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EFFECT OF PERLITE AND MOISTURE CONTENT ON THE AVAILABILITY AND MOVEMENT OF PHOSPHORUS IN CALCAREOUS SOIL CULTIVATED WITH SUDAN GRASS PLANTS

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ABSTRACT: A pot experiment was conducted under greenhouse condition at the Experimental Farm, Faculty of Agriculture, Zagazig University. The experiment aimed to study the effect of two phosphate fertilizers *i.e.*, ordinary super phosphate (OSP) and rock phosphate (RP) combined with or without perlite under different soil moisture levels (80, 65 and 50% of saturation point) on sudan grass (*Sorghum vulgare* var. sudanense) plant as well as available P behavior through the investigated calcareous soil. Soil samples were taken from the surface layers (0-30 cm) from El-Noubaria Research Station, El-Noubraria District, Egypt. Results showed that the application of various phosphorus source *i.e.* OSP or RP as individual application or combined with perlite under different soil moisture levels increased fresh weight, dry matter and phosphorus uptake of sudan grass compared to untreated soil. The highest value of each of fresh and dry weight, P-uptake and available P was found in calcareous soil treated with OSP combined with perlite under 80% moisture level, while the lowest ones were obtained with untreated soils under 50% moisture level in absence of perlite. Application of OSP showed greater values of fresh weight, dry matter and P-uptake by sudan grass plants than RP. The promotive effect of different soil moisture levels on available phosphorus after three cuts in the two layers follows the descending order: 80>65> 50% under the application of ordinary super phosphate or rock phosphate in presence of perlite. Treatments under OSP gave higher values of available phosphorus after cutting than those under RP. These increases represented as much as 9.2, 8.8 and 29% after the first, second and third cuts, respectively in the first layer (0-5cm) as well as 10.1, 8.6 and 23.4%, respectively in the second layer (5-10 cm). Available P were higher in the first layer (0-5 cm) than in the second one (5-10 cm) after all cuts under different treatments.

Key words: Phosphorus, calcareous soil, perlite, soil moisture, sudan grass.

INTRODUCTION

Phosphorus is the second most commonly soil limiting nutrient element after nitrogen. Phosphorus is very important element to plant growth and plays a key role in metabolic processes such as the conversion of sugar into starch and cellulose (Mengel and Kirkby, 1987).

Growth parameters and soil available P increased with the increase of P application (Johnston *et al.,* 2016 ; Mali *et al.*, 2017) who revealed that application of various sources and levels of phosphorus with vermiculture significantly increased grain, stover and biological yields of maize and nutrient uptake.

Desertic soils in Egypt are mostly calcareous and sandy soils. These soils, generally, attended some problems, related to their physical properties, salinity and low potentiality for productivity. There are several means for solving their problems, one of them is the use of soil conditioners (El-Kholy *et al.,* 2000). Soil conditioning means improve the physical conditions of such soils by using small amounts of natural or artificial products to promote germination, increasing water holding capacity

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and reducing evaporation from the surface of soil under arid conditions. However, minor attention was paid to the effect of conditioners on the status of nutritive elements as well as the chemistry of their intergradient, during the improvement of the desert soils (El-Hady *et al.,* 2001). Conditioning calcareous soils became a necessity to increase agricultural production and to overcome the deficiency in food requirements (Ali, 2002; El-Zaher *et al.,* 2007; Hassanien *et al.,* 2007; Telep, 2008). Calcareous soils have content of $CaCO_3$ which contributes to the unfavorable structure for plant roots development and unfavorable effect on nutrients availability to plants. Mineral soil amendments are soil improving agents .The application of such amendments could improve the retentive capacity of soils for water and fertilization nutrients and also may help in improving the unfavorable structure and in increasing nutrients availability in calcareous soil.

Perlite is a natural bio stimulant for plant growth. Vermiculite and perlite is an excellent regulator of the soil moisture and positively influences the development of roots with its favorable properties of aeration and air capacity. When added to soil, it supports optimal conditions of soil moisture; air capacity and heat balance, creating favorable conditions for plant nutrition (Marinova *et al.,* 2012). Merwad (2013) reported that the application of perlite combined with chicken manure gave the highest values of yield, N, P and K-uptake of barley and faba bean plants in calcareous soil and also increased phosphorus availability at different incubation periods.

Water content is an important property of soils, influencing soil solution chemistry and nutrient uptake by plants. Morphology and other specific properties of the root, nutrient concentration in the soil solution, the mobility of nutrients in the soil, and supply from solid phases, affect nutrient uptake (Barber, 1995). Soil moisture is important factor affecting adsorption, transformation and the availability of soil phosphorus to plants (Song *et al*., 2012). Eissa *et al.* (2013) found that keeping the soil moisture at 125% of field capacity, significantly increased the total uptake of P in 60-days old corn plants from 9.38 to 10.16 kg P fad^{-1}. Forms of P fertilizers had a little effect on P concentrations in corn plants. Increasing the amount of irrigation water increased the grain and straw yield of corn. Sinegani and Mahohi (2009) found that soluble P was higher in soil incubated in FC as compared to those incubated in other moisture(sat,0 bar), field capacity (FC,-0.3 bar),and permanent wilting point (PWP,-15 bar). Al-Oud (2011) indicated that the availability of P from rock phosphate was increased by increasing incubation period up to 90 days in calcareous soil. Al-Tameemi *et al.* (2015) indicated that application of concentrated superphosphate to calcareous soils converted during short time (one week) to phosphate minerals by precipitation reaction. Increasing soil moisture content up to field capacity increased solubility of calcium phosphate in soil solution of calcareous soils. Mobility of calcium phosphate minerals and through in soil depths was limited. Improvement of nutrients availability subsequently to plant growth is important while planning the fertilization regime in perlite substrate. Enhancement of P availability may be the most important outcome, because solution–P concentrations are governed by adsorption/ desorption and precipitation/dissolution reactions (Silber *et al.,* 2010)

The present work aims to study the efficiency of phosphatic fertilizers (ordinary super phosphate and rock phosphate) as influenced by soil moisture and perlite application in calcareous soil and their effect on fresh and dry matter yield, phosphorus uptake of sudan grass and availability of phosphorus at different soil depths.

MATERIALS AND METHODS

A pot experiment was conducted under greenhouse condition. The experiment aimed to study the effect of two phosphate fertilizers *i.e.,* ordinary super phosphate and rock phosphate in presence or absence of perlite under different levels of soil moisture on sudan grass plant (*Sorghum vulgare* var. sudanense). Representative soil samples were taken from the surface layers (0-30 cm) from El-Noubaria Research Station El-Noubraria District, Egypt. Soil samples were air dried, crushed, sieved to pass through 2 mm plastic screen, thoroughly mixed and stored in plastic bags for analysis and experimental work.

Some physical and chemical characteristics of the investigated soils were determined including available content of N, P and K as shown in Table 1. Physical and chemical properties of the soils were determined according to Piper (1950), Black *et al.* (1965) and Jackson (1973). Air dried soil equivalent 8 kg oven dry soil was placed in plastic pots of internal dimentions 20 × 25 cm. The experiment was conducted in a complete randomized block design under controlled conditions in the greenhouse of the Faculty of Agriculture, Zagazig University, Egypt. Three replicates of treated soil were performed.

Before planting, the treatments of phosphatic fertilizers as ordinary super phosphate (67.6 g P kg^{-1}) and rock phosphate (150 g P kg^{-1}) were thoroughly mixed with the soil samples at a rate of 13 kg P fad^{-1}. Also, the treatments of perlite were mixed with the soil samples at a rate of 0.2% (2 Mg $fad.^{-1}$). Some characteristics of perlite are shown in Table 2. Soil moisture levels were adjusted at 80, 65 and 50% of saturation percent.

Twenty seeds of sudan grass were sown per pot. The pots were daily weighed and the soil moisture content was adjusted at different levels as mentioned before. After germination, plants were thinned to ten plants per pot.

Nitrogen was added as ammonium sulphate (205 g kg^{-1}) at the rate of 150 mg N kg^{-1} soil at three equal doses, the first was before the 1st irrigation while the second and third doses were added after the first and second cuts, respectively. The recommended doses of potassium was added as potassium sulphate (410 g K kg^{-1}) at the rate of 40 mg K kg^{-1} soil before sowing.

Three successive cuts were taken from growing plants, 5 cm. above the soil surface, each after 60 days. Fresh weight was recorded after each cut. Each of the three cuts were dried at 70˚C for 72 hr., weighed, digested and phosphorus concentration was determined colourmetrically using ascorbic acid method (Watanabe and Olsen, 1965).

Soil samples were taken at different depths, (0-5 cm) and (5-10 cm) after each cut where available phosphorus was determined. Available phosphorus was determined using Watanabe and Olsen, (1965) method, 5 grams of soil sample being shaken with 50 ml 0.5 M $NaHCO_3$ solution (pH 8.5) with one gram activated charcoal for 0.5 hour and filtered, then determined calorimetrically. The obtained data of plant parameters and soil were statistically analyzed (LSD at 0.05) according to the method described by (Russell, 1991).

RESULTS AND DISCUSSION

Fresh Weight

Results presented in the Table 3 show the effect of applied different P sources and perlite under soil moisture levels on sudan grass taken in three successive cuts in calcareous soil. Results reveal that the application of various phosphorus sources *i.e.* ordinary super phosphate and rock phosphate individually or combined with perlite under different soil moisture levels gave an increase in the total fresh weight of the three cuts of plants compared to control. Many investigations illustrated the importance of phosphorus fertilizers for soils and their effect on plant growth and increasing the availability of nutrients in soil solution and uptake by plants (Ziardi *et al.*, 2001; Csathó *et al.*, 2005; Abd Alla *et al.*, 2007).

The highest values of total fresh weight were found in the treatment of ordinary super phosphate combined with perlite under 80% moisture level, while the lowest ones were obtained with the untreated soils under 50% moisture level in the absence of perlite. This view point is in agreement with Silber *et al.* (2010) and Merwad (2013).

Taking the effect of P-source addition into consideration, the results showed that using ordinary super phosphate combined with perlite under different soil moisture levels gave higher values than those under rock phosphate. These results are in agreement with those of Cao *et al.* (2004) and Amaizah *et al.* (2013). Mohamed *et al.* (2008) found that addition of compost, taffla and rock phosphate to sandy calcareous soil increased dry matter yield and NPK uptake by corn plants.

Table 1. Some physical and chemical properties of the investigated soil

Soil characteristics	Value
Soil particles distribution	
Sand (%)	45.95
Silt (%)	25.52
Clay (%)	28.53
Textural class	Loamy sand
Field capacity (FC) (%)	16.84
$CaCO_3$, (g kg^{-1})	225
Organic matter (g kg^{-1})	8.70
pH (1:2.5) *	8.01
EC (dSm^{-1}) **	1.23
Soluble ions, (mmolc l^{-1})**	
Ca^{++}	3.52
Mg^{++}	3.98
Na^{+}	2.75
K^{+}	2.05
$CO_3^{=}$	-
HCO_3^{-}	4.75
Cl^{-}	5.02
$SO_4^{=}$	2.53
Available N, P and K(mg kg^{-1}soil)	
Available N	45.87
Available P	8.52
Available K	95.3

* Suspension of 1:2.5 soil:water ** Soil paste extract

Table 2. Some characteristics of perlite (Silber *et al.*, 2010)

Characteristics	Value
SiO_2, (g kg^{-1})	720
$AI_2 O_3$, (g kg^{-1})	110
K_2O, (g kg^{-1})	40
Na_2O, (g kg^{-1})	29
Ca O , (g kg^{-1})	25
$Fe_2 O_3$, (g kg^{-1})	15
MgO, (g kg^{-1})	5
TiO_2, (g kg^{-1})	2
H_2O, (g kg^{-1})	40
pH (paste)	6.7
EC, dSm^{-1}	2.50
Water holding capacity (WHC) (%)	601
Hygroscopic moisture (%)	0.50
Bulk density, kg m^{-3}	90
CEC, $cmol_c$ kg^{-1}	210
specific surface, m^2 g^{-1}	1.75

Table 3. Fresh weight (g pot^{-1}) of the successive cuttings of sudan grass plants as affected by phosphorus source, perlite and soil moisture levels in calcareous soil

P-Source (A)	Soil moisture (%) of SP (B)	Perlite (C) 1st Cut Without	1st Cut With	1st Cut Mean	2sd Cut Without	2sd Cut With	2sd Cut Mean	3rd Cut Without	3rd Cut With	3rd Cut Mean	Cumulative Without	Cumulative With	Cumulative Mean
	80	349	379	364	304	370	337	257	279	268	910	1028	969
Untreated	65	340	462	401	298	351	325	246	269	258	884	1082	983
	50	327	349	338	290	310	300	235	258	247	852	917	885
Mean		339	397	368	297	344	321	246	269	258	882	1009	946
	80	478	631	555	390	523	457	385	431	408	1253	1585	1419
OSP	65	461	565	513	379	487	433	368	395	382	1208	1447	1328
	50	435	482	459	363	458	411	344	367	356	1142	1307	1225
Mean		458	559	509	377	489	433	366	398	382	1201	1446	1324
	80	460	587	534	379	466	423	368	387	378	1207	1440	1324
RP	65	448	567	508	370	454	412	355	367	361	1173	1388	1281
	50	431	551	491	358	443	401	339	351	345	1128	1345	1237
Mean		446	568	507	369	454	412	354	368	361	1169	1391	1280
					Mean of soil moisture								
	80	429	532	481	358	453	406	337	366	352	1123	1351	1237
	65	416	531	474	349	431	390	323	344	334	1088	1306	1197
	50	398	461	430	337	404	371	306	325	316	1041	1190	1116
G. Mean		414	508	461	348	429	389	322	345	334	1084	1282	1183
$LSD_{0.05}$													
A			1.86			2.19			1.82			1.52	
B			1.84			2.09			1.73			1.98	
AB			3.21			3.79			3.16			4.12	
C			1.51			1.79			1.49			1.36	
AC			2.62			3.09			2.58			2.54	
BC			2.62			3.09			2.58			2.68	
ABC			4.54			5.36			4.46			3.98	

OSP: ordinary super phosphate, RP: rock phosphate, 1^{st}, 2^{nd} and 3^{rd} =first, second and third cuts.

As for the effect of perlite addition, the results in Table 3 show that using perlite combined with different phosphatic fertilizers gave higher average values than those of untreated soil. This view point is in agreement with Osman *et al.* (2004). This result may be due to improving of soil available water content by perlite materials in presence of phosphatic fertilizers. The increase of soil available water content and reduction soil pH values are leading to increase dissolved mineral phosphorus. This finding agrees with that obtained by Savini *et al.* (2006).

From the results presented in Table 3, it showed that application of perlite to calcareous soil increased cumulative fresh weight of sudan grass compared to the untreated ones. These increases represent 20 and 19% in the case of OSP and RP, respectively under different soil moisture levels. On the other hand, treatments under OSP gave higher values of cumulative fresh weight of sudan grass than those under RP. These increases represent 10 and 4% in the presence of perlite for 80 and 65% soil moisture, while the increases represent 4, 3 and 1% in the absence of perlite application for 80, 65 and 50% soil moisture, respectively. These results agree with those of Rivaie *et al*. (2008).

The fresh weight of the treatments were the lowest in the third cut if compared to the first and second cuts. The decrease in fresh weight yield for third cut may be due to the reduction in nutrients supply and to the gradual decrease in availability of remaining portions. This view point is in agreement with Nassar *et al*. (2000) and Mali *et al*. (2017).

Dry Weight

The results of Table 4 show the effect of added phosphorus sources and perlite material under soil different moisture levels on dry weight of three cuts of sudan grass plants grown on calcareous Soil.

Results of the total dry weight indicated that the application of various phosphorus sources *i.e.* ordinary super phosphate and rock phosphate individually or combined with perlite under different soil moisture levels (80, 65 and 50%) gave increases in the total dry weight of the three cuts of plants grown on calcareous soil compared to control. Metwally (2000) reported that the addition of phosphorus fertilizer as ordinary superphosphate had a significant increasing effect on grain and straw yields of wheat.

The greatest values of total dry weight were found in soil treated with ordinary super phosphate combined with perlite under 80% moisture level, while the lowest ones were obtained with untreated soils under 50% moisture level in absence of perlite. These results were similar to those obtained by El-Zaher *et al*. (2007), Matter *et al*. (2007) and Telep (2008). The promotive effect of different soil moisture levels on dry weight of sudan grass plants at three cuts can follow the order: 80>65> 50% under the application of ordinary super phosphate or rock phosphate in the present of perlite

Taking the mean effect of P-source addition into consideration, the results show that using ordinary super phosphate with perlite under different soil moisture levels gave higher values than those under rock phosphate. This result is in agreement with that obtained by El-Fayoumy *et al*. (2000) and Song *et al.* (2017).

From the results presented in Table 4, it showed that application of perlite to calcareous soil increased cumulative dry weight of sudan grass compared to the untreated ones. These increases represent 36 and 4% in the case of without phosphatic fertilizers and RP, respectively under different soil moisture levels. On the other hand, treatments under OSP gave higher values of cumulative dry weight of sudan grass than those under RP. These increases represent 33, 30 and 28% in the presence of perlite for 80, 65 and 50% soil moisture, while the increases represent 21 and 4% in the absence of perlite application for 65 and 50% soil moisture, respectively.

Individually the dry matter values of treatments were the lowest in the third cut if compared to the first and second cuts of grown plants. This view point is in agreement with Buddh (2014), Ademba *et al.* (2015) and Mojaddam *et al.* (2015).

Phosphorus Uptake

Results in Table 5 show the effect of added phosphorus source, perlite under soil moisture levels on phosphorus uptake of three cuts of sudan grass plants.

Results of the total phosphorus uptake indicated that the application of various phosphorus source *i.e.* ordinary super phosphate and rock phosphate applied individually or in combination with perlite under different soil moisture levels (80, 65 and 50%) gave increase in the total phosphorus uptake of the three cuts of plants grown on calcareous soil compared to control. The greatest values of total phosphorus uptake were found in plants treated with ordinary super phosphate combined with perlite under 80% moisture level, while the lowest ones were obtained with untreated soils under 50% moisture level in absence of perlite. Osman *et al.* (2004) reported that N, P and K uptake by faba bean plants increased by adding acidic water capture fertilizer (WCF) conditioner compared to untreated one particularly with the higher rates of K (40 and 60 kg K $fad.^{-1}$) and found that application of WCF increased N,P and K content in seeds and straw of plants.

Taking the mean effect of P-source addition into consideration, the results showed that using ordinary super phosphate with perlite under different soil moisture levels gave higher values of P uptake than those under rock phosphate. These results are in agreement with those of Khalil (2011).

Table 4. Dry weight (g pot^{-1}) of the successive cuttings of sudan grass plants as affected by phosphorus source, perlite and soil moisture levels in calcareous soil

P-Source (A)	Soil moisture (%) of SP (B)	Perlite (C)											
		Without	With	Mean	Without	With	Mean	Without	With	Mean	Without	With	Mean
		1st Cut			2sd Cut			3rd Cut			Cumulative		
	80	32.24	44.67	38.46	27.70	36.05	31.88	18.07	21.46	19.77	78.01	102	90.01
Untreated	65	27.19	39.91	33.55	24.43	31.28	27.86	14.67	19.68	17.18	66.29	90.87	78.58
	50	24.68	37.50	31.09	22.35	28.47	25.41	10.60	15.66	13.13	57.63	81.63	69.63
Mean		28.04	40.69	34.37	24.83	31.93	28.38	14.45	18.93	16.69	67.31	91.50	79.44
	80	53.87	69.36	61.62	41.92	61.43	51.68	37.95	54.49	46.22	134	185	160
OSP	65	49.75	66.48	58.12	39.56	57.84	48.70	34.84	42.25	38.55	125	167	146
	50	42.25	57.12	49.69	34.47	48.46	41.47	27.03	34.40	30.72	103	140	122
Mean		48.62	64.32	56.47	38.65	55.91	47.28	33.27	43.71	38.49	120.67	164	142.34
	80	46.46	58.58	52.52	36.71	49.71	43.21	25.02	30.99	28.01	166	139	153
RP	65	41.53	53.30	47.42	33.49	44.87	39.18	23.23	29.52	26.38	103	128	116
	50	33.01	46.93	39.97	27.67	37.79	32.73	17.55	24.60	21.08	89.73	109	100
Mean		40.33	52.94	46.64	32.62	44.12	38.37	21.93	28.37	25.15	120	125	123
		Mean of soil moisture											
	80	44.19	57.54	50.87	35.44	49.06	42.25	27.01	35.65	31.33	126	142	134
	65	39.49	53.23	46.36	32.49	44.66	38.58	24.25	30.48	27.37	97.90	128	113
	50	33.31	47.18	40.25	28.16	38.24	33.20	18.39	24.89	21.64	83.70	110	96.85
G. Mean		39.00	52.65	45.83	32.03	43.99	38.01	23.22	30.34	26.78	103	127	115
$LSD_{0.05}$													
A		0.72			0.81			0.85			0.95		
B		0.72			0.81			0.85			0.98		
AB		1.25			1.41			1.47			1.67		
C		0.59			0.66			0.70			0.82		
AC		1.02			1.15			1.20			1.45		
BC		1.02			1.15			1.20			1.36		
ABC		1.77			1.99			2.09			2.23		

OSP: ordinary super phosphate, RP: rock phosphate, 1st, 2nd and 3rd =first, second and third cuts.

Table 5. Phosphorus uptake (mg pot^{-1}) of the successive cuttings of sudan grass plants as affected by phosphorus source, perlite and soil moisture levels in calcareous soil

P-Source (A)	Soil moisture (%) of SP (B)	Perlite (C)											
		Without	With	Mean	Without	With	Mean	Without	With	Mean	Without	With	Mean
		1st Cut			2sd Cut			3rd Cut			Cumulative		
Untreated	80	70.82	108	89.41	59.54	87.71	73.63	37.95	50.79	44.37	168	246	207
	65	45.14	67.04	56.09	39.70	52.75	46.23	48.77	32.85	40.81	134	153	144
	50	31.40	53.10	42.25	28.25	40.56	34.41	13.24	21.94	17.59	73.00	116	94.50
Mean		49.12	76.05	62.59	42.50	60.34	51.42	33.32	35.19	34.26	125	172	149
	80	193	315	254	150	280	215	144	206	160	487	801	644
OSP	65	169	267	218	133	236	185	138	170	154	440	673	557
	50	128	184	156	101	158	130	78.30	110	94.15	308	452	380
Mean		163	255	209	128	225	177	120	162	141	412	642	527
	80	163	234	199	127	201	164	90.71	124	107	382	559	471
RP	65	140	197	169	112	227	170	77.20	108	92.60	330	533	432
	50	91.78	136	114	76.49	110	93.25	47.73	70.46	59.10	216	316	266
Mean		132	189	161	105	179	142	72	101	87	309	469	389
		Mean of soil moisture											
	80	142	219	181	112	190	151	91	127	109	346	535	441
	65	118	177	148	95	172	134	87.99	104	95.99	301	453	377
	50	83.73	124.37	104	68.58	103	85.79	46.42	67.47	56.95	199	295	247
G. Mean		115	173	144	91.86	155	123	75.14	99.49	87.32	282	428	355
$LSD_{0.05}$													
A		14.73			17.11			11.29			12.29		
B		13.71			16.10			12.22			10.97		
AB		25.51			29.63			19.55			18.15		
C		12.03			13.97			9.21			8.36		
AC		20.83			24.19			15.96			14.16		
BC		20.83			24.19			15.96			13.92		
ABC		36.08			41.91			27.64			26.10		

OSP: ordinary super phosphate, RP: rock phosphate, 1st, 2nd and 3rd =first, second and third cuts.

Regarding the mean effect of perlite addition, the results in Table 5 show that using perlite combined with different phosphatic fertilizers gave higher values of P-uptake than those untreated soil. The increase of soil available water content are leading to increase phosphorus in soil as reported by Marinova *et al.* (2012). Nassar *et al.* (2006) reported that application of phosphorus to soil or foliar fertilization enhanced plant growth, nutrient uptake, quantity and quality of onion crop.

Results showed that application of perlite to calcareous soil, increased cumulative phosphorus uptake of sudan grass compared to the untreated ones. These increases represent 38, 56 and 52% in the case of without phosphatic fertilizers, OSP and RP, respectively under different soil moisture levels. Nassar (2007) studied the application of phosphorus fertilizers at levels of 0, 15 and 30 kg P_2O_5 under sandy and calcareous soils condition, found that there was an increase in growth, seed and straw yields and NPK uptake by faba bean and soybean and this increase was significant. Phosphorus fertilizers increased the availability of nutrients in soil solution subsequently increasing the uptake of nutrients. However, nutritive and protein contents of both crops were significantly increased by the application of phosphorus.

On the other hand, treatments under OSP gave higher values of cumulative phosphorus uptake of sudan grass than those under RP. These increases represent 43, 26 and 43% in the presence of perlite for 80, 65 and 50% soil moisture, while the increases represent 27, 33 and 43% in the absence of perlite application for 80, 65 and 50% soil moisture, respectively. Application of ordinary superphosphate showed greater values of dry matter, N, P and K-uptake by wheat plants than rock phosphate under application of chicken manure or town refuse as reported by Khalil (2011), Buddh (2014) and Ademba *et al.* (2015). Individually dry matter values of treatments were the lowest in the third cut if compared to the first and second ones of plants grown on calcareous soil. This view point is in agreement with El-Sedfy *et al.* (2008).

Soil Available Phosphorus

Results illustrated in Fig. 1 show that, the values of available phosphorus (mg kg^{-1}) at different depths were affected by the application of different phosphorus sources and perlite under different soil moisture levels. The treatment of OSP plus perlite under 80% soil moisture gave the highest values of available phosphorus in the first layer (0-5cm) after the first, second and third cuts (15.3, 15.0 and 12.9 mg ka^{-1}, respectively), while the lowest ones (7.4, 7.2 and 5.1 mg kg^{-1}, respectively) were found with untreated phosphate fertilizers in absence of perlite under 50% soil moisture. These results are in agreement with those obtained by Sadegh-Zadeh *et al*. (2008) and Opala (2017). The highest values of available phosphorus occurred with OSP treatments followed by RP and without application of phosphorus fertilizers. The ordinary super phosphate plus perlite under different soil moisture levels was more efficient than rock phosphate. Therefore, ordinary super phosphate could be recommended as a good source of phosphorus in these soils to attain higher available phosphorus content. Fouda (2017) reported that the application of phosphorus fertilizers gave the highest values of available phosphorus in soil after harvesting stage of faba bean.

Treatments under OSP gave higher values of available phosphorus after three cuts than those under RP. These increases represent 9.2, 8.8 and 29% after the first, second and third cuts, respectively in the first layer (0-5cm) and 10.1, 8.6 and 23.4%, respectively in the second layer (5-10 cm). This view point is in agreement with Song *et al.,* 2017.

Results in Fig. 1 showed that application of perlite to calcareous soil increased available phosphorus compared to the untreated ones in the two layers after cuts. These increases represent 9.5, 8.4 and 11.7% after the first, second and third cuts, respectively in the first layer (0-5 cm) and 9.6, 8.8 and 8.5% in the second layer (5-10 cm), respectively. Available P in calcareous soil was generally accumulated in the surface layer (0-5 cm) and gradually decreased with soil depth. However, there were appreciable differences in P distribution in the

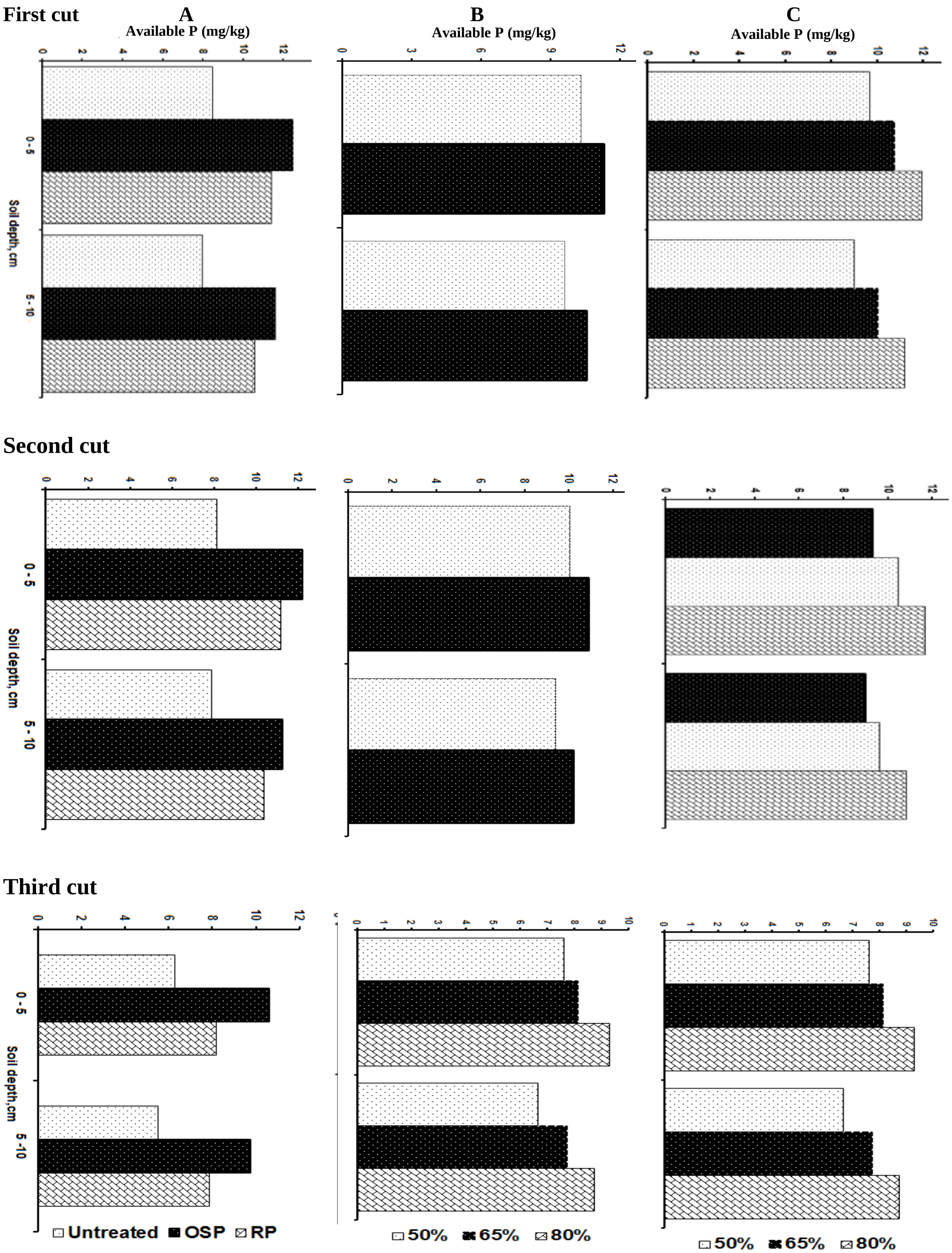

Fig. 1. Available phosphorus (mg kg^{-1}) after cuts of sudan grass plants as affected by phosphorus source and perlite under soil moisture levels in. A) Effect of P-source B) Effect of perlite and C) Effect of soil moisture level

root zone between P fertilizers (Eissa *et al*., 2013). Regarding the effect of soil moisture, results showed that, the available phosphorus was increased with increasing soil moisture level. This trend was found true under different phosphate fertilizers and perlite, after three cuts.

Results in Fig. 1 showed that the treatment of 80% soil moisture increased available phosphorus compared to 50% soil moisture in the two tested layers after cutting. These increases represent 23.6, 25.4 and 22.1% after the first, second and third cuts, respectively, in the first layer (0-5cm) and 24.3, 20.9 and 30.8% in the second layer (5-10 cm), respectively. The promotive effect of different soil moisture levels on available phosphorus after three cuts in the two layers may follow the order: 80>65> 50% under the application of ordinary super phosphate or rock phosphate in the presence of perlite. These results are in agreement with Khalil (2011) and Rosolem and Merlin (2014). High rate of irrigation water increased the downward movement of all forms of P fertilizers. As the moisture content of the soil is lowered, the moisture films around the soil particles become thinner and the diffusion of phosphate ions through these films become more tortuous, thus reduced the overall movement of phosphate ions (Tisdale *et al.*, 1997). Increasing the mobility of P dissolved in irrigation water with increasing the amount and frequency of irrigation has been observed, especially for sandy soils (Kargbo *et al.*, 1991).

Comparing the values of available phosphorus in soil, in Fig. 1 showed that available phosphorus values were higher in the first layer (0-5 cm) than in the second one (5-10 cm) after all cuts under different treatments. These results are in agreement with those of Siemens *et al.* (2004) and Yang *et al.* (2013). Pearse *et al.* (2006) observed a significant increase in soil labile P down to 10 cm and an increasing tendency down to 30 cm with P application on the soil surface. Phosphorus derived from triple superphosphate and rock phosphate applications moved down to 10–20 cm soil depth within 2 years of application in the Pumice soil, but did not move below 10 cm depth in the higher P fixing and less porous Allophanic soil (Rivaie *et al.*, 2008).

Results of all treatments showed that available phosphorus in soil was relatively high until the second cuts in the two layers. Thereafter, available phosphorus was decreased after the third cut. The lowest available phosphorus after the third cut as compared with the first and second cuts may be related to the gradual depletion for nutrients reserve in the soils with progressing age of plants. Similar results were obtained by Merwad and Abdel-Fattah 2015. The lowest available phosphorus was obtained after the third cut which may be related to the reduction in nutrients supply and to the gradual decrease in availability of the remained portion. This view point is in agreement with Yang *et al.* (2013).

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تأثير البيرليت والمحتوى الرطوبى على تيسر وحركة الفوسفور في الأراضي الجيرية المزروعة بنباتات حشيشة السودان

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أجريت تجربة أصص تحت ظروف محكمه في صوبة كلية الزراعة جامعة الزقازيق لدراسة تأثير نوعين من الأسمدة الفوسفاتية، سوبر الفوسفات الأحادي وصخر الفوسفات مع إضافة البرليت أو بدون إضافته تحت مستويات رطوبة مختلفة (٥٠، ٦٥ و ٨٠% من السعة التشبعية) على نبات حشيشة السودان وكذلك على تيسر وحركة الفوسفور في الأرض الجيرية، تم أخذ عينات من الطبقات السطحية للتربة (صفر -٣٠ سم) من محطة البحوث بالنوبارية بالقرب من الإسكندرية بمصر، وأظهرت النتائج أن مختلف مصادر الأسمدة الفوسفاتية كالسوبر فوسفات الأحادي أو صخر الفوسفات المضافة منفردة أو مخلوطة مع البيرليت تحت مستويات الرطوبة المختلفة أعطت زيادة في وزن النبات الطازج والجاف وأيضا زيادة الفوسفور الممتص بواسطة النبات مقارنة بالتربة غير المعاملة، كانت أعلى قيم لكل من الوزن الطازج والوزن الجاف للنبات والفوسفور الممتص بواسطة النبات وكذلك الفوسفور الميسر في التربة الجيرية المعاملة بالسوبر فوسفات الأحادي مخلوطا بالبيرليت تحت مستوى رطوبة ٨٠% بينما كانت أقل قيم مع التربة غير المعالجة تحت مستوي رطوبة ٥٠% وفي غياب للبيرليت، أعطي سماد السوبر فوسفات الأحادي أعلى قيم لكل من الوزن الطازج والوزن الجاف للنبات وكذلك الفوسفور الممتص بواسطة النبات مقارنة بالمعاملة بصخر الفوسفات، تأثير الرطوبة علي الفوسفور الميسر عقب الثلاث حشات في طبقتي التربة تحت مستويات الرطوبة المختلفة ٥٠، ٦٥ و ٨٠% كان إيجابيا تحت المعاملة بسوبر الفوسفات الأحادي أو صخر الفوسفات في وجود البيرليت، المعاملة بسوبر الفوسفات الأحادي أعطت أعلي قيم للفوسفور الميسر بعد الحشات الثلاث مقارنة بتلك المعاملة بصخر الفوسفات، الزيادات كانت بنسب ٩.٢ ، ٨.٨ و ٢٩% بعد الحشة الأولى والثانية والثالثة على التوالي وذلك في الطبقة الأولي (صفر-٥ سم)، ١٠.١ ، ٨.٦ و ٢٣.٤% على التوالي في الطبقة الثانية (٥-١٠ سم)، الفوسفور الميسر كان أعلى في الطبقة الأولى (صفر-٥ سم) مقارنة بالطبقة الثانية (٥-١٠ سم) عقب الثلاث حشات وتحت المعاملات المختلفة.

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