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USING PHOSPHATE SOLUBILIZING BACTERIA TO ENHANCE PRODUCTIVITY OF TWO LENTIL VARIETIES

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ABSTRACT: Two field experiments were conducted under surface irrigation system during two successive winter growing seasons 2017/2018 and 2018/2019 in private farm at El Qantra-West, Ismailia Governorate, Egypt to evaluate the effect of the combinations of three levels of phosphorus fertilizer (0, 15.5 and 31.0 kg P_2O_5/fad.) and three rates of bio-fertilizers (300, 600, 900g Phosphorein/ fad.) on yield, yield attributes and yield quality of two lentil varieties, Giza-51 and Sinai-1. Giza-51 variety surpassed Sinai-1 variety in plant height, number of primary branches/plant and 100-seed weight. Sinai-1 surpassed Giza-51 in number of pods/plant by (10.39% and 15.08%) and number of seeds/plant by (15.4% and 14.36%) in the first and second seasons, respectively. Also, Sinai-1 over weighted Giza-51 in pod yield/plant by 18.39 and 10.99%, seed yield/plant by 20% and 22.09%, seed yield/fad., by 17.1% and 25.69%, straw yield/fad., by 7.92% and 8.26% and protein yield/fad., by 18.70% and 23.28% in the first and second seasons, respectively. Soil mineral fertilization with calcium superphosphate at the highest level (31 kg P_2O_5/fad.) accompanied with bio-fertilizer (Phosphorein) at 900 g/fad. gave the highest values of yield, yield attributes and protein yield/fad. in the two seasons. A significant interaction between varieties, phosphorus and bio-fertilization was recorded for number of secondary branches/plant, number of seeds/plant, 100-seed weight and straw yield (kg/fad.) in the first season and weight of pods/plant in the second one as well as for seed yield (kg/fad.) and protein yield (kg/fad.) in the two seasons.

Keywords: Lentil**,** varieties, phosphatic fertilizer, phosphorein, yield.

INTRODUCTION

Lentil (*Lens culinaris*, Medic), is considered one of the most important food legumes in the countries of the Mediterranean Sea region. In Egypt, Lentil cultivars have some advantageous characters; like short life span, small cumulative thermal needs, low water needs along life, its good tolerance to drought (**Hamdi *et al.*, 1992**), and the possibility of growing under rainfall without supplementing water. Moreover, its seeds are rich in carbohydrates (60%), is a source of high quality protein in human diet and animal consumption. Also, lentil plants used as green fertilizer at flowering stage. Moreover, lentil enhances fertility of the soil because of provides it by nitrogen (**Thomson and Siddique, 1997; Katerji *et al.*, 2001**). Many investigators recorded significant differences between lentil varieties (**Ezatt *et al.*, 1998; Hamdi *et al.*, 2003; Hamdi *et al.*, 2004; Hamdi *et al.*, 2012; Haque and Khan, 2012; Datta *et al.*, 2013; Mandi *et al.*, 2015; Khattab *et al.*, 2016; Geja, 2019**).

The lentil crop shows good response to phosphorus fertilization (**Hussain *et al.*, 2002; Datta *et al.*, 2013; Ali *et al.*, 2017; Sonet *et al.*, 2020**). To increase production of lentil, limit imports and reduce the food gap, as Egypt import more than 98% of local consumption, where **Mohammad (2017)** stated that the average local production of lentils was 1.92

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thousand tons and the average consumption of lentils was 77.88 thousand tons, with a gap of 76.16 thousand tons, with self-sufficiency of 2.43% during the period (2000-2015). Cultivated areas must be increased which is often by expanding into new lands and increasing their productivity. Moreover, lentil as legumes crop needs more amount of phosphorus fertilizer compared to the other plant families. In Egypt, soil is suffering from fixing phosphorus ions in insoluble form as a result to increase pH number, so must apply all possible techniques to increase the available amounts of phosphor uptakes by plants such as using Phosphate Soluble Bacteria. Phosphate solubilizing bacteria is known to enhance the productivity of the crop as it increase the availability of soil phosphorus (**El Sayed, 1999; Sharma *et al.*, 2022**). Phosphorus is one of the major plant nutrients. It is an important component of many organs of every living cell. Phosphorus takes part in several living processes including heredity and energy transport system (**Donahue *et al*., 1990**).

The present study aimed to evaluate the effect of the combination between three levels of phosphoric fertilizer *i.e.,* 0, 15.5 and 31.0 kg P_2O_5/fad., and three bio-fertilizers rates (300, 600, 900 g Phosphorein/fad., on yield, yield components and yield quality of two lentil varieties, Giza-51 and Sinai-1.

MATERIALS AND METHODS

Two field experiments were conducted during two successive winter growing seasons 2017/2018 and 2018/2019 in private farm at El Qantra-West, Ismailia Governorate, Egypt to evaluate the effect of three levels of phosphorus fertilizer (0, 15.5 and 31.0 kg P_2O_5/fad.) and three rates of bio-fertilizers (300, 600, 900 g Phosphorein/fad.) (1 package = 300 g**)** on yield, yield attributes and yield quality of two lentil varieties, Giza-51 and Sinai-1.

Dates of planting were on 15 November in the first and second seasons. A randomized complete block split-plot design with three replications was used in each season. The two varieties and nine combination between phosphorus and bio-fertilizers were randomly allocated in the main and sub-plots, respectively. Each experimental plot is a bed consisting of ten rows, 3 m in length and 2 m apart and 5 cm intra plant space. Mineral phosphorus fertilizer was applied in form calcium super phosphate (15.5% P_2O_5). Phosphorein was obtained from Agricultural Research Center, Institute of Water and Soil Research, Giza. The biofertilizers (Phosphorein) was mixed with moisten sand and drilled beside seedlings after 5 days from sowing.

All other agronomic practices were applied as recommended. The preceding crop was corn in the two seasons. Physical and chemical properties of the soil experimental sites are shown in Table 1. At physiological maturity stage (145 days for Sinia-1 and 152 days for Giza-51) sample of five guarded plants from each plot was taken at random to determine yield attributes *i.e*., plant height (cm), number of primary and secondary branches/plant, number and weight of pods/plant (g), number and weight of seeds/plant (g), 100-seed weight (g). Seeds and straw yields/fad were determined by harvesting the central two rows from each experimental plots and then the yield converted to fad.

Total nitrogen in seeds was determined after drying and grinding seed samples using Micro-Kjeldahl method as described by **AOAC (1990)** and protein% was calculated by multiplying nitrogen percentage by a factor of 6.25.

Data obtained from each trail were statistically analyzed according to analysis of variance of split plot design by using computer program Co-STAT as described by **Snedecor and Cochran (1981)**. Means of treatments were compared using the least significant differences (LSD) developed by **Waller and Duncan (1969)** at 0.5% level.

RESULTS AND DISCUSSION

Varietal Differences

It is clearly evident that lentil Giza-51 variety significantly surpassed Sinai-1 variety in plant height in the first season, number of primary branches/plant and 100-seed weight in the two seasons. The differences between the two varieties not reached the level of significance for plant height in the second season and for number of

Table 1. Physical and chemical properties of the experimental soil (average of both seasons)

Chemical properties												
pH	EC dsm-^{1}	Soluble cations meq/100 g soil				Soluble anions meq/100 g soil				Available NPK (mg.kg-1) Soil		
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{2-}	Cl^{-}	SO_4^{2-}	N	p	K
7.86	1.9	5.5	3.3	8.5	0.7	-	1.0	12.8	4.2	18.11	4.75	64.35

Physical analysis					
Organic matter (%)	Particle size distribution (%)				Soil texture
	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	
0.59	6.4	23.8	35.0	34.8	Lomy clay

secondary branches/plant in both seasons as given in Tables (2 and 4). Giza-51 recorded more than 5 g for 100-seed weight, while Sinai-1 recorded less than 5 g and that was true in the two seasons.

On the other hand, results in Tables 3, 4 and 5 illustrated that lentil variety Sinai-1 significantly surpassed Giza-51 variety in number and weight of pods/plant, number and weight of seeds/plant, seed yield/fad, straw yield/fad as well as seed protein content and protein yield/fad and that was true in the two seasons.

Sinai-1 surpassed Giza-51 in number of pods / plant (by 10.38% and 15.08%) and number of seeds/plant by (by 15.4% and 14.36%) in the first and second seasons, respectively. Also, Sinai-1 over weighted Giza-51 in pod yield/ plant by 18.39 and 10.99%, seed yield/plant by 20% and 22.09%, seed yield/fad. by 17.1% and 25.69%, straw yield/fad by 7.92% and 8.26% and protein yield/fad. by 18.70% and 23.28% in the first and second seasons, respectively. These results are confirmed with those obtained by **El-Nahas *et al*. (2011) and Kassab *et al.* (2014)**. Moreover, significant differences between lentil **v**arieties were recorded by **Ezatt *et al*. (1998), Hamdi *et al*. (2003), Hamdi *et al*. (2004), Hamdi *et al.* (2012), Haque and Khan (2012), Datta *et al*. (2013), Mandi *et al.* (2015), Osama *et al.* (2018), Geja (2019) and Abdelsalam and El-Sanatawy (2022)**.

Effect of Mineral and Bio-Fertilizers of Phosphorus

Results presented in Tables 2, 3, 4 and 5 cleared that soil mineral fertilization with calcium superphosphate at the highest level (31 kg P_2O_5/fad.) accompanied with bio-fertilizer (Phosphorein) at 900 g/fad., gave the highest values of the all studied characters in the two seasons.

At the highest level of calcium superphosphate (31 kg P_2O_5/fad.), increasing bio-fertilizer (Phosphorein) level from 300 g/fad. to 600 or 900 g/fad. gave the same effect (highest) without significant differences between them concerning plant height in the second season and number of primary branches/plant in the two seasons (Table 2). Also, increasing level of bio-fertilizer (Phosphorein) from 300 g/fad. to 600 or 900 g/fad., either at the highest (31 kg P_2O_5/fad.) or at the middle (15.5 kg P_2O_5/fad.) level of calcium superphosphate gave the same effect concerning number of secondary branches/plant and that was true in the two seasons (Table 2). These may be attributed to the ability of the added Phosphorein bacteria to turned soil unavailable mineral phosphorous into available phosphorous suitable for uptake by plants.

Results given in Table 3 showed that the highest levels of calcium superphosphate (31 kg P_2O_5/fad.) and bio-fertilizer (Phosphorein at 900 g/fad.) produced the highest significant values

Table 2. Effect of mineral and bio-fertilization of phosphorus on plant height (cm), number of primary branches/plant and number of secondary branches/plant of two lentil varieties (Sinai-1 and Giza-51) in the two growing seasons

Treatments		Plant height (cm)		No. of primary branches/plant		No. of secondary branches/plant	
		2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019
Varieties							
Sinai-1		37.56 b	36.59 a	2.68 b	2.15 b	8.11 a	7.29 a
Giza-51		40.26 a	38.00 a	3.18 a	2.59 a	8.03 a	7.22 a
LSD at 5%		2.41	N. S	0.38	0.28	N.S	N.S
P_2O_5 Kg/fad. Phosphorein g/fad.							
	300	35.67 f	34.33 d	2.56 d	2.04 e	5.17 d	5.67 d
0	**600**	37.17 e	35.50 c	2.67 cd	2.09 de	6.67 c	5.83 cd
	900	37.17 e	35.67 c	2.67 cd	2.12 de	7.33 bc	6.67 bcd
	300	38.33 de	36.00 c	2.67 cd	2.18 de	8.00 abc	7.67 abc
15.5	**600**	39.17 cd	36.00 c	2.78 bcd	2.40 bcde	8.50 ab	7.67 abc
	900	40.67 b	38.00 b	3.00 bcd	2.57 bcd	8.80 a	7.83 abc
	300	40.00 bc	39.00 a	3.17 abc	2.72 abc	8.83 a	8.00 a
31	**600**	41.10 bc	39.33 a	3.22 ab	3.00 ab	9.00 a	8.50 a
	900	42.33 a	39.67 a	3.67 a	3.07 a	9.00 a	8.50 a
LSD at 5%		1.34	0.91	0.51	0.49	1.37	1.19
		Interaction					
VxF		Ns	Ns	Ns	Ns	*	Ns

Where: V: varieties, F: combination between Phosforus and Phosphorein fertilization, Ns: non-significant and *: significant at 0.05

Table 3. Effect of mineral and bio-fertilization of phosphorus on number of pods/plant, weight of pods/plant and number of seeds/plant of two lentil varieties (Sinai-1 and Giza-51) in the two growing seasons

Treatments		No. of pods/plant		Wt. of pods/plant(g)		No of seeds /plant	
		2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019
Varieties:							
Sinai-1		42.30 a	40.37 a	4.70 a	4.24 a	46.31 a	47.00 a
Giza-51		38.32 b	35.08 b	3.97 b	3.82 b	40.13 b	41.10 b
LSD at 5%		0.75	1.72	0.05	0.17	0.40	0.99
P_2O_5 Kg/fad. Phosphorein g/fad.							
	300	37.10 e	34.97 e	4.08 f	3.65 f	40.70 e	40.80 e
0	**600**	37.72 e	35.53 de	4.12 ef	3.65 f	41.85 d	41.70 e
	900	38.02 de	36.83 cd	4.23 def	3.85 de	42.33 cd	43.28 d
	300	38.93 d	37.15 c	4.27 de	3.85 de	42.85 c	43.68 cd
15.5	**600**	40.07 c	37.28 c	4.28 cde	3.97 cd	42.87 c	43.82 bcd
	900	41.72 b	38.20 bc	4.45 bc	4.05 c	43.92 b	44.75 bc
	300	41.72 b	39.10 b	4.31 cd	4.35 b	44.07 b	44.98 b
31	**600**	42.17 b	39.57 ab	4.53 b	4.33 b	45.13 a	46.33 a
	900	43.98 a	40.88 a	4.75 a	4.60 a	45.27 a	47.10 a
LSD at 5%		1.09	1.40	0.17	0.13	0.66	1.28
		Interaction					
VxF		Ns	Ns	Ns	*	*	Ns

Where: V: varieties, F: combination between Phosforus and Phosphorein fertilization, Ns: non-significant and *: significant at 0.05

Table 4. Effect of mineral and bio-fertilization of phosphorus on weight of seeds/plant, 100-seed weight and seed protein content (%) of two lentil varieties (Sinai-1 and Giza-51) in the two growing seasons

Treatments		Wt. of seeds/plant (g)		100- seed weight (g)		Seed protein content%	
		2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019
Varieties:							
Sinai-1		3.36 a	3.04 a	4.26 b	4.59 b	26.47 a	26.13 a
Giza-51		2.80 b	2.49 b	5.07 a	5.37 a	25.21 b	25.23 b
LSD at 5%		0.09	0.13	0.02	0.32	0.15	0.15
P_2O_5 Kg/fad.	**Phosphorein g/fad.**						
	300	2.83 e	2.52 e	4.47 d	4.87 b	25.57 f	25.05 e
0	**600**	3.00 cd	2.65 cde	4.55 d	4.90 b	25.68 ef	25.25 d
	900	2.93 de	2.67 cde	4.58 cd	4.95 ab	25.75 de	25.62 c
	300	3.08 bc	2.77 bcd	4.60 cd	4.95 ab	25.85 cd	25.67 c
15.5	**600**	3.08 bc	2.75 bcd	4.66 bcd	4.96 ab	25.87 bcd	25.75 bc
	900	3.03 bcd	2.75 bcd	4.69 bc	5.03 ab	25.90 bc	25.90 ab
	300	3.17 b	2.82 bc	4.74 abc	5.03 ab	25.92 bc	25.93 ab
31	**600**	3.17 b	2.87 b	4.79 ab	5.04 ab	25.98 ab	25.98 a
	900	3.40 a	3.10 a	4.89 a	5.14 a	26.05 a	25.98 a
LSD at 5%		0.15	0.16	0.15	0.20	0.12	0.19
		Interaction					
VxF		Ns	Ns	*	Ns	Ns	Ns

Where: V: varieties, F: combination between Phosforus and Phosphorein fertilization, Ns: non-significant and *: significant at 0.05

Table 5. Effect of mineral and bio-fertilization of phosphorus on seeds/plant, 100-seed, straw and protein yields/fad., of two lentil varieties (Sinai-1 and Giza-51) in the two growing seasons

Treatments		Seed yield (kg/fad.)		Straw yield (kg/fad.)		Protein yield (kg/fad.)	
		2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019
Varieties:							
Sinai-1		692.2 a	609.1 a	1409.8 a	1370.9 a	183.36 a	159.44 a
Giza-51		591.1 b	484.6 b	1306. 3 b	1266.3 b	149.07 b	122.33 b
LSD at5%		13.6	27.7	20.2	30.1	2.57	6.47
P_2O_5 Kg/fad.	**Phosphorein g/fad.**						
	300	580.0 f	466.7 f	1290.8 g	1251.7 e	148.42 f	116.97 f
0	**600**	590.0 ef	489.2 ef	1304.2 fg	1271.7 de	151.70 ef	123.63 ef
	900	595.8.ef	495.0 e	1311.7 f	1275.0 d	153.61 e	127.00 e
	300	596.7 e	533.3 d	1315.8 ef	1277.5 d	154.42 e	142.21 cd
15.5	**600**	618.3 d	554.2 cd	1331.7 e	1290.0 d	160.25 d	137.67 d
	900	647.5 c	563.3 c	1357.5 d	1312.5 c	168.32 c	146.54 c
	300	652.5 c	563.3 c	1391.7 c	1349.8 b	169.58 c	146.48 c
31	**600**	686.7 b	603.3 b	1445.8 b	1402.5 b	178.99 b	157.35 b
	900	807.5 a	653.3 a	1473.3 a	1426.7 a	210.63 a	170.11 a
LSD at 5%		16.3	24.5	18.7	20.4	4.23	7.27
		Interaction					
VxF		*	*	*	Ns	*	*

Where: V: varieties, F: combination between Phosforus and Phosphorein fertilization, Ns: non-significant and *: significant at 0.05

concerning number of pods/plant in the first season and weight of pods/plant in the two seasons. While, under the same level of calcium superphosphate (31 kg P_2O_5/fad.), both application of Phosphorein at 600 g or 900 g/fad. gave the same effect without significant differences between them concerning number of pods/plant in the second season and number of seeds/plant in the two seasons.

Results in Table 4 revealed that application of 31 kg P_2O_5/fad. accompanied with bio-fertilizer (Phosphorein) at 900 g/fad. surpassed significantly the other treatments and produced the highest significant value of seed yield/plant and that was true in the two seasons.

Using bio-fertilizer (Phosphorein) at 900 g/ fad., without mineral phosphorus fertilization not differ significantly from using middle or high level of calcium superphosphate (15.5 or 31kg P_2O/fad.) accompanied with any level of Phosphorein concerning 100-seed weight and that was true in the second season only. These results show the presence of metallic phosphorous in the soil, which was converted by Phosphorein bacteria from a form that is not suitable for absorption to a form suitable for uptake by plants. While in the first season, the high level of calcium superphosphate (31 kg P_2O_5/fad.) with any studied level from bio-fertilizer (300, 600 or 900 g Phosphorein/fad.) gave the highest value of 100-seed weight (Table 4).

Also, application of 31 kg P_2O_5/fad., accompanied with bio-fertilizer (Phosphorein) at 600 or 900 g/fad., surpassed significantly the other treatments and produced the highest significant value of seed protein content in the first season, but in the second season, 900 g Phosphorein/fad., with mineral phosphorus fertilization by 15.5 kg P_2O_5/fad., as well as 300, 600 or 900 g Phosphorein/fad. with 31 kg P_2O_5/fad., surpassed the other studied factors and gave the highest significant value of seed protein content. This might be attributed to that fertilization with Phosphorein converted the unavailable phosphorus as tri-calcium phosphate to the available phosphorus. That led to enhance the efficiency of lentil plants in utilizing phosphorus fertilizer which in turn had favorable effects on lentil productivity. Similar results were obtained by **El Sayed (1999), Hussain *et al*. (2002), Shahid and Janardan (2016) and Sharma *et al*. (2022)**.

Results presented in Table 5 indicated that mineral phosphorus fertilization at the highest level (31 kg P_2O_5/fad.) accompanied with 900 g Phosphorein/fad., surpassed the other studied treatments and produced the highest seed (807.5 kg and 653.3 kg), straw (1473.3 kg and 1426.7 kg) and protein yields (210.63 kg and 170.11 kg) per fad. in the first and second seasons, respectively. These results indicate that the lentils need more amounts of phosphate fertilizer, perhaps greater than what was added at the highest level. Many investigators reported that phosphorus and bio fertilization increased lentil yield, yield attributes and yield quality (**El Sayed, 1999; Hussain *et al*., 2002; Datta *et el*., 2013; Ali *et al*., 2017; Sonet *et al*., 2020; Sharma *et al*., 2022**).

Interaction Effect

The interaction effect between varieties and combination of phosphorus and bio-fertilization for number of secondary branches/plant, number of seeds/plant, 100-seed weight and straw yield (kg/fad.) in the first season and weight of pods/ plant in the second season was significant, as well as for seed yield (kg/fad.) and protein yield (kg/fad.) through the two seasons.

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استخدام البكتيريا المذيبة للفوسفات لتحسين إنتاجية صنفين من العدس

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أجريت تجربتان حقليتان تحت نظام الري السطحي خلال موسمين زراعيين شتويين متتاليين 2018/2017 و2018/2019 في مزرعة خاصة بالقنطرة غرب بمحافظة الإسماعيلية، مصر. لتقييم تأثير التوافيق بين ثلاثة مستويات من السماد الفوسفاتي (0 ، 15.5 ، 31.0 كجم/فدان فو$_2$ا$_5$) وثلاثة معدلات من المخصبات الحيوية (300، 600، 900 جم فوسفورين/فدان) على المحصول ومساهماته وجودته علي إنتاجية صنفين من العدس جيزة 51 وسينا1. تفوق صنف جيزة 51 على صنف سينا1 في ارتفاع النبات وعدد الأفرع الأولية/نبات ووزن 100 بذرة. بينما تفوق سيناء 1 على جيزة 51 في عدد القرون/ نبات بنسبة (10.39% و 15.08%) وعدد البذور/نبات بنسبة (15.4% و 14.36%) في الموسمين الأول والثاني، على التوالي. كذلك ، تفوق سينا1 من حيث الوزن علي جيزة 51 في محصول القرون/نبات بنسبة 18.39 و10.99%، محصول البذور/نبات بنسبة 20% و 22.09% ، محصول البذور/فدان بنسبة 17.1% و25.69%، محصول القش/فدان بنسبة 7.92%. و 8.26% ومحصول البروتين/فدان 18.70% و23.28% في الموسمين الأول والثاني، على التوالي. أعطى التسميد المعدني للتربة بسماد سوبر فوسفات الكالسيوم عند المستوى الأعلى (31 كجم/فدان فو$_2$ا$_5$) مع المخصب الحيوي (Phosphorein)عند 900 جم/فدان أعلى القيم لجميع الصفات المدروسة وصفات الإنتاجية والمحصول والجودة في الموسمين. تم تسجيل تفاعل معنوي بين الأصناف والفوسفور والتسميد الحيوي لعدد الأفرع الثانوية/نبات وعدد البذور/نبات ووزن 100 بذرة ومحصول القش (كجم/فدان) في الموسم الأول ووزن القرون/نبات في الموسم الثاني. وكذلك محصول البذور (كجم/فدان) وحاصل البروتين (كجم/فدان) في الموسمين.

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