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Exogenous potassium or yeast extract boosts Faba bean seed yield and quality by modulating its components in nutrient-deficient soil

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ABSTRACT

Arid and semi-arid environments, including Egypt, have poor soil fertility. However, very little information is known about the beneficial effect of soil applied-potassium (K) and foliar yeast extract (YE) under low-fertility soil conditions. A two-field trial (2017/18-2018/19) was conducted to evaluate the potential positive impacts of three K rates [0 as a control (K_0), 50 (K_{50}), and 75 (K_{75}) kg K_2O feddan^{-1} (feddan = 4200 m^2)] and three foliar spraying with YE concentrations [0 as a control (YE_0), 4 (YE_4), and 8 (YE_8) ml l^{-1}] on faba bean productivity. This experiment was laid out in a split-plot arrangement in which YE concentrations were randomized within K rates replicated thrice. Seed yield and its components, seed protein, and seed K content of faba bean were positively affected by the two studied factors. Higher rates of K_{75} or YE_8 had a considerable improvement in seed yield components, resulted in increases by 18.2 or 22.8% for seed yield, by 19.0 or 27.1% for biological yield, by 6.0 or 13.0% for seed protein, by 12.0 or 10.7% for seed K content, respectively, when compared to their respective controls (K_0 or YE_0). The best values of plant height (63.58 cm), branches number plant^{-1} (4.50), pods number plant^{-1}(9.30), seeds weight plant^{-1} (33.07 g), 100-seeds weight (109.23), biological yield (4.45 t feddan^{-1}), seed protein (27.98%), and seed K content (2.76 mg g^{-1}) were achieved when the $K_{75} \times YE_8$ was considered. Stepwise analysis revealed that harvest index, plant height plant^{-1}, branches number plant^{-1}, and seeds weight pant^{-1} were the most influential seed yield-affected attributes. It can be concluded that exogenous application of 75 kg K_2O and foliar spraying of YE with 8 ml l^{-1} as an eco-friendly bio-stimulant may be an effective practical practice for maximizing seed yield and quality grown on nutrient-deficiency soil under arid conditions.

Keywords: *Vicia faba* L., Nutrients management, Seed yield, Seed protein, Correlation and Stepwise regression.

1. INTRODUCTION

Faba bean (*Vicia faba* L.) is called many famous names such as field bean, fava bean, broad bean, and bell bean is a 'bean' have a main place to the family of *Fabaceae*, which is the third considerable angiosperm family, containing 19400 species and 740 genera (Lewis et al., 2005). It has a significant position in the conventional nourishment peoples of the Mediterranean basin, Indian, Chinese, English, Middle Eastern, African, and South American. It has great importance as minimal-expenditure nourishment riches in proteins and carbohydrates. Faba bean seeds are an excellent source of protein, fiber, and essential vitamins and minerals for human in world low-income zones (Duc, 1997). Based on dry matter, faba bean seeds are high enrichment in protein 24 - 35%, carbohydrates 51–68%, minerals like potassium (K), iron, calcium, and zinc.

In 2018, world production was 4.92 million tons from nearly 2.51 million hectares (FAOSTAT, 2018). China was the first producer with 0.86 million hectares (34% of the world) and 1.81 million tons (36.70% of world). Locally, the cultivated area was 0.40 million hectares which yielded about 0.139 million tons (FAOSTAT, 2018). The total production of faba seeds produced is still insufficient to meet local requirements. Therefore, there is an imperative request to bridge this gap by raising yield through different agronomic practices package including selecting high-yield cultivars and good nutrients management, particularly under abiotic stresses such as low-fertility soil.

Potassium as macro-nutrient, is required with relatively a large amount due to its vital role in carbohydrates metabolism and protein biosynthesis (Mekdad et al., 2021). Potassium element is uptake from the soil in K^+ form via plant root system. K^+ functions in plants are multifaceted as regulation of water relations, photosynthesis improvement, maintain cell pressure necessitate for cell enlargement, beneficial in nitrogen fixation, and translocation of photo-assimilates from source (leaves) to sink (seeds) to better withstand poor soil (Zamani et al., 2020).

Natural bio-stimulants are a viable sustainable strategy for boosting crop growth and productivity while also improving the plant's ability to withstand abiotic stressors (Hammad and Ali, 2014). Dry yeast (Saccharomyces cerevisiae) extract contains many enzymes that transform sugars into alcohol and CO_2, which is utilized in the plant photosynthetic process. Also, yeast extract (YE) contains many growth hormones (i.e., cytokinins, gibberellins, auxins) and B-group vitamins. These growth-boosting molecules have a stimulatory effect on cell division and expansion, biosynthesis of proteins, nucleic acid, and chlorophyll pigment (Taha et al., 2021).

Thus, the well management of phytonutrients during the plant life cycle can help to improve growth for crop plants gown under nutrients-deficient soil conditions. Therefore, the main objective of our study was to find out the impact of K-fertilization as a soil application or YE as a foliar application on faba bean seed yield and its components, seed protein percentage, and seed K content in the nutrients-deficient soils such Egyptian newly-reclaimed lands.

2. MATERIAL AND METHODS

During the winter seasons of 2017/18 and 2018/19, two field experiments were conducted at the Experimental Farm of Fayoum University's Faculty of Agriculture. The experimental soil (Southeast Fayoum; 29°17'N, 30°53'E) was loamy sand with organic matter 0.81 %, the electrical conductivity of 3.56 dS m^{-1}, and pH of 7.52, to investigate the effects of K soil fertilizer levels and foliar spray with YE application on faba bean yield, its components, and quality (*Vicia faba* L.). The experimental plot was 10.5 m^2 in size and consisted of five ridges that were each 3.5 m long and 60 cm apart. In the first and second seasons, faba bean plants were sown on October 15^{th} and October 15^{th}, respectively. The Nubaria-1 variety of faba bean was inoculated with certain rhizobium bacteria inoculants soon before sowing. Except for the parameters under research, which were placed in a split-plot in an RCBD design with three replicates, The K fertilizer rates were randomly designated for the main plots, concentrations of YE were randomly distributed in subplots. The standard agricultural techniques for cultivating faba bean were followed. The K fertilizer as potassium sulfate (48% K_2O) source was used in this study with rates [0 as a control (K_0), 50 (K_1), and 75 (K_2) kg K_2O feddan^{-1} (fed^{-1}= 4200 m^2)]. As a soil addition, the K fertilizer was top-dressed in two equal portions at sowing time and the 1^{st} irrigation. Also, the YE was foliage sprayed with three concentrations [0 as a control (YE_0), 4 (YE_4), and 8 (YE_8) ml l^{-1}] at 35, 50, and 65 days after sowing (DAS). The YE treatments were sprayed using a hand-operated compressed air sprayer with a rate of 200 L fed^{-1}. According to Spencer et al. (1983), the extract of dry bread yeast scientifically known as *Saccharomyces cerevisiae*, was freshly prepared using a technique that enables yeast cells (pure active dry yeast 100 g l^{-1}) to be grown and effectively multiplied during aerobic and nutritional conditions. These optimal conditions allow producing useful components such as total carbohydrates, soluble sugars, total proteins, amino acids, fatty acids, hormones, etc. These chemical components could be released from yeast cells in readily form by two freezing cycles. The preceding field crops were squash (*Cucurbita pepo* L.) and maize (*Zea mays* L.) in the first and second seasons, respectively. Physical

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and chemical analysis of soil at the experimental site (data pooled over 2017/18 and 2018/19 seasons) of study are obtained in Table (1).

The faba bean was manually harvested on April 25th and April 25th, respectively, in the first and second seasons. During harvest, a random sample of ten plants from each subplot was chosen to determine plant height (cm), branches no. plant^{-1}, pods no. plant^{-1}, seeds weight plant^{-1}, and 100-seeds weight (g). To calculate seed yield (t fed^{-1}), biological yield (t fed^{-1}), and harvest index, plants on the middle two ridges of each subplot were taken and dried.

Table 1. Some initial physio-chemical properties of the experimental soil (data pooled over 2017/18 and 2018/19 seasons).

Property	Value
Soil particles analysis	
Sand %	76.73
Silt %	12.01
Clay %	11.26
Texture class	loamy sand
pH in soil Extract (1:2.5)	7.47
ECe (dS m^{-1})	3.57
CEC (meq 100^{-1}g soil)	9.33
$CaCO_3$ (%)	6.63
Organic matter (%)	0.78
N (mg kg^{-1} soil)	
Exchangeable cations:	
Ca^{2+} (meq 100^{-1} g soil)	4.89
Mg^{2+} (meq 100^{-1} g soil)	2.85
Na^{+} (meq 100^{-1} g soil)	1.58
K^{+} (meq 100^{-1} g soil)	0.60
Available nutrients:	
P (meq 100^{-1} g soil)	3.94
K (meq 100^{-1} g soil)	0.92
Fe (meq 100^{-1} g soil)	2.21
Mn (meq 100^{-1} g soil)	2.80
Zn (meq 100^{-1} g soil)	0.81
Cu (meq 100^{-1} g soil)	0.47

For chemical analysis, 50 g seeds were ground into a fine powder and stored in brown glass bottles. A.O.A.C. (1995) outlined the procedures for determining N percent, and the seed protein percent was estimated by multiplying total nitrogen percent by 6.25. The total seed content of K was measured by flame photometry (Gallenkamp Co., London, U.K.) as defined by Lachica et al. (1973). All collected data were statistically analyzed according to the technique of analysis of variance for split-split plot design by "GEN STAT Version 12th 2009" computer software package (VSN International, Hemel Hempstead, UK). The differences among treatment means were compared by LSD test at ($p \leq 0.05$) Payne et al. (2009). Combined analysis for the two seasons of experimentation was done according to the homogeneity of experimental error variance (Bartlett, 1937).

3. RESULT AND DISCUSSION

Effect of potassium (K) soil fertilization rates application

Tables 2 and 3 showed that increasing K rates from 0 to 75 kg K_2O fed^{-1} had a highly significant ($p \leq 0.01$) effect on almost all studied faba bean attributes. Soil application rate of 75 kg K_2O fed^{-1} improved plant height, branches no. plant^{-1}, pods no. plant^{-1}, seeds weight plant^{-1}, 100-seeds weight, seed yield, biological yield, and harvest index by 5.1%, 12.0%, 12.8%, 22.2%, 4.1%, 18.2%, and 19.0%, respectively, compared to untreated control. Moreover, K application of 75 kg K_2O fed^{-1} improved seed protein percentage and seed K content by 6.02% and 12.03%, respectively, compared to control; however, harvest index significantly decreased. These findings are in consistent with those of Shaban et al. (2013), El Habbasha et al. (2014), Hussain et al. (2016), El-Said et al. (2019), Quddus et al. (2019), and Sekhar et al. (2020), they indicated K fertilization resulted in significant increases in growth, seed yield and its attributes, harvest index, seed protein, and seed k content of faba bean and other legume crops. These findings may be attributed to the beneficial effect of K on promoting plant growth and development by cell dividing and stretching, translocation, and accumulation of carbohydrates toward seeds, positively reflecting on seed yield production.

Table 2. Effect of three different potassium rates and three concentrations of foliar spray yeast extract on some faba bean yield components (data pooled over 2017/18 and 2018/19 seasons).

Treatment	Plant height (cm)	Branches no. plant^{-1}	Pods no. plant^{-1}	Seeds weight plant^{-1} (g)	100-seeds weight (g)
Potassium rates (K)					
0 kg fed^{-1} (K_0)	59.16	3.83	7.81	23.77	103.45
50 kg fed^{-1} (K_{50})	59.99	3.96	7.90	26.38	103.21
75 kg fed^{-1} (K_{75})	62.18	4.29	8.81	29.04	107.65
LSD 0.05	1.36**	0.14**	0.24**	0.41**	0.54**
Yeast extract (YE)					
0 ml l^{-1} (YE_0)	56.53	3.85	7.60	22.63	101.66
4 ml l^{-1} (YE_4)	60.78	4.03	8.21	27.60	106.12
8 ml l^{-1} (YE_8)	64.02	4.21	8.70	28.97	106.53
LSD 0.05	1.10**	0.07**	0.15**	0.46**	0.39**
K × YE					
K_0 × YE_0	53.22	3.53	7.32	21.55	101.00
K_0 × YE_4	59.88	3.97	7.87	24.88	102.82
K_0 × YE_8	64.38	4.00	8.23	24.89	106.53
K_{50} × YE_0	56.35	3.87	7.37	21.49	98.83
K_{50} × YE_4	59.52	3.90	7.77	28.70	106.98
K_{50} × YE_8	64.10	4.12	8.57	28.95	103.82
K_{75} × YE_0	60.02	4.15	8.12	24.85	105.15
K_{75} × YE_4	62.95	4.23	9.00	29.22	108.57
K_{75} × YE_8	63.58	4.50	9.30	33.07	109.23
LSD 0.05	1.95**	0.16**	0.30*	0.74**	0.73**
C.V. (%)	2.6	2.4	2.7	2.5	0.5

*$p \leq 0.05$; **$p \leq 0.01$, ns = non-significant, and C.V.= Coefficient of variability.

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Table 3. Effect of three different potassium rates and three concentrations of foliar spray yeast extract on harvest index, seed and biological yield, seed protein, seed K content (data pooled over 2017/18 and 2018/19 seasons).

Treatment	Harvest index (%)	Seed yield (t feddan^{-1})	Biological yield (t feddan^{-1})	Seed protein (%)	Seed K content (mg g^{-1} dry weight)
Potassium rates (K)					
0 kg fed^{-1} (K_0)	39.55	1.32	3.48	25.23	2.41
50 kg fed^{-1} (K_{50})	34.08	1.27	3.72	25.40	2.65
75 kg fed^{-1} (K_{75})	37.95	1.56	4.14	26.75	2.70
LSD $_{0.05}$	3.81*	0.14**	0.20**	0.54**	0.07**
Yeast extract (YE)					
0 ml l^{-1} (YE_0)	38.17	1.27	3.36	23.97	2.43
4 ml l^{-1} (YE_4)	36.82	1.32	3.71	26.34	2.63
8 ml l^{-1} (YE_8)	36.60	1.56	4.27	27.08	2.69
LSD $_{0.05}$	ns	0.14**	0.24**	0.34**	0.06**
K × YE					
$K_0 \times YE_0$	44.62	1.32	2.97	23.82	2.15
$K_0 \times YE_4$	42.44	1.27	3.11	25.50	2.51
$K_0 \times YE_8$	31.59	1.37	4.36	26.38	2.57
$K_{50} \times YE_0$	30.28	1.01	3.37	23.37	2.55
$K_{50} \times YE_4$	32.63	1.21	3.79	25.96	2.63
$K_{50} \times YE_8$	39.34	1.58	4.00	26.86	2.76
$K_{75} \times YE_0$	39.61	1.47	3.74	24.73	2.60
$K_{75} \times YE_4$	35.38	1.49	4.24	27.56	2.75
$K_{75} \times YE_8$	38.87	1.72	4.45	27.98	2.76
LSD $_{0.05}$	6.87**	ns	0.38*	0.68*	0.10**
C.V. (%)	16.8	15.1	9.2	1.9	3.3

$^{*}p \leq 0.05$; $^{**}p \leq 0.01$, ns = non-significant, and C.V.= Coefficient of variability.

Effect of foliar spraying with yeast extract (YE) concentrations

Tables 2 and 3 showed that foliar spray with YE noticeable affected on faba bean yield, yield components, and seed protein percent and seed K content. Except for harvest index, foliar spray with YE application of 8 ml l^{-1} considerably ($p \leq 0.05$) enhanced plant height, branches no. plant^{-1}, pods no. plant^{-1}, seeds weight plant^{-1}, 100-seeds weight, seed yield, and biological yield that were13.2%, 12.0%, 12.8%, 22.2%, 4.1%, 18.2%, and 19.0% higher than un-sprayed control treatment (0 ml l^{-1}). Further, seed protein percent and seed K content were 6.0% and 12.0%, respectively, higher than the control when the YE concentration of 8 ml l^{-1} was sprayed. Similar trend was noted in Abou EL-Yazied and Mady (2012), Dawood et al. (2013), Abo-El-Hamd et al. (2015), Khattab et al. (2015), El-Shafey et al. (2016), Sadak, (2016), Abdel- Rahman et al. (2020), and Huthily et al. (2020). The recovering of faba bean's growth and seed yield components by application of YE indicated that these growth regulators may involve mechanisms to attenuate the negative effects of nutrient-deficiency soil. This is potentially ascribed to the growth-related metabolites of YE dissolved substances

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such as protein, total soluble sugars, free amino acids, B-group vitamins, and mineral phytonutrients, which help faba bean plants to retrieve their growth and development under poor soil conditions.

Effect of K × YE interaction

Plant height, branches no. plant^{-1}, pods no. plant^{-1}, seeds weight plant^{-1},100-seeds weight, harvest index, biological yield, seed protein, and seed K content were significantly affected by K × YE interaction. All aforementioned characteristics were significantly enhanced except seed yield when K_{75} × YE_8 interaction was applied.

Table 4. Correlation coefficient (r), coefficient of determination (R²) and standard error of the estimates (SEE) for predicting seed yield (t fed^{-1}), data pooled over 2017/18 and 2018/19 seasons.

r	R^2	SEE	Sig.	Fitted equation
0.821	0.673	0.180	**	Seed yield = - 1.77 + 0.023 harvest index + 0.015 plant height plant^{-1} + 0.231 branches no. plant^{-1} + 0.017 seeds weight pant^{-1}

** $p \leq 0.01$.

Regression analysis

The analysis of stepwise regression was used to understand the extent of relationships between seed yield and its components i.e., branches and pods number, seed weight plant^{-1}, 100-seeds weight and harvest index were computed in Table 4. The results showed that there are four traits i.e., harvest index, plant height plant^{-1}, branches number plant^{-1} and seeds weight plant^{-1} over both seasons were a highly significantly contributed to variation ($R^2 = 0.673^{**}$) in seed yield.

4. CONCLUSION

Based on the obtained results, exogenous application of 75 kg K_2O and foliar spraying of YE with 8 ml l^{-1} as an eco-friendly bio-stimulant may be an effective practical practice for maximizing seed yield and quality grown on nutrient-deficiency soil under arid conditions.

Author Contributions

All authors contributed equally to this work.

Conflict of interest

The authors declare that they have no conflict of interest.

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Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Data and materials availability

All data associated with this study are present in the paper.

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