40	356.60
Total C (%, w:v)	10.22	10.50	10.86

*NECT and ECTP1 and ECTP2 = non enriched compost tea and enriched compost tea with P1 and P2 i.e. 31.6 and 63.2 ml H_3PO_4 l^{-1}, respectively.

Field experiment

During spring growing seasons of 2018 and 2019, a field experiment was carried out on newly reclaimed calcareous soil at private farm at El-Nobaria, Al-Behaira Governorate, Egypt. The experimental treatments in this study were seven as follows:

1- P0: without any supplemental P fertilization.

2- P1: phosphoric acid at rate of 3.4 kg P fed^{-1} (12.65 l H_3PO_3).

3- P2: phosphoric acid at rate of 6.8 kg P fed^{-1} (25.3 l H_3PO_3).

4- P1 + NECT: P1 + 400 l non-enriched compost tea fed^{-1}, individually.

5- P2 + NECT: P2 + 400 l non-enriched compost tea fed^{-1}, individually.

6- ECTP1: P1 with 400 l non-enriched compost tea fed^{-1}, together.

7- ECTP2: P2 with 400 l non-enriched compost tea fed^{-1}, together.

The experiment area (441 m^2) was divided into 21 plots with 21m^2 (3×7 m) for each plot. The studied treatments were arranged within the experimental units in completely randomized block design in three replicates. A common bean (Nebraskacv) plants was cultivated in this study as test plant. Seeds of common bean were obtained from Horticulture Research Institute, Agricultural Research Center, Giza, Egypt. To improve seed germination and plant growth especially under calcareous soil conditions, directly before planting the seeds of common bean were inoculated with the symbiotic N-fixing bacteria of *Rhizobium phaseoli* (Oqadin) by coating seeds at rate of 800 g/ seeds of feddan using Arabic gum 50 % as a staking substance. This inoculation level was approximately 10^7 CFU, which was confirmed by colony counts on yeast mannitol agar media. Also, before planting all plots were manured by farmyard manure (FYM) at rate of 10Mg fed^{-1}. The sowing date was 19thMarch 2018 and 2019 for the first and second season, where two inoculated seeds were sowed in each hole with a 25cm distance between holes and raw spacing of 60 cm. Drip irrigation system was used and irrigation process was carried out according to plant requirements. Application of P fertilization treatments under study were carried out on four equal doses with irrigation water i.e. at sowing and after 15, 30 and 45 days of planting. Other farming practices were done following the recommendation of Egyptian Ministry of Agriculture and Land Reclamation. Activation dose of N as ammonium sulphate (20.5 %N) at rate of 25kg fed^{-1} was added at the same time of sowing. Other dose of N fertilizer at the same application rate was added at 30 days of planting. Potassium sulphate (50% K_2O) was added to all experimental units at rate of 100 kg fed^{-1} in two equal doses after 20 and 40 days of planting. Application of N and K fertilization was carried out by fertigation technique.

At 60 days of planting, five plants were taken randomly from each replicate representing the first sample, washed several times with tap water to remove the soil particles contacted on the roots, separated into roots and shoots and weighed separately to record fresh weight as g $plant^{-1}$. Nodules formed on the roots per plant were counted and recorded. Plant samples (roots and shoots) were oven dried at 70 °C for 48 hr and weighed to obtain the dry matter yield.

At harvest stage, common bean plants of each plot were harvested at 5 cm above the soil surface, separated into seeds and straw, weighed separately and the found weights recorded. A portion of each plant sample (straw and seeds) weighed, oven dried at 70 °C up to constant weight was recorded, weighed, ground and kept for chemical analysis. At the same day of harvesting, three surface (0-20cm) soil samples were taken randomly from each plot, ground, mixed, sieved through a 2 mm sieve and kept for determination of its chemical properties as well as the content of available essential nutrients (Cottenie et al., 1982 and Page et al., 1982).

A weight (0.2 g) of each oven dried and ground plant sample was digested using the mixture of concentrated H_2SO_4 and $HClO_4$ acids as described by Chapman and Pratt (1961). The final clear digests content of some essential nutrients was determined using the methods described by Cottenie et al. (1982). Seeds content (%) of protein was calculated by multiplying N concentration (%) by 6.25 (AOAC, 1990).

The relative changes "RC" of the obtained data as percentage (%) affected by the studied treatments compared with those resulted from control may be calculated using Equation (1):

RC = {(dry matter yield of treated plants-dry matter yield of untreated plants) / (dry matter yield of untreated plants)} × 100. (Eq. 1).

Equation (2) was used to calculate the harvest index "HI"(%) of common bean:

HI = {(seed yield kg fed-1) / biological yield (straw + seeds) kg fed-1} × 100. (Eq. 2)

Also, agronomical efficiency (AE) of P fertilizer as kg seeds per kg P fertilizer was calculated using Equation (3):

AE (kg kg-1) = (seed yield of treated plants) -(seed yield of untreated plants)/ added P (kg fed.-1). (Eq. 3)

The obtained results were statistically analyzed using coStat software according to Snedecor and Cochran (1982).

Results and Discussions

Data of 60 days growth period

Nodules number

Nodules number formed on the roots of common bean plants as an indicator for nodulation efficiency and biological activity and its relative change "RC" (%) affected by forms and application rates of P fertilization were determined.The obtained data were listed in Table 3. Nodules number per plant showedhigh response to the studied treatments, of P fertilization, where this number was increased significantly with the increase rate of added P. Increase rate of added P in H_3PO_4 alone from 0 to 3.4 and 6.4 kg fed^{-1} resulted in an increase of root nodules number per plant from 40 to 45 and 52 with RC of 12.5 and 30.0 %, respectively. Similar significant increases were found with the other forms of P fertilization. Also, these increases are indicating more effective N fixation. These findings are similar to those obtained by El-Shinnawi et al. (2014) on faba bean and Fageria and Baligar (2016) and Hammad (2019) on common bean. In general, the legume plants have more demand of P for optimal N fixation compared to non-nodulating plants like cereals because P play acritical and important role nodule energetic transformation (Rotaru and Sinclair 2009).

In addition, P application in alternative with NECT, *i.e.* P1+NECT and P2+ NECT and together with ECT (*i.e.* ECTP1 and ECTP2) to common bean plants under calcareous soil conditions resulted in more and significant increases of root nodules formation compared with those resulted from the individual application of P at the same added rate (Table 3). These findings may be cleared from RC values of root nodules with alternative and combined applications of P which were high positive than those calculate for its individual applications (Table 3). Also, P application in combination with ECT resulted in a high root nodules formation than those observed with the alternative application of P and NECT at the two rates of added P. For example, nodules number /plant in the control treatment "P0" was 40 which increased to 50 and 63 with corresponding RC values of 25.0 and 57.5 % with the treatments of P1+NECT and ECTP1, respectively. These variations clearly related with the chemical composition of added compost tea (CT) types and their improve effect on different soil properties as well as increase in the biological activities (Hamer et al., 2009 and Hammad, 2019). Recently, El-Noamany (2020) pointed out that, application of ECT (enriched by humic substances) resulted in high increases of root nodules formation on the roots of peanut plants compared with those formed on the plants manured by farmyard manure and compost. This study reviewed this effect to suitability of added organic fertilizers for use by soil microorganisms and its chelating action on P.

TABLE 3. Root nodules number and common bean (roots and shoots) plants weights (fresh and dry) g plant^{-1} at growth period of 60 days and their relative changes "RC" (%) affected by P fertilization

Phosphorus treatments	Nodules number		Roots				Shoots			
			Fresh weight		Dry weight		Fresh weight		Dry weight	
	No plant^{-1}	RC %	g plant^{-1}	RC %	g plant^{-1}	RC %	g plant^{-1}	RC %	g plant^{-1}	RC %
P0	40 e	--	30.50 g	--	6.85 g	--	125.1 g	--	30.30 g	--
P1	45 d	12.5	35.71 f	17.1	8.96 f	30.8	140.5 f	12.3	35.11 f	15.9
P2	52 c	30.0	43.47 d	42.5	10.25 d	49.6	157.3 d	25.7	38.80 d	28.1
P1+NECT	50 c	25.0	40.60 e	33.1	9.55 e	39.4	152.8 e	22.1	37.40 e	23.4
P2+NECT	65 b	62.5	52.11 b	70.9	12.65 b	84.7	168.7 b	34.9	42.15 b	39.1
ECTP1	63 b	57.5	50.50 c	65.6	11.50 c	67.9	165.9 c	32.6	40.85 c	34.8
ECTP2	80 a	100.0	63.70 a	108.9	15.72 a	129.5	182.7 a	46.0	47.82 a	57.8
Mean	56.4	47.9	45.23	56.3	10.78	67.0	156.14	29.0	38.92	33.2

Fresh and dry weights of common bean plants

Data in Table 3 show fresh and dry weights of common bean (roots and shoots) plants as g/plant at growth period of 60 days under calcareous soil conditions and its relative "RC" in relation with rate of added P in different forms. Both fresh and dry weights were increased significantly as a result of P applications compared to with the control treatment (P0), where there is a wide range of found weights and their relative change values. Increasing rate of added P from P0 to P1 and P2 increased roots and shoots dry weights (g/plant) from 6.85 and 30.30 to 8.90 and 35.11 and 10.25 and 38.80 g/plant, respectively. Tantawy et al. (2019) and Abou Hussien et al. (2020) pointed out a significant effect of P fertilization with or without organic fertilization on fresh and dry weights of barley and common bean plant. Similar increase effect of P fertilization on fresh or dry weights was observed by Emam (2018) and Hmmuda et al. (2019).

More increases of common bean (roots and shoots) fresh and dry weights (g/plant) were obtained with the treatments of P1+NECT, P2+NECT, ECTP1 and ECTP2 compared with those obtained with the treatments of P1 and P2. At the same rate of added P, the found fresh and dry matter yields of both roots and shoots with the treatments of ECTP1 and ECTP2 were higher than those associated with the treatments of P1+NECT and P2+NECT. These variations are attributed mainly to the chemical composition of added P compounds and its effect on different soil properties and its content of available nutrients (Elgezery, 2016 and Rabie, 2019). Fageria and Baligar (2016) and Hmmuda*et al*. (2019) found that P application resulted in significant increases of accumulated dry weights of bean and peanut plants, where more increases were found with combined applications of P and organic fertilizers in different forms. Also, Emam (2018) and Hammad (2019) pointed out that efficiency of P was increased significantly in the soils manured with different sources of organic fertilizers. Such increases are mainly attributed to the increase effect of added P and/or organic fertilizers on nodulation efficiency and dehydrogenase activity.

Data of harvest stage

Soil chemical properties

Soil pH, EC (dSm^{-1}), CEC (c mole kg^{-1}) and its content (%) of OM and $CaCO_3$ in relation with P fertilization at different rates and in different forms were studied under calcareous soil conditions and the obtained data are listed in Table 4. All application of P as H_3PO_4 soil through fertigation technique resulted in significant decrease of calcareous soil pH and its content of $CaCO_3$, but resulted in significant increases of soil OM and CEC while EC values were slightly and insignificantly increased. These changes (decrease or increase) were found with different rates of added P fertilizers as shown from the RC (%) values of the determined properties. For each property, and with same treatment of P, RC (%) values were increased with the increases of added P and the highest values were found in soil fertigated by ECTP followed by those resulted from the alternative applications of P and NECT. This trend shows the high effect of compost tea application on soil chemical properties. Decrease of soil pH and $CaCO_3$ was resulted from acidic effect of H_3PO_4 as well as organic acids produced from organic fertilizers decomposition on dissolved soil $CaCO_3$, which may be transferred to more soluble salts (HCO_3) as pointed before that by Sweed (2012) and El-Gamal (2014) followed by a slight increase in soil EC especially under drip irrigation system. In addition, organic fertilizers application considered as main source to increase soil CEC and its content of OM as pointed out before that by several authors (AbdelAal, 2018, Helmi, 2018,Faiyad et al., 2020, Rabie, 2019 and Elshahri, 2020). These finding show the high efficiency of compost tea (non- and enriched) to improve chemical properties of calcareous soils.

Soil content of available macronutrients

Data in Table 5 show calcareous soil content (mg kg^{-1}) of available N, P, K and Ca after harvesting common bean plants and its relative changes "RC" (%) affected by the studied treatments of P fertilization. Phosphorus application at P1 and P2 rates in different forms resulted in an increase in the soil content of available N, P, K and Ca with wide variation from nutrient to another as cleared from RC values for the determined nutrients at the same treatment of P. For example, the contents of available N, P, K and Ca were increased from 31.05, 3.10, 74.11 and 17.20 mg kg with the treatment of P0 to 31.50, 5.82, 75.83 and 20.11 mg kg^{-1} with RC values of 1.444, 87.742, 2.320 and 16.919 % with the treatment of P2, respectively. These findings means that, the content of available P followed by that of Ca have higher RC values with the same treatments of Pwhich mainly attributed to the found decrease in the soil content of $CaCO_3$ followed by increase of P and Ca solubility (El-Meselawe, 2014). More increases in soil content of available N, P, K and Ca was found in the soil treated by P1+NECT and P2+NECT and even increased more with the treatments of ECTP1 and ECTP2. These increases resulted from the effect of added organic substances (compost tea) on decrease soil pH, $CaCO_3$ content as well as microbial activity (Sweed, 2012, Abou Hussein et al., 2017, Mosaad, 2019 and Hammad, 2019). Recently Abou Hussein et al. (2019) found a significant increase in the calcareous soil content of available N, P, K, Ca and S as a result of compost applications in different sources. Similar increases were found in the soils treated by compost and biochar by Elshahri (2020). Also, El-Meselawe (2014) found a significant increase of P and Ca solubility as a result of adding bioorganic additives.

TABLE 4. Effect of P fertigation (rates and methods) on some chemical properties of calcareous soil and their relative changes "RC" (%) after common bean plants harvesting

Phosphorus treatments	pH		EC		OM		$CaCO_3$		CEC	
	value	RC %	dSm^{-1}	RC %	g kg^{-1}	RC %	%	RC %	cmolc kg^{-1}	RC %
P0	8.45 a	--	2.09 e	--	5.22 f	--	16.20 a	--	18.96 e	--
P1	8.40 b	-0.59	2.11 d	0.96	5.30 e	1.53	16.05 b	-0.93	18.96 e	0.00
P2	8.32 c	-1.54	2.14 c	2.39	5.35 e	2.49	15.85 c	-2.16	19.05 e	0.47
P1+NECT	8.25 d	-2.37	2.20 b	5.26	6.11 d	17.05	14.50 d	-10.49	21.13 d	11.45
P2+NECT	8.21 ef	-2.84	2.23 a	6.70	6.70 b	28.35	14.25 e	-12.90	21.60 c	16.82
ECTP1	8.24 de	-2.49	2.21 b	5.74	6.25 c	19.73	14.11 f	-12.04	22.15 b	13.92
ECTP2	8.18 f	-3.20	2.24 a	7.18	6.82 a	30.65	13.95 g	-13.89	22.55 a	18.93
Mean	8.29	-2.17	2.17	4.70	5.96	16.63	14.99	-8.73	20.63	10.27

TABLE 5. Effect of P fertigation (rates and methods) on calcareous soil content of (mg kg-1) of available N, P, K and Ca and their relative changes "RC" (%) after common bean plants harvesting

Phosphorus treatments	N		P		K		Ca	
	mg kg^{-1}	RC %	mg kg^{-1}	RC %	mg kg^{-1}	RC %	mg kg^{-1}	RC %
P0	31.05 f	--	3.10 f	--	74.11 g	--	17.20 g	--
P1	31.11 f	0.19	4.65 e	50.00	75.05 f	1.27	17.85 f	3.78
P2	31.50 e	1.45	5.82 c	87.74	75.83 e	2.32	20.11 e	16.92
P1+NECT	33.11 d	6.63	5.55 d	79.03	80.13 d	8.12	21.85 d	27.03
P2+NECT	36.17 b	16.49	6.11 b	97.10	92.17 b	24.37	25.23 b	46.69
ECTP1	35.50 c	14.33	5.80 c	87.10	85.05 c	14.76	23.63 c	37.38
ECTP2	36.65 a	18.04	6.25 a	101.61	93.22 a	25.79	25.90 a	50.58
Mean	33.58	9.52	5.33	83.76	82.22	12.77	21.68	30.40

Soil content of available micronutrients

The listed data in Table 6 show that, increasing added rate of P in H_3PO_4 alone (P1 and P2), in alternative with NECT (P1+NECT and P2+NECT) and in combination with ECT (ECTP1and ECTP2) resulted in significant increases in calcareous soil content (mg kg^{-1}) of available Fe, Mn, Zn, and Cu compared with those found with P0 treatment. The rate of these increases varied from treatment to another depending on the effect of added P form on calcareous soil properties and its reaction with different soil compounds as well as its transformation in the growth medium. Prado et al. (2013) reported that, using organic residues in agriculture helps to conserve natural resources by recycling mineral nutrients and carbon.

With the same application rate of P (3.4 and 6.8 kg fed^{-1}), the highest contents of available micronutrients under study were found in the soil fertigated with ECTP followed by those treated by P+NECT. These findings indicate the high importance of organic additives in the improvement of different soil properties and its fertility (Elgezery, 2016, Emam, 2018, Abou Hussein et al., 2019 and Rabie, 2019). In addition, with the same study treatments, the determined micronutrients may be arranged according to their content in the order Mn > Fe > Zn > Cu with no clear order of their relative changes (RC %) as shown in Table 6. The found unclear trend in RC values in relation to the studied treatments may be attributed to the variation in stability of micronutrient-organic matter complexes formed under calcareous soil conditions.

Straw, seeds and biological yield

Yield (kg fed^{-1}) of common bean (straw, seeds and biological) plants grown on calcareous soil and their relative changes "RC" (%) significantly responded to fertigation by different rates of P as H_3PO_4 in three forms (Table 7). These findings mean that P fertilization enhanced growth of common bean plants by increasing N fixation and other biological activities (Abou Hussein et al., 2020). Increasing rate of added P in different forms significantly raised the yields of common bean plants. The rates of these increases varied from treatment to another as cleared from RC values of common bean plant yields with different P applications compared to the treatment of P0, where these values were positive with a wide range (Table 7). Phosphorus plays a significant role in many metabolic processes including energy generation, respiration, nucleic acid synthesis, activation or inactivation of enzymes and carbohydrates metabolism (Mengel at al., 2001 and Zhang et al., 2014). With the same P treatment, straw yield of common bean plants was higher than that of its seeds. These results are in agreement with those obtained by Veeresh (2003) and Hammad (2019).

Phosphorus applications in alternative with NECT and together with ECT have superior increases of straw, seeds and biological yields (kg fed^{-1}) of common bean plants grown on calcareous soil compared with that found with the individual P applications. The yields of the plants fertigated with ECTP and its relative changes (%) were higher than those found with the treatments of P+NECT (Table, 7). These variations are attributed to the chemical composition of added fertilizer form and its effect on soil properties and its content of essential plant nutrients (Abdel- Aal, 2018, Helmi, 2008 and El-Noamany, 2020).

Data in Table 7 also show the harvest index (HI) of common bean plants and its relative change as indicator for P fertilization treatments under study. The calculated HI values were varied significantly with the studied P treatments. These values also show that there was no clear trend in relation with added P fertilization. These data showed that all HI of common bean plants received P fertilization were lower than that found with the treatment of P0. Therefore, the calculated RC values were negative. These findings means that, the increase rate of straw yields as a result of P fertilization treatments was higher than that found with seeds yield. These results are similar with those obtained Hammad (2019) on common bean plants fertigated by H_3PO_4 individually and in combination with vinasse or molasses at different growth periods.

Agronomical efficiency of P fertilization

Agronomical efficiency (AE) of P fertilizers (kg seeds/ kg P) under calcareous soil conditions listed in Table (7) show that it was related with both rate and form of added P. Under the studied P treatments, AE ranged between 14.69(kg seeds kg P^{-1})in the treatment of P1and 68.75(kg seeds kg P^{-1}) in the treatment of ECTP2. This means that, the high AE and its RC values were found in the plants fertigated by ECTP followed by those calculated for the plants grown on the soil received P+NECT. These findings means that, the efficiency of P fertilization especially in calcareous soils may be increased if P applications were carried in combination with organic manures, which transfer added and native soil P to more soluble by it chelating action (Fu et al., 2013). Increasing P efficiency as a result of organic fertilization was pointed before that by Fageria (2002), Emam (2018) and Hammad (2019).

TABLE 6. Effect of P fertigation (rates and methods) on calcareous soil content of (mg kg-1) of available Fe, Mn, Zn and Cu and their relative changes "RC" (%) after common bean plants harvesting

Phosphorus treatments	Fe		Mn		Zn		Cu	
	mg kg^{-1}	RC %	mg kg^{-1}	RC %	mg kg^{-1}	RC %	mg kg^{-1}	RC %
P0	2.20 f	--	2.90 e	--	1.22 e	--	0.50 f	--
P1	2.20 f	0.00	2.90 e	0.69	1.24 e	1.64	0.53e	6.00
P2	2.25 e	2.27	2.98 d	2.76	1.28 d	4.92	0.57 d	14.00
P1+NECT	2.63 d	19.55	3.11 c	7.24	1.35 c	10.66	0.65 c	30.00
P2+NECT	2.71 b	23.18	3.25 ab	12.07	1.43 b	17.21	0.68 b	36.00
ECTP1	2.68 c	21.82	3.20 b	10.34	1.42 b	16.39	0.67 bc	34.00
ECTP2	2.76 a	25.45	3.30 a	13.79	1.56 a	27.87	0.75 a	50.00
Mean	2.49	15.38	3.09	7.82	1.36	13.11	0.62	28.33

TABLE 7. Straw, seeds and biological yields (kg fed-1) of common bean plants and harvest index "HI" as well as agronomical efficiency "AE" of P fertilizer and their relative changes "RC" (%) affected by P fertilization.

Phosphorus treatments	Straw yield		Seeds yield		Biological yield		Harvest index (HI)		Agronomical efficiency (AE)*
	kg fed^{-1}	RC %	kg fed^{-1}	RC %	kg fed^{-1}	RC %	%	RC %	kg kg^{-1}
P0	1225 g	--	748 g	--	1973 g	--	37.91 a	--	--
P1	1517 f	23.84	795 f	6.28	2312 f	17.18	34.39 b	-9.30	14.69
P2	1935 d	57.96	856 d	14.44	2791 d	41.46	30.67 d	-19.10	16.88
P1+NECT	1825 e	48.98	832 e	11.23	2657 e	34.67	31.31 c	-17.40	26.25
P2+NECT	2365 b	93.06	915 b	22.33	3280 b	66.24	27.90 e	-26.41	26.09
ECTP1	2282 c	86.29	873 c	16.71	3155 c	59.91	27.67 f	-27.01	39.06
ECTP2	2595 a	111.84	1188 a	58.82	3783 a	91.74	31.40 c	-17.16	68.75
Mean	1963.43	70.33	886.71	21.64	2850.14	51.87	31.61	-19.40	31.95

*AE calculated for seeds yield only.

Common bean plants content of macronutrients and protein

Common bean plants (straw and seeds) content of N, P, K and Ca and its relative changes "RC" (%) were increased significantly with increasing added P as H_3PO_4 either alone i.e. P1 and P2, alternative with NECT i.e. P1+NECT and P2+NECT or together with ECT i.e. ECTP1 and ECTP2 compared with that found in the plants fertigated with P (P0) as shown in Table (8). The increases in the determined macronutrients uptake as a result of P fertigation reveals the important role of P to plant (common bean) growth, metabolic processes and enzymes activities (Marschener, 2012). Recent study of Hammad (2019) on common bean plants showed that, P application alone and in combination with organic manures (vinasee or molasses) increased root nodules, dehydrogenase activity and nutrient (N, P and K) uptake. With the same treatment of P, uptake of N, P, K and Ca by straw were higher than absorbed by seeds which attributed to the high straw yield than of seeds yield. Also, with the same treatment of P, the uptake amounts of the determined macronutrients by straw and seeds takes the order N > Ca > K >P, with wide range of RC values. This trend is in harmony with the effect of added P forms on soil properties and its content of available N, P, K and Ca (Tables 4 and 5) (Fageria*et al*., 2010 and Fageria and Baligar 2016).

With the same application rate of added P, the high uptake of N, P, K and Ca by straw and seeds of common bean plants was found in plants fertigated by P together with ECT(ECTP1 and ECTP2) followed by the uptake by plants fertigated by P in alternative with NECT (P1+NECT and P2+NECT) (Table, 8). These findings reviewed to improve in the soil health as a result of NECT and ECT applications as a source of organic substances (Emam, 2018, Abou Hussein *et al*., 2019 and El-Noamany, 2020).

In addition, data in Fig. 1 show greater effect of added treatments on common bean plants (straw and seeds) protein content (%), where this content followed the same trend found with plants content of N, but this content (%) in seeds was higher than that in straw. This trend was found with all P fertigation treatments under study. The increase in protein content resulted from increased nodules formation andN fixation rate. These results are in agreement with those obtained by Hammad (2019).

TABLE 8. Effect of P fertigation (rates and methods) on common bean (straw and seeds) uptake (kg fed-1) of N, P, K and Ca and their relative changes "RC" (%) under calcareous soil conditions

Phosphorus treatments	N		P		K		Ca	
	kg fed^{-1}	RC %	kg fed^{-1}	RC %	kg fed^{-1}	RC %	kg fed^{-1}	RC %
Straw								
P0	21.19 g	--	4.29 g	--	17.39 g	--	16.54 g	--
P1	27.61 f	30.28	7.59 f	76.91	22.45 f	29.07	21.85 f	32.09
P2	35.80 d	68.92	12.00 d	179.81	29.41 d	69.08	29.03 d	75.51
P1+NECT	32.85 e	55.01	10.59 e	146.88	29.20 e	67.86	28.29 e	71.05
P2+NECT	45.41 b	114.26	16.79 b	291.64	38.78 b	122.97	37.37 c	125.95
ECTP1	42.45 c	100.28	15.51 c	261.93	36.97 c	112.52	37.65 b	127.68
ECTP2	54.76 a	158.37	19.21 a	347.88	44.38 a	155.10	45.67 a	176.17
Mean	37.15	87.85	12.28	217.51	31.23	92.77	30.91	101.41
Seeds								
P0	20.57 g	--	3.14 g	--	11.67 g	--	11.00 g	--
P1	22.81 f	10.92	5.17 f	64.49	12.72 f	9.01	12.88 f	17.13
P2	25.08 e	21.93	6.85 e	117.98	14.30 d	22.51	16.01 d	45.58
P1+NECT	27.04 d	31.45	7.07 d	125.11	14.15 e	21.21	15.39 e	39.98
P2+NECT	30.83 b	49.91	8.15 b	159.22	16.65 b	42.71	18.12 b	64.77
ECTP1	28.81 c	40.05	7.51 c	138.98	15.36 c	31.67	16.94 c	54.03
ECTP2	42.06 a	104.45	11.05 a	251.68	23.17 a	98.53	25.54 a	132.29
Mean	28.17	43.12	6.99	142.91	15.43	37.61	16.55	58.96

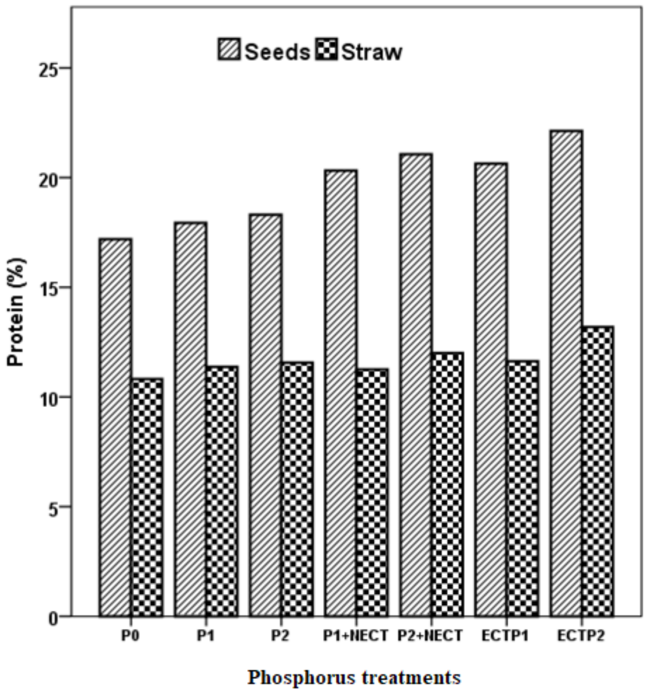

Fig. 1. Effect of P fertigation (rates and methods) on common bean (straw and seeds) protein content (%)

Common bean plants content of micronutrients

The uptake (g fed^{-1}) of Fe, Mn, Zn and Cu by straw and seeds of common bean plants planted on calcareous soil fertigated by P as H_3PO_4 in three forms i.e. H_3PO_4alone (P1 and P2), alternative with NECT (P1+NECT and P2+NECT) and together with ECT (ECTP1 and ECTP2) show significant increases as a result of P application (Table 9). There are wide variations in Fe, Mn, Zn and Cu uptake response to P fertigation as shown through RC (%) values of the nutrients' uptake. At the same rate of added P, the high uptake of the determined micronutrients and its RC values were found in the plants fertigated by ECTP followed by those resulted from P+NECT applications. This trend isin harmony with the effect of added P compounds on soil properties, health,biological activity and its content of available micronutrients. Also, with the same treatment of P, the uptake of the determined micronutrients takes the order Fe > Mn > Zn > Cu in both straw and seeds.

TABLE 9. Effect of P fertigation (rates and methods) on common bean (straw and seeds) uptake (g fed-1) of Fe, Mn, Zn and Cu and their relative changes "RC" (%) under calcareous soil conditions

Phosphorus treatments	Fe		Mn		Zn		Cu	
	g fed^{-1}	RC %	g fed^{-1}	RC %	g fed^{-1}	RC %	g fed^{-1}	RC %
Straw								
P0	30.85 g	--	24.75 g	--	19.80 g	--	5.03 f	--
P1	38.99 f	26.39	31.02 f	25.37	24.65 f	24.53	6.55 e	30.16
P2	50.52 d	63.79	40.29 d	62.81	32.74 d	65.39	9.04 d	79.48
P1+NECT	48.64 e	57.68	38.53 e	55.69	32.34 e	63.36	9.09 d	80.52
P2+NECT	63.97 b	107.40	51.49 b	108.07	42.52 b	114.80	12.82 c	154.60
ECTP1	63.49 c	105.82	50.43 c	103.81	41.33 c	108.76	12.89 b	156.09
ECTP2	74.08 a	140.19	59.55 a	140.68	48.91 a	147.10	15.85 a	214.92
Mean	52.93	83.54	42.29	82.74	34.61	87.32	10.18	119.29
Seeds								
P0	22.57 g	--	19.82 g	--	18.03 g	--	3.94 g	--
P1	24.85 f	10.09	22.05 f	11.22	19.84 f	10.03	4.56 f	15.78
P2	27.48 e	21.80	24.92 e	25.71	21.96 d	21.75	5.10 e	29.67
P1+NECT	29.41 d	30.33	26.33 d	32.85	21.78 e	20.78	5.41 d	37.45
P2+NECT	33.60 b	48.88	30.15 b	52.10	25.16 b	39.53	6.26 b	59.07
ECTP1	31.39 c	39.07	27.82 c	40.36	23.38 c	29.64	5.83 c	48.22
ECTP2	46.12 a	104.36	40.69 a	105.27	34.83 a	93.14	8.38 a	112.87
Mean	30.77	42.42	27.40	44.58	23.57	35.81	5.64	50.51

Conclusion

The data of this study showed the high important of P fertigation alone or in combination with compost teas especially in calcareous soil. Phosphorus and composttea applications improved soil chemical properties and its content of available essential nutrients. Also, the studied treatments increased N- fixation by increasing nodules formed on the roots of common bean plants as well increased its straw and seeds productivity and content of macro and micronutrients and protein. Improving effect of P fertigation on soil properties, common bean productivity and agronomical efficiency of P fertilizers was maximum when P fertilizers applied in combination with organic fertilizers in compost tea form.

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إستخدام شاى الكمبوست في تعظيم كفاءة إستخدام التسميد الفوسفاتى و تأثيرهما على صحة و إنتاجية الأراضى الجيرية

أجريت تجربة حقلية خلال موسمى ربيع متتاليين (٢٠١٨ و ٢٠١٩) بمزرعة خاصة ممصلة لأرض جيرية حديثة الإستصلاح (١٦.٢٢٪ كربونات كالسيوم) بالنوبارية محافظة البحيرة (٣٠°٤٠' ٤٦" شمال و ٣٠°٠٨' ٤٣" شرق) لتقييم كفاءة التسميد الفوسفاتى سواء مضاف على صورة منفردة أو بالتبادل مع شاى الكمبوست غير المخصب أو مع شاى الكمبوست المخصب عند معدلى إضافة ٣.٤ و ٦.٨ كجم فوسفور للفدان ولقد تم توزيع معاملات الدراسة على الوحدات التجريبية فى نظام قطع كاملة العشوائية فى ثلاث مكررات. وتم دراسة تأثير معاملات التسميد الفوسفاتى على الخواص الكيميائية للأرض الجيرية ومحتواها الميسر من المغذيات وكذلك تأثيرهما على إنتاجية الفاصوليا (صنف نيبراسكا) وكفاءة التعقد ومحتواها من العناصر الغذائية.

أدى زيادة معدل إضافة الفسفور فى صور الإضافة الثلاثة إلى نقص فى رقم حموضة الأرض وكذلك محتوى الأرض من كربونات الكالسيوم مع زيادة طفيفة فى محتوى الأرض من الأملاح الكلية الذائبة وكذلك إلى زيادة السعة التبادلية الكاتيوينة للأرض وكذلك محتوى الأرض من المادة العضوية والمحتوى الميسر من المغذيات الكبرى (نيتروجين و فوسفور و بوتاسيوم وكالسيوم) والصغرى (حديد و منجنيز و زنك و نحاس) حيث سجل التغير فى هذه الصفات معدلات مختلفة وكان أعلى قيم معدلات التغير النسبى مصاحبة لإضافة الفوسفور وشاى الكمبوست المخصب تلاه فى ذلك القيم المسجلة للأراضى التى تم تسميدها بالإضافات المتبادلة لكل من الفوسفور وشاى الكمبوست غير المخصب. كما صاحب زيادة المضاف من الفوسفور فى الصور الثلاثة زيادة فى عدد العقد الجذرية المتكونة بالإضافة إلى محصول القش والبذورلنباتات الفاصوليا ومحتواها من النيتروجين و الفوسفور والبوتاسيوم والكالسيوم والحديد والمنجنيز و الزنك والنحاس. كما وجد أن إضافة الفوسفور مع شاى الكمبوست المخصب متبوعا بالإضافات المتبادلة للفوسفور مع شاى الكمبوست غير المخصب أدى إلى زيادة الكفاءة المحصولية للسماد الفوسفاتى تحت ظروف الأراضى الجيرية.