Journal of Horticultural Science & Ornamental Plants 12 (3): 259-268, 2020
ISSN 2079-2158

DOI: 10.5829/idosi.jhsop.2020.259.268

Effect of Phosphate Dissolving Bacteria and Foliar Applied Potassium on Growth, Yield and Chemical Constituents of Broad Bean

A.E.M. Eata

Vegetable Research Department, Horticulture Research Institute,
Agriculture Research Center, Giza, Egypt

Abstract: Two field experiments were performed at a private farm in El-Gammalia District, Dakahlia Governorate, Egypt, during winter seasons of 2018/19 and 2019/20 to study the effect of phosphorin (phosphate dissolving bacteria) PDB and foliar applied potassium on growth, pod yield and chemical constituents of broad bean (*Vicia faba* L. var. *major*) as a vegetable for fresh consumption. The studied treatments were the combination among three phosphorin rates; 0, 1 and 2 kg fed^{-1} and three rates of potassium citrate; 0, 1 and 2 $cm^3\,l^{-1}$. The results showed significant effects on broad bean plant height, number of leaves and branches $plant^{-1}$ and fresh and dry weight of leaves and branches $plant^{-1}$ due to phosphorin and foliar applied potassium treatments. Application of phosphorin or potassium citrate at the high rate significantly surpassed the low rate and the control treatment in all growth and yield characters of vegetable broad bean. The data also showed a positive response of the studied characters to the interaction between phosphorin and potassium. Highly significant effects on chlorophyll content in leaves, N, P and K as well as protein and carbohydrates contents in green seeds were reported due to phosphorin or foliar applied K treatment. In general application of 2 kg fed^{-1} phosphorin and foliar applied potassium citrate at the highest rate resulted in greater broad bean yields and improving N, P, K, protein and carbohydrate% in green seeds which in turn reflected on the nutritional value of green pods of broad bean.

Key words: Broad Bean · Potassium Citrate · Phosphorin · Yield · Quality

INTRODUCTION

In Egypt, broad bean (*Vicia faba* L. var. *major*) is one of the most important legume winter crops, for human consumption as a major source of vegetarian protein [1], as well as in animal production. The broad bean can be harvested when the seeds are fresh and green and used as a vegetable, or harvested at the maturity stage when the seeds are dry [2]. Seeds contain slight proteins including trypsin inhibitors, lectins, lipoxygenase and urease, which are appropriate to the nutritional quality [3]. In addition, the seeds also contain many biologically active compounds such as polyphenols [4]. However, due to shrinking the cultivated area from 271, 000 fed in the year of 2000 to 81, 000 fed in 2018, with increasing the demand ofbroad bean crop [1], it is important to increase the productivity of unit area in order to meet this increasing demand. The horizontal expansion especially the new lands is a proposed solution to overcome this problem [5]. In sandy soils growing broad bean need integration between inoculation with bacteria and mineral fertilizer for high quality and quantity yield production [1]. The nutritious value of broad bean has always been attributed to its high protein content (27-34%) which depend on genotypes [6, 7]. The poor status of soil fertility of newly reclaimed lands is not the main production constraint [8]. However, the production of broad bean in Egypt is limited and affected by different factors such as soil fertility and water supply [9].

Phosphorus is an essential element in the energy transfer processes. It has an important role in producing energy in various metabolic processes. It is needed in the formation of fat, transformation of starch to sugar, flowering and fruiting stages. Phosphorus deficiency causes important nutritional problems in newly reclaimed

Corresponding Author: A.E.M. Eata, Vegetable Research Department, Horticulture Research Institute, Agriculture Research Center, Giza, Egypt.

soils [10]. Many investigators reported that increasing phosphorus levels improved the plant growth, yield and yield and quality of vegetable crops [11, 12]. Most arable soils in Egypt cause fixation of phosphate turning applied soluble phosphates into insoluble ones [13, 14]. Rhizosphere microorganisms such as *Bacillus* spp. and *Rhizobium* spp. are essential for facilitating P mobilization in alkaline soil since they can solubilize insoluble phosphates through different mechanisms [15, 16]. Immobilization of phosphorus is the most important problem of phosphate fertilization in Egypt, due to soil alkalinity, the applied phosphorus fertilizers could be converted to unavailable form for plant absorption. Phosphorin is a bio-fertilizer product containing active micro-organisms hydrolyzing the insoluble phosphate into soluble form under high soil pH. Therefore, the utilization of bio-fertilizers may be dissolve the unavailable form of phosphate to available form and adding bio-phosphorus fertilizer led to significant increase in vegetative growth, yield and quality of vegetable crops [12].

Potassium (K) is a major plant nutrient, which is essential for a variety of physiological processes *i.e.* photosynthesis, protein synthesis, enzyme activation, maintenance of water status in plant tissues, location, transformation and storage of carbohydrates, tuber quality and processing characteristics as well as plant resistance to stresses and diseases [17]. K is an essential nutrient for broad bean growth and productivity, the excellence of plant growth with the supplement of potassium might be due to role of potassium in protein synthesis, nutrients translocation, anti-oxidant enzymes, root proliferation and leaves growth [18]. The most growth promote effect of potassium is due to more increase of carbohydrates, proteins, enzymes and energy synthesis [19]. Shafeek *et al*. [20] reported that spraying broad bean plants with the high standard of potassium thiosulfate (2 l fed^{-1}) generated the highest values of growth parameters followed by spraying plants with lower grade (1 l fed^{-1}) in both seasons; while control treatment (without potassium foliar application) recorded the minimum values of these characters in both seasons. Increasing nutritional values of pods could be attributed to the rapid absorption of these elements by the plant surface, especially the leaves and their translocation within the plant [19]. The Egyptian soils are characterized with high pH values and tended to be alkaline which in turn result in fixing the major nutrients especially P and K. Therefore, it is essential to solubilize P to be readily available to broad bean through phosphorin (phosphate dissolving bacteria) PDB application as well as the external compensation of K via leaves to overcome these situations. So, the aim of this work is to study the effect of phosphate dissolving bacteria and foliar applied potassium on growth, yield and chemical constituents of broad bean.

MATERIALS AND METHODS

Two field experiments were conducted at a private farm in El-Gammalia District, Dakahlia Governorate, Egypt during winter seasons of 2018/19 and 2019/20 to study the effect of phosphate dissolving bacteria and foliar applied potassium on growth, pod yield and chemical constituents of broad bean (*Vicia faba* L. var. *major*) as a vegetable for fresh consumption. The physical and chemical analyses of the experimental soil are shown in Table (1).

The experimental layout was factorial in a randomized complete block design with three replicates (2WRB). The experiment included 9 treatments which were the combination among three phosphorin (phosphate dissolving bacteria) 0, 1 and 2 kg fed^{-1} and three rates of potassium citrate (38% K) 0, 1 and 2 cm^3 l^{-1}. Seeds of broad bean (*Vicia faba* L. var. *major*) were obtained from Argic. Res. Inst. and were inoculated with the specific *Rhizobia* and sown immediately in hills (2 seeds hill^{-1}) at 15 cm apart on 20th and 25th of October in the first and the second seasons, respectively and thinned at one plant hill^{-1}. The experimental unite area was 15 m^2 (5 ridges, each 5 m long and 60 cm width). During preparing the soil, basal fertilizers of (50, 200 and 50 kg fed^{-1}) of ammonium sulphate, calcium super-phosphate, potassium sulphate fertilizers, respectively) were added through soil preparation. The normal agricultural practices of broad bean production were followed according to the recommendations of Egyptian Ministry of Agriculture.

The treatments were arranged as follow and randomly distributed in the experimental unites:

- P0K0: Without treatment.
- P0K1: Potassium citrate at 1 cm l^{-1}.
- P0K2: Potassium citrate at 2 cm l^{-1}.
- P1K0: Phosphorin at 1 kg fed^{-1}
- P1K1: Phosphorin at 1 kg fed^{-1} + potassium citrate at 1 cm l^{-1}.
- P1K2: Phosphorin at 1 kg fed^{-1} + potassium citrate at 2 cm l^{-1}.
- P2K0: Phosphorin at 2 kg fed^{-1}.
- P2K1: Phosphorin at 2 kg fed^{-1} + potassium citrate at 1 cm l^{-1}.
- P2K2: Phosphorin at 2 kg fed^{-1} + potassium citrate at 2 cm l^{-1}.

Table 1: The physical and chemical analysis of the experimental soil

Seasons	Mechanical analysis			Soil texture	Chemical analysis				Available (ppm)			Organic matter %
	Sand %	Silt %	Clay %		PH	EC mmohs	$CaCo_3$ meq/l	Soluble HCo_3 meq/l	N	P	K	
2018/19	20.2	28.6	51.2	Clay	8.4	1.11	0.04	0.84	44.1	4.75	370	2.57
2019/20	21.4	25.2	53.4	Clay	8.2	1.17	0.05	0.59	46.5	4.62	350	2.65

The plants were sprayed with potassium citrate (38 % k) at 25, 40 and 55 days after sowing. As for soil application of phosphorin, it was mixed with sand, divided and drilled of the assigned plots just after sowing and before the 1st irrigation.

Data Recorded

Vegetative Growth Characters: At 70 days after sowing, five plants were randomly taken from each plot for determining the following data: Plant heights (cm), number of leaves plant^{-1}, fresh weight of leaves plant^{-1} (g), dry weight of leaves plant^{-1} (g), number of branches plant^{-1}, fresh weight of branches plant^{-1} (g) and dry weight of branches plant^{-1} (g).

Yield and its Components: At the mature stage, the following parameters were calculated; Number of pods plant^{-1}, pod length (cm), pod diameter (cm), number of seeds pod^{-1}, pod weight plant (g), fresh weight of 100 seeds (g) and total fresh pod yield fed^{-1} (ton).

Chemical Constituents: Total Chlorophyll in leaves was determined according to [21]. A sample of fresh green seeds was taken and dried at 70°C then it was grounded and the following chemical constituents were determined: N %, P %, K% and carbohydrates % in green seeds were determined according to [22]. Crude protein % in green seeds was determined by multiplying N% in 6.25%.

Statistical Analysis: The analysis of variance The variance analysis of the factorial layout in a randomized was carried out using MSTAT-C Computer Software [23], for both seasons. Means of the different characters were compared using Duncan's Range Test at $P < 0.05$.

RESULTS AND DISCUSSION

Vegetative Growth

Effect of Phosphorin Treatment: Data presented in Table (2) clearly show significant effects on broad bean plant height, No. of leaves and branches, fresh and dry weight of leaves and branches plant^{-1} and fresh and dry weight of leaves and branches due to phosphorin treatments compared with untreated plants in both seasons of the study. Generally, the application of 2 kg fed^{-1} phosphorin significantly surpassed the application of 1 kg fed^{-1} and the control treatment in all growth characters of vegetable broad bean except plant height in the first season.

Such increases in growth characters of broad bean reveal the importance of microorganism in solubilizing fixed phosphate to available form for plant absorption which clearly reflected on these criteria. Moreover, the effect of phosphate solubilizing inoculations on the plants inoculated with *R. leguminosarum* exhibited higher nodules numbers and nodules dry weight plant^{-1} of broad bean plants as compared to control [13, 24]. Akl and Abdel-Fattah [25] reported that inoculated broad bean plants with phosphorus solubilizing bacterial gave increase in nodules numbers plant^{-1}, nodules dry weight plant^{-1}, phosphatase activity, biomass plant^{-1} and yield.

Effect of Potassium Foliar Application: Data presented in Table (3) clearly show the significant effect of potassium foliar treatment on broad bean plant height, No. of leaves and branches plant^{-1} and fresh and dry weight of leaves and branches plant^{-1} compared with untreated plants in both seasons of study. Generally, application of 2 kg fed^{-1} significantly surpassed application of 1 kg fed^{-1} and the control treatment in all growth characters of vegetable broad bean except no of leaves plant^{-1} in the first season.

The superiority of potassium citrate could be attributed to the role of K in photosynthesis, assimilate transport, enzyme activation and oxidative stress [26, 27]. Shafeek *et al.* [20] reported that spraying broad bean plants with potassium thiosulfate at (2%) markedly improved vegetative growth.

Effect of Interaction Between Phosphorin and Potassium Application: Data presented in Table (4) show that the interaction between phosphorin and potassium spray was only significant on fresh weight of leaves and branches plant^{-1} and dry weight of branches plant^{-1} in the first season and dry weight of leaves and branches plant^{-1} in the second season.

Such positive responses may be due to the lowering of pH value (8<) which increases soil acidity, which in turn allow better circumstances for cowpea growth.

Table 2: Effect of phosphorin application on broad bean growth characteristics

Phosphorin rates	Plant height (cm)	No. of leaves plant^{-1}	No. of branches plant^{-1}	Fresh weight of leaves plant^{-1} (g)	Fresh weight of branches plant^{-1} (g)	Dry weight of leaves plant^{-1} (g)	Dry weight of branches plant^{-1} (g)
				2018/19 Season			
0 kg	66.4 b	23.1 c	2.9 c	64.5 c	49.0 c	12.1 c	9.3 c
1 kg	69.6 a	31.4 b	4.0 b	71.3 b	68.0 b	14.2 b	10.2 b
2 kg	71.6 a	38.1 a	4.6 a	80.5 a	92.4 a	16.1 a	11.9 a
Significance at 0.05 level	**	**	**	**	**	**	**
				2019/20 Season			
0 kg	62.4 c	21.6 c	2.3 c	56.1 c	50.0 c	11.3 c	9.4 c
1 kg	70.0 b	29.2 b	3.7 b	69.9 b	67.1 b	14.0 b	10.4 b
2 kg	77.5 a	36.0 a	4.4 a	80.7 a	87.8 a	16.2 a	11.6 a
Significance at 0.05 level	**	**	**	**	**	**	**

Values followed by the same letters within a column are not significantly different at the 0.05 level of probability according to Duncan's multiple range test.

Table 3: Effect of potassium citrate application on broad bean growth characteristics

Potassium citrate rates	Plant height (cm)	No. of leaves plant^{-1}	No. of branches plant^{-1}	Fresh weight of leaves plant^{-1} (g)	Fresh weight of branches plant^{-1} (g)	Dry weight of leaves plant^{-1} (g)	Dry weight of branches plant^{-1} (g)
				2018/19 Season			
0 cm	64.1 c	28.3 b	3.2 c	63.0 c	63.3 c	12.8 c	10.0 b
1 cm	69.8 b	31.3 a	3.8 b	73.8 b	69.9 b	14.3 b	10.4 b
2 cm	73.4 a	33.0 a	4.1 a	79.5 a	76.6 a	15.4 a	11.1 a
Significance at 0.05 level	**	**	**	**	**	**	*
				2019/20 Season			
0 cm	67.3 c	26.7 c	2.9 c	64.0 c	63.2 b	12.9 c	9.9 b
1 cm	69.8 b	28.6 b	3.6 b	69.2 b	66.0 b	13.8 b	10.3 b
2 cm	72.7 a	31.4 a	4.0 a	73.6 a	75.7 a	14.8 a	11.1 a
Significance at 0.05 level	**	**	**	**	**	**	*

Values followed by the same letters within a column are not significantly different at the 0.05 level of probability according to Duncan's multiple range test

Table 4: Effect of Interaction between phosphorin and potassium application on broad bean growth characteristics

Treatment	Plant height (cm)	No. of leaves plant^{-1}	No. of branches plant^{-1}	Fresh weight of leaves plant^{-1} (g)	Fresh weight of branches plant^{-1} (g)	Dry weight of leaves plant^{-1} (g)	Dry weight of branches plant^{-1} (g)
				2018/19 Season			
P0K0	61.7	21.0	2.3	50.2 d	47.4 e	10.0	8.9 f
P0K1	65.0	23.3	3.0	69.1 c	49.5 e	13.8	9.5 e
P0K2	72.7	25.0	3.3	74.5 b	50.3 e	15.0	9.6 e
P1K0	63.3	28.0	4.0	62.9 c	64.0 d	12.7	10.2 d
P1K1	71.3	32.3	4.0	74.1 b	65.3 d	14.8	10.2 d
P1K2	73.0	34.0	4.0	77.1 b	74.9 c	15.4	10.3 d
P2K0	67.0	36.0	4.0	76.1 b	78.7 c	15.3	11.1 c
P2K1	73.0	38.3	4.7	78.3 b	95.0 b	15.5	11.6 b
P2K2	74.7	40.0	5.0	87.2 a	103.7 a	17.6	13.1 a
Significance at 0.05 level	ns	ns	ns	*	**	ns	**
				2019/20 Season			
P0K0	59.3	18.7	1.7	47.9	47.8	9.7 g	9.2 f
P0K1	62.0	21.3	2.3	56.4	49.7	11.3 f	9.4 ef
P0K2	66.0	25.0	3.0	64.3	52.4	12.9 e	9.5 e
P1K0	67.7	27.7	3.0	67.0	64.1	13.5 d	10.1 d
P1K1	70.0	28.7	4.0	70.3	63.8	14.0 c	10.2 d
P1K2	72.3	31.3	4.0	98.7	73.3	14.6 c	10.8 c
P2K0	75.0	34.0	4.0	77.2	77.7	15.4 b	10.6 c
P2K1	77.7	36.0	4.3	81.0	84.4	16.2 a	11.3 b
P2K2	80.0	38.0	5.0	83.9	101.4	16.8 a	12.9 a
Significance at 0.05 level	ns	ns	ns	ns	ns	*	*

Values followed by the same letters within a column are not significantly different at the 0.05 level of probability according to Duncan's multiple range test. P0K0: without treatment, P0K1: potassium (1 cm), P0K2: potassium (2 cm), P1K0: phosphorin (1 kg), P1K1: phosphorin (1 kg) + potassium (1 cm), P1K2: phosphorin (1 kg) + potassium (2 cm), P2K0: phosphorin (2 kg), P2K1: phosphorin (2 kg) + potassium (1 cm) and P2K2: phosphorin (2 kg) + potassium (2 cm).

Moreover, it was found that depending on the nutrient supply, the interaction can modify plant growth and yield. Shrivastava *et al.* [28] explained the role of solubilization of mineral P is possible due to organic acid production which contribute to lowering the pH in rhizosphere, chelation of the cations taking part in precipitation of P, forming soluble complexes with metal ions from insoluble P compounds (Ca-P, Al-P, Fe-P) and to competing with P for sorption sites on the soil. Interactions can be assessed by examining the relationship between nutrient supply and nutrient concentrations in plants and by examining the relationship between nutrient supply and plant growth [29]. The obtained results on the interaction between P and K are in harmony with those obtained by Abd El-Lateef [30] who reported beneficial effects of the interaction between (P×N) and (P×K) on mungbean growth.

Pod Yield and its Components

Effect of Phosphorin Treatment: The effect of phosphorin on broad bean yield is presented in Table (5). It was observed that number of pods plant^{-1}, pod length, pod width, pod weight number of seeds pod^{-1}, fresh weight of 100-seeds as well as total fresh pod yield fed^{-1} were significantly affected by phosphorin treatments in 2018/19 and 2019/20 seasons.

The improvement of yield and quality of vegetable crops in response to adding bio-phosphorus fertilizer was reported by several investigators [11, 12]. It also found that phosphate solubilizing bacteria (PSB) inoculation significantly increased broad bean seed yield [13, 24].

Effect of Potassium Foliar Treatment: Concerning broad bean yield characters, it was observed in Table (6) that potassium foliar treatments significantly affected number of pods plant^{-1}, pod length, pod width, pod weight plant^{-1}, number of seeds pod^{-1} as well as fresh weight of 100 seeds and total fresh pod yield in both seasons of study. Spraying broad bean plants with potassium citrate at 2 cm l^{-1} exhibited exhibited the highest values in all studied yield characters compared with other treatments in both seasons.

Effect of Interaction Between Phosphorin and Potassium Application: Significant effects due to the interaction between phosphorin and potassium citrate (Table 7) were reported on number of seeds pod^{-1}, fresh weight of 100 seeds and total fresh pod yield fed^{-1} in the 1st season. In the 2nd season, pod width, pod weight and number of seeds pod^{-1} were only significantly affected.

The data also show that the positive response resulted from the interaction between phosphorin and K was attained when broad bean plants treated with phosphorin at 2 kg fed^{-1} before sowing and sprayed with potassium citrate at 2 cm l^{-1}. These results emphasize the beneficial effect of the solubilizing P through phosphate dissolving bacteria on yield characteristics of broad bean.

Chemical Constituents

Effect Phosphorin Application: Data presented in Table (8) and Fig. 1 show highly significant effects on chlorophyll content in leaves and N, P and K as well as protein and carbohydrates contents in green seeds in both seasons of study. Generally, application of phosphorin at 2 kg fed^{-1} significantly surpassed either application of 1 kg fed^{-1} or the control treatment for chlorophyll content and other chemical constituents. Ahmed *et al*. [31] mentioned that co-inoculation of bacterial strains also increased plant growth and nutritional status of mungbean and maize crops. It increased nitrogen (N) concentration up to 142 and 18%, phosphorus (P) concentration up to 90 and 43% and potassium (K) concentration up to 71 and 44%, in shoots of mungbean and maize crops, respectively.

Effect of Potassium Foliar Application: Table (9) and Fig. 2 show highly significant effect due to foliar applied K on chlorophyll content in leaves, N, K, protein% and carbohydrates% in green seeds of broad bean in both seasons of the study. No significant difference was reported between the two rates of foliar applied K on N, P and protein contents in broad bean green seeds in the 1st season and total chlorophyll, P and K in the 2nd season.

The improvement in chemical constituents of broad bean due to foliar applied K was attributed to the role of K in protein synthesis, nutrients translocation, anti-oxidant enzymes [18]. Deficiency of this element in the initial growth stage significantly disturbs the distribution of assimilates between above-ground organs and roots [32].

Effect of Interaction Between Phosphorin and Potassium Application: Data presented in Table (10) show that there was no significant effect on chemical constituents of leaves and green seeds of broad bean due to the interaction between phosphorin and foliar applied K, except carbohydrate % in seeds in both seasons of the study. In general application of 2 kg fed^{-1} phosphorin and foliar applied K at the highest rate resulted in improving N, P, K, crude protein content and carbohydrate content

Table 5: Effect of phosphorin application on broad bean yield characteristics

Phosphorin rates	No. of pods plant^{-1}	Pod length (cm)	Pod width (cm)	Pod weight (g)	No. of seeds pod^{-1}	Fresh weight of 100 seeds (g)	Total fresh pod yield fed $^{-1}$
				2018/19 Season			
0 kg	5.1 c	14.4 c	2.0 c	19.5 c	3.8 c	130.1 c	1.8 c
1 kg	7.2 b	19.2 b	2.5 b	21.8 b	4.9 b	141.2 b	2.1 b
2 kg	9.4 a	22.7 a	3.0 a	24.5 a	5.8 a	150.8 a	2.7 a
Significance at 0.05 level	**	**	**	**	**	**	**
				2019/20 Season			
0 kg	5.0 c	12.7 c	2.1 c	12.6 c	3.6 c	122.0 c	2.0 c
1 kg	6.8 b	16.4 b	2.4 b	17.8 b	4.9 b	134.9 b	2.4 b
2 kg	8.9 a	21.3 a	2.9 a	23.7 a	5.7 a	144.3 a	3.0 a
Significance at 0.05 level	**	**	**	**	**	**	**

Values followed by the same letters within a column are not significantly different at the 0.05 level of probability according to Duncan's multiple range test.

Table 6: Effect of potassium citrate application on broad bean growth characteristics

Potassium citrate rates	No. of pods plant^{-1}	Pod length (cm)	Pod width (cm)	Pod weight plant^{-1} (g)	No. of seeds pod^{-1}	Fresh weight of 100 seeds (g)	Total fresh pod yield fed $^{-1}$
				2018/19 Season			
0 cm	6.4 c	17.3 c	2.3 c	20.6 b	4.5 c	135.7 c	2.0 b
1 cm	7.2 b	18.6 b	2.4 b	22.5 b	4.9 b	141.3 b	2.2 b
2 cm	8.1 a	20.4 a	2.6 a	27.3 a	5.2 a	145.0 a	2.8 a
Significance at 0.05 level	**	**	**	*	**	**	*
				2019/20 Season			
0 cm	6.2 c	15.5 c	2.2 c	16.7 c	4.4 c	129.8 c	2.2 b
1 cm	6.9 b	16.8 b	2.4 b	18.0 b	4.7 b	133.4 b	2.4 b
2 cm	7.6 a	18.1 a	2.6 a	19.5 a	5.1 a	138.1 a	3.8 a
Significance at 0.05 level	**	**	**	**	**	**	*

Values followed by the same letters within a column are not significantly different at the 0.05 level of probability according to Duncan's multiple range test

Table 7: Effect of interaction between phosphorin and potassium application on broad bean yield characteristics

Treatment	No. of pod plant^{-1}	Pod length (cm)	Pod width (cm)	Pod weight plant^{-1} (g)	No. of seeds pod^{-1}	Fresh weight of 100 seeds (g)	Total fresh pod yield fed $^{-1}$
				2018/19 Season			
P0K0	4.3	12.7	3.7	13.4	3.2 h	121.5 g	1.7 f
P0K1	5.0	13.7	4.0	15.0	3.9 g	133.6 f	1.8 e
P0K2	6.0	16.8	4.3	17.6	4.2 f	135.5 e	1.8 e
P1K0	6.3	17.3	4.6	18.8	4.6 e	140.3 d	1.9 de
P1K1	7.3	19.7	5.0	21.6	4.9 d	141.5 d	2.0 d
P1K2	8.0	20.7	5.3	23.0	5.3 c	141.8 d	2.3 c
P2K0	8.7	21.9	5.7	23.7	5.6 b	145.4 c	2.4 c
P2K1	9.3	22.5	5.9	25.2	5.8 b	149.0 b	2.6 b
P2K2	10.3	23.6	6.2	26.9	6.1 a	158.0 a	3.2 a
Significance at 0.05 level	ns	ns	ns	ns	*	**	**
				2019/20 Season			
P0K0	4.3	12.0	3.4 g	11.5 i	3.2 h	117.3	1.7
P0K1	5.0	12.8	3.7 f	12.4 h	3.5 g	121.0	1.9
P0K2	5.7	13.5	4.1 e	13.7 g	4.2 f	127.6	5.3
P1K0	6.0	14.8	4.3 e	15.7 f	4.5 e	131.2	2.2
P1K1	6.7	16.0	4.8 d	17.7 e	4.9 d	135.5	2.5
P1K2	7.7	18.2	5.3 c	20.0 d	5.2 c	138.2	2.7
P2K0	8.3	19.8	5.6 b	22.7 c	5.5 b	140.9	2.7
P2K1	9.0	21.5	5.9 a	23.8 b	5.8 a	143.8	2.9
P2K2	9.3	22.6	6.1 a	24.7 a	6.0 a	148.4	3.3
Significance at 0.05 level	ns	ns	*	*	*	ns	ns

Values followed by the same letters within a column are not significantly different at the 0.05 level of probability according to Duncan's multiple range test. P0K0: without treatment, P0K1: potassium (1 cm), P0K2: potassium (2 cm), P1K0: phosphorin (1 kg), P1K1: phosphorin (1 kg) + potassium (1 cm), P1K2: phosphorin (1 kg) + potassium (2 cm), P2K0: phosphorin (2 kg), P2K1: phosphorin (2 kg) + potassium (1 cm) and P2K2: phosphorin (2 kg) + potassium (2 cm).

Table 8: Effect phosphorin application on broad bean chlorophyll content and chemical constituents in green seeds

Phosphorin rates	Total Chl. (mg/g FW)	N%	P%	K%	Protein%	Carbohydrates%
			2018/19			
0 kg	1.21 c	4.11 c	0.29 c	3.97 c	25.72 c	56.57 c
1 kg	1.41 b	4.27 b	0.31 b	4.12 b	26.68 b	57.65 b
2 kg	1.64 a	4.38 a	0.33 a	4.26 a	27.39 a	58.78 a
Significance at 0.05 level	**	**	**	**	**	**
			2019/20			
0 kg	1.28 c	4.15 c	0.30 c	4.00 c	25.93 c	56.84 c
1 kg	1.46 b	4.29 b	0.32 b	4.15 b	26.85 b	57.83 b
2 kg	1.58 a	4.44 a	0.34 a	4.28 a	27.75 a	58.93 a
Significance at 0.05 level	**	**	*	**	**	**

Values followed by the same letters within a column are not significantly different at the 0.05 level of probability according to Duncan's multiple range test.

Table 9: Effect of potassium application on leaves content of chlorophyll and chemical constituents in green seeds of broad bean.

Potassium citrate rates	Total Chl. (mg/g FW)	N%	P%	K%	Protein%	Carbohydrates%
			2018/19 Season			
0 cm	1.30 c	4.16 b	0.30 a	4.07 c	25.90 b	57.18 c
1 cm	1.38 b	4.26 a	0.31 a	4.12 b	26.62 a	57.66 b
2 cm	1.45 a	4.30 a	0.32 a	4.16 a	26.88 a	58.15 a
Significance at 0.05 level	**	*	ns	**	**	**
			2019/20 Season			
0 cm	1.39 b	4.25 c	0.31 a	4.10 b	26.56 b	57.40 c
1 cm	1.45 a	4.29 b	0.32 a	4.15 a	26.85 b	57.86 b
2 cm	1.48 a	4.34 a	0.33 a	4.17 a	27.12 a	58.35 a
Significance at 0.05 level	*	*	ns	*	*	**

Values followed by the same letters within a column are not significantly different at the 0.05 level of probability according to Duncan's multiple range test

Table 10: Effect of Interaction between phosphorin and potassium application on leaves content of chlorophyll and chemical constituents in green seed

Treatment	Total Chl. (mg/g FW)	N %	P %	K %	Protein%	Carbohydrates%
			2018/19 Season			
P0K0	1.10	4.00	0.29	3.90	25.00	56.03 f
P0K1	1.20	4.10	0.30	3.95	25.63	56.33 e
P0K2	1.30	4.15	0.30	4.00	25.94	56.57 e
P1K0	1.35	4.20	0.30	4.05	26.25	57.00 d
P1K1	1.40	4.25	0.31	4.10	26.56	57.60 c
P1K2	1.45	4.28	0.32	4.15	26.75	57.82 c
P2K0	1.50	4.30	0.32	4.20	26.88	57.90 c
P2K1	1.55	4.32	0.33	4.25	27.00	58.50 b
P2K2	1.60	4.36	0.33	4.30	27.25	59.50 a
Significance at 0.05 level	ns	ns	ns	ns	ns	**
			2019/20 Season			
P0K0	1.20	4.1	0.3	4.0	25.6	56.5 g
P0K1	1.30	4.2	0.3	4.0	25.9	57.0 f
P0K2	1.35	4.2	0.3	4.1	26.3	57.1 e
P1K0	1.43	4.3	0.3	4.1	26.6	57.2 e
P1K1	1.45	4.3	0.3	4.2	26.9	57.9 d
P1K2	1.51	4.3	0.3	4.2	27.1	58.4 c
P2K0	1.55	4.4	0.3	4.3	27.5	58.5 c
P2K1	1.60	4.4	0.3	4.3	27.8	58.7 b
P2K2	1.61	4.5	0.3	4.3	28.0	59.6 a
Significance at 0.05 level	ns	ns	ns	ns	ns	*

Values followed by the same letters within a column are not significantly different at the 0.05 level of probability according to Duncan's multiple range test.
P0K0: without treatment, P0K1: potassium (1cm), P0K2: potassium (2 cm), P1K0: phosphorin (1 kg), P1K1: phosphorin (1 kg) + potassium (1 cm), P1K2: phosphorin (1 kg) + potassium (2 cm), P2K0: phosphorin (2 kg), P2K1: phosphorin (2 kg) + potassium (1 cm) and P2K2: phosphorin (2 kg) + potassium (2 cm).

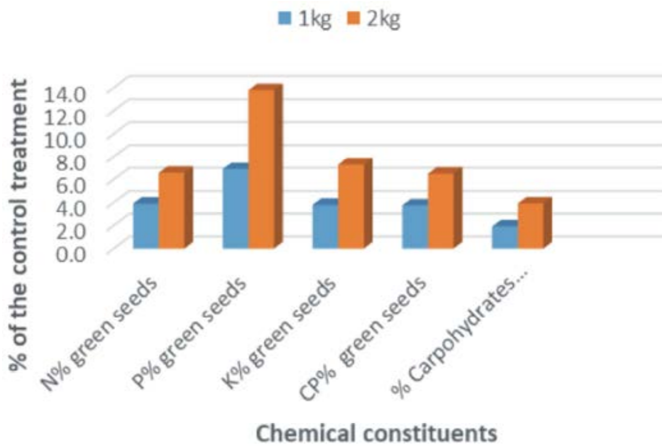

Fig. 1: Effect phosphorin application on broad bean chlorophyll content and chemical constituents increase over the control treatment in green seeds (Mean of two seasons)

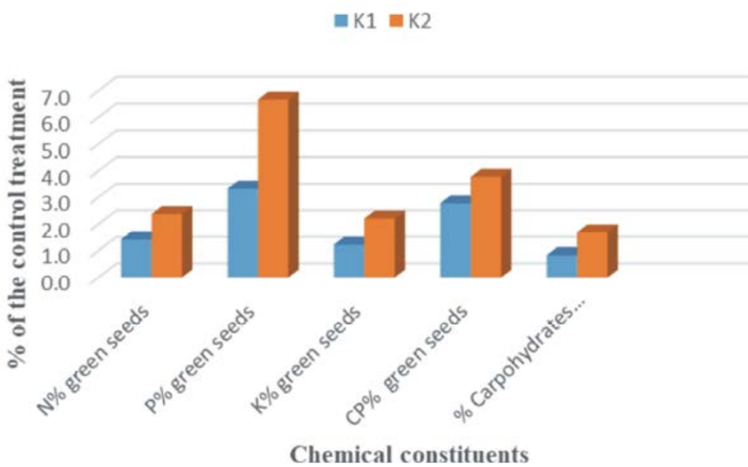

Fig. 2: Effect of potassium application on broad bean chemical constituents increase over the control treatment in green seeds (Mean of two seasons)

in green seeds which in turn reflected on the nutritional value of green pods of broad bean. Although it is evident that either phosphorin or K alone improved broad bean chemical constituents but the interaction between them is insignificant in most components which match to these elements act independently from each other.

CONCLUSION

It could be concluded from this study that vegetable broad bean treated with low inputs of phosphate dissolving bacteria combined with potassium citrate (38%) via leaves are effective tools in improving growth, yield characters and increasing productivity of green pods for human consumption with high nutritive value .

REFERENCES

1. El-Habbasha, S.F., M. Hozayn and M.A. Khalafallah, 2007. Integration effect between phosphorus levels and bio-fertilizers on quality and quantity yield of faba bean (*Vicia faba* L.) in Newly Cultivated Sandy Soils. Research Journal of Agriculture and Biological Sciences, 3(6): 966-971.
2. Singh, A.K., R.C. Bharati, N.C. Manibhushan and A. Pedpati, 2013. An assessment of faba bean (*Vicia faba* L.) current status and future prospect. Afr. J. Agric. Res., 8: 6634-6641.
3. Hossain, M.S. and M.G. Mortuza, 2006. Chemical composition of Kalimatar, a locally grown strain of faba bean (*Vicia faba* L.). Pak. J. Biol. Sci., 9: 1817-1822.

4. Turco, I., G. Ferretti and T. Bacchetti, 2016. Review of the health benefits of faba bean (*Vicia faba* L.) polyphenols. J. Food Nutr. Res., 55: 283-293.
5. Karkanis, A., G. Ntatsi, L. Lepse, J.A. Fernández, I.M. Vagen, B. Rewald, I. Alsin, A. Kronberga, A. Balliu, M. Olle, G. Bodner, L. Dubova, E. Rosa and D. Savvas, 2018. Faba bean Cultivation – Revealing Novel Managing Practices for More Sustainable and Competitive European Cropping Systems. Front. Plant Sci., 9: 1-14.
6. Duc, G., 1997. Faba bean (*Vicia faba* L.). Field crops Res., 53: 99-109.
7. Haciseferogullari, H., I. Gezer, Y. Bahtiyarca and H.O. Menges, 2003. Determination of some chemical and physical properties of sakis faba bean (*Vicia faba* L. var. major). J. Food Eng., 60: 475-479.
8. Khatab, A.Kh., 2016. Improving growth, yield and nutrient uptake on faba bean (*Vicia faba* L.) by inoculation with mycorrhizay and foliar application of cobalt under saline irrigation water on a calcareous soil. J. Soil Sci. and Agric. Eng., Mansoura Univ., 7(3): 249-258.
9. Bakry, B.A., T.A. Elewa, M.F. El-Karamany, M.S. Zeidan and M.M. Tawfik, 2011. Effect of row spacing on yield and its components of some faba bean varieties under newly reclaimed sandy soil condition. World J. Agric. Sci., 7(1): 68-72.
10. Abd El-Salam, I.Z., M.M. Arafa and O.E. Shalaby, 2005. Effect of rock phosphate and rare earth minerals on growth, yield, chemical constituents and active ingredients of hot pepper (*Capsicum annuum* L.) under new reclaimed soils conditions. Egypt. J. Appl. Sci., 20(12): 285-310.
11. Brahma, S. and D.B. Phookan, 2006. Effect of nitrogen, phosphorus and potassium on yield and economics of broccoli cv. Pusa Broccoli KTS 1. Research on Crops, 7(1): 261-262.
12. Islam, M.H., M.R. Shaheb, S. Rahman, B. Ahmed, A.T.M.T. Islamand and P.C. Sarker, 2010. Curd yield and profitability of broccoli as affected by phosphorus and potassium. Int. J. Sustain. Crop Prod., 5(2): 1-7.
13. Demissie, S., D. Muleta and G. Berecha, 2013. Effect of phosphate solubilizing bacteria on seed germination and seedling growth of faba bean (*Vicia faba* L.). Int. J. Agric. Res., 8(3): 123-136.
14. Rakha, M. and M.E. El-Said, 2013. Growth and yield of faba bean (*Vicia faba* L.) as affected by chemical and/or natural phosphorus with different biofertilizer. J. Plant Production, Mansoura Univ., 4(12): 1857-1869.
15. Abd-Alla, M.H., 1994. Use of organic phosphorus by *Rhizobium leguminosarum* biovar *viceae* phosphatases. Biology and Fertility of Soils, 18(3): 216-218.
16. Zheng, B.X., X.L. Hao, K. Ding, G.W. Zhou, Q.L. Chen, J.B. Zhang and Y.G. Zhu, 2017. Long-term nitrogen fertilization decreased the abundance of inorganic phosphate solubilizing bacteria in an alkaline soil. Scientific Reports, 7: 42284.
17. Marschner, P., 2012. Marschner's Mineral Nutrition of Higher Plants, 3rd ed.; Academic Press: London, UK, pp: 178-189.
18. Chen, Y., C. Clapp and H. Magen, 2004. Mechanism of plant growth stimulation by humic substances: The role of oregano-iron complexes. Soil Sci. Plant Nutr., 50: 1089-1095.
19. Marschner, H., 1995. Functions of mineral nutrients: micronutrients. In: Mineral Nutrition of Higher Plants. 2nd Ed., Academic Press, London, pp: 313-404.
20. Shafeek, M.R., A.R. Mahmoud, A.H. Ali, Y.I. Helmy and N.M. Omar, 2017. The Potential of different levels of compost manure and usage of potassium foliar spraying on growth, yield and seed chemical build of broad bean plant. Middle East J. Appl. Sci., 7(4): 703-712.
21. Von Wettstein, D., 1957. Chlorophyll lethals and submicroscopic morphological changes in plastids. Exp Cell Res., 12(3): 427-506.
22. AOAC, 2000. Association of Official Analytical Chemists, 17th ed. of A.O.A.C. international published by A.O.A.C. international Maryland, U.S.A., pp: 1250.23.
23. MSTAT-C, 1988. MSTAT-C, a microcomputer program for the design, arrangement and analysis of agronomic research. Michigan State University, East Lansing.
24. El-Wakeil, N.E. and T.N. El-Sebai, 2007. Role of biofertilizer on faba bean growth, yield and its effect on bean aphid and the associated predators. Res. J. Agric. Biol. Sci., 3(6): 800-807.
25. Akl, B.A. and M.K. Abdel-Fattah, 2019. Impact of some specific phosphorus solubilizing microorganisms and different phosphorus fertilizers on nutrients content and yield of faba bean (*Vicia faba* L.) in sandy soil. J. Soil Sci. and Agric. Eng., Mansoura Univ., 10(10): 559-566.

26. Abd-Alla, M.H., A.W.E. El-Enany, N.A. Nafady, D.M. Khalaf and F.M. Morsy, 2014. Synergistic interaction of *Rhizobium leguminosarum* bv. *viciae* and arbuscular mycorrhizal fungi as a plant growth promoting biofertilizers for faba bean (*Vicia faba* L.) in alkaline soil. Microbiol. Res., 169(1): 49-58.
27. Cakmak, I., 2005. The role of potassium in alleviating detrimental effects of abiotic stresses in plants. J. Plant Nutr. Soil Sci., 168: 521-530.
28. Pettigrew, W.W., 2008. Potassium influences on yield and quality production for maize, wheat, soybean and cotton. Physiol. Plant, 133: 670-681.
29. Robson, A.D. and M.G. Pitman, 1983. Interactions between nutrients in higher plants. In Inorganic plant nutrition, eds. A. Laeuchli and R.L. Bieleski, 147-180. Berlin: Springer 31.
30. Abd El-Lateef, E.M., 1996. Mungbean (*Vigna radiata* (L.) Wilczek) yield response to foliar applied nitrogen and potassium under different levels of phosphatic fertilization. Proc 7th Conf Agron Mansoura Univ, 9-10 Sept, pp: 229-237.
31. Ahmad, M., Z. Adil1, A. Hussain, M.Z. Mumtaz, M. Nafees, I. Ahmad and M. Jamil, 2019. Potential of phosphate solubilizing *bacillus* strains for improving growth and nutrient uptake in mungbean and maize crops. Pak. J. Agri. Sci., 56(2): 283-289.
32. Marschner, H., E.A. Kirkby and J. Cakmak, 1996. Effect of mineral nutritional status on shoot-root partitioning of photo-assimilates and cycling of mineral nutrients. J. Exp. Bot., 47: 1255-1263.