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Research article

Effect of phosphorus fertilization and humic acid on the growth, yield and nutritional status of pea plants grown in sandy soil

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Abstract

Two field experiments were carried out in consecutive winter season of 2022 and 2023 at the Research and Production Station of the National Research Centre at the Nubaria site in Beheira Governorate, Egypt, to determine the response of pea (*Pisum sativum* L.) to foliar application of humic acid and phosphorus fertilization on growth, yield parametres and nutrients content of pea plant. Phosphate fertilization rates (0, 36, 72 and 108 P_2O_5 kg ha^{-1}) were used as the main factor, while humic acid concentrations (0, 1000 and 2000 mg l^{-1}) were used as a second factor. The results showed significant growth and yield responses to phosphate fertilizer application and humic acid spraying. Increasing the application rate of humic acid at various concentrations and at the same time increasing the application rate of phosphorus fertilizer affected the growth and yield of pea in two consecutive growing seasons. The experimental treatment (humic acid at 2000 mgl^{-1} + 108 Kg P_2O_5 $ha^{-1}$of phosphorus fertilizer) was given the highest values for the pea growth and yield coordinates. Increasing the concentration of humic acid spraying led to a raise in the nitrogen, phosphorus, and potassium content of pea seeds. The research results summarize the importance of paying attention to phosphorus fertilization, and spraying plants with humic acid during plant growth can increase the effectiveness of phosphorus fertilization and its effect on pea plants growing on sandy soils.

Introduction

Pea (*Pisum sativum* L.) is one of the main winter crops grown in Egypt for domestic and export markets. Peas are highly nutritious, as they are rich in protein, carbohydrates, and some vitamins [1].

Phosphorus is one of the generality vital nutrients that has a significant leverage on the growth of all crops. Phosphorus is a major productivity-limiting nutrient in most regions of the world, with more than 30% of global agricultural production being limited by phosphorus availability [2]. Phosphorus can be a nuisance limitation for all legumes in nutrient-poor environments due to high phosphorus requirements during N_2 fixation [3]. Phosphorus is required for root growth and the formation of phosphoproteins and phospholipids [4]**.** Vikram and Hamzehzarghani [5] stated that phosphorus is the second major macronutrients for plants because it has an important role in plant metabolism. Application of phosphorus chemical fertilizers separately significant increased ash content, protein and carbohydrates of faba bean seeds, as observed by Rugheim *et al.* [6].

Humic acid is a polymeric substance derived from humic substances that has a higher molecular weight than fulvic acid and is often used as a complexing agent in foliar feeding to enhance the uptake of nutrient solutions by plants. Humic acids are primarily formed as a result of the biodegradation of organic plant materials, including lignin [7]. The use of humic acid leads to an increase in dry matter production, due to its role in enhancing auxin activity during the plant growth period [8]. Humic acid application is a wide spread compound used in agriculture development. It improves physical, chemical, fertility and biological properties of soils [9]. humic acid application increased yield of vegetables such as tomatoes, potatoes, onions, pepper, pea and other leafy vegetables [10]. Humic materials are the final product of decomposition of each organic matter in specific conditions by a special microorganism. Some of the characteristics of humic acid are: it improves soil structure; it contributes in rooting; it increases plant growth promoting bacteria in soil and finally reduces toxicity of fertilizers and extra nutrients in soil [11].

The aim of the study was to investigate the effects of applying different concentrations of humic acid and different proportions of phosphorus fertilizer on the growth, yield parametrers and nutritional status of pea grown in sandy soil over two consecutive seasons.

Material and methods

The study was carried out at the National Research Center Experimental Station in Beheira Governorate during the winter months of 2022 and 2023 to investigate the response of pea (*Pisum sativum* L.) plants to various rates of P fertilization and concentrations of humic acid. Table 1 shows some of the physical and chemical properties of the soil used in the experiments and t able 2 shows analysis of irrigation water using the standard procedures outlined by Cottenie *et al.* [12].

The field experiment was designed as a factorial experiment in a randomized complete block design with four replications. The first factor was the phosphorus fertilizer application rates (0, 36, 72 and 108 P_2O_5 kg ha^{-1}). The second factor was the foliar application of humic acid concentrations (0, 1000 and 2000 mg l^{-1}). Phosphorus treatments in the form of mono super phosphate (15 % P_2O_5) were added during soil preparation. Foliar applications of humic acid (85 %) were added at 30 days after sowing, and repeat the spray every two weeks once.

Table 1. Some physical and chemical properties of the test soil at the beginning of the experiment.

Soil properties		Values	
		First season	**Second season**
Particle size distribution (%)	Sand	93.32	94.0
	Silt	4.68	3.56
	Clay	2.00	2.44
	Texture	Sandy soil	Sandy soil
$CaCO_3$ (%)		2.21	2.24
pH (1:2.5 soil suspension)		8.21	8.20
EC (dS m^{-1})		1.98	1.80
Soluble cations (mmol L^{-1})	Ca^{++}	8.02	7.96
	Mg^{++}	2.88	3.16
	Na^{+}	5.95	5.20
	K^{+}	2.95	1.68
Soluble anions (mmol L^{-1})	CO_3^{--}	-	-
	HCO_3^{-}	1.52	1.52
	Cl^{-}	8.30	7.82
	SO_4^{--}	9.98	8.66
Available nutrients (mg kg^{-1})	N	24.2	26.5
	P	2.05	2.00
	K	68.6	59.5
	Fe	4.11	3.95
	Mn	0.97	1.01
	Zn	1.20	0.99

Table 2. Some chemical analyses of irrigation water.

pH	**EC dS m^{-1}**	**Soluble cation**				**Soluble anions**			
		meq. L^{-1}							
		Ca^{++}	**Mg^{++}**	**Na^{+}**	**K^{+}**	**CO_3^{--}**	**HCO_3^{-}**	**Cl^{-}**	**SO_4^{--}**
7.10	2.69	7.45	3.81	15.2	0.44	nd.	5.20	14.6	7.10

Measured parameters

Plant growth and plant productivity

A random sample of four plants was taken 75 days after planting to measure plant height, number of leaves per plant, and dry weight. All production indicators were recorded: pod length, number of seeds per pod, weight of 100 seed, pod yield per plant, seeds yield per plant and protein content were recorded also.

Nutritional status

Total nitrogen content was estimated by modified Kjeldahl's methods [13]. Phosphorus was determined calorimetrically by NH –Metavanidate method [13]. Potassium was flame-photometrically estimated [13].

Statistical analysis

All data were subjected to statistical analysis using Mstatc software. Different treatments were compared as described by Snedecor *et al.* [14].

Results and discussion

The results presented in table 3 showed the effects of increasing the application rate of different concentrations of humic acid and increasing rates of phosphorus fertilization on the characteristics growth of pea plants during two successive growing seasons. Increasing the concentration of humic acid from zero to 2000 mgl^{-1} with increasing the phosphorus fertilizer rate from zero to 108 Kg P_2O_5 ha^{-1}, led to significantly increased the growth parameters of pea. The experimental treatment (humic acid at 2000 mgl^{-1} + 108 Kg P_2O_5 ha^{-1}of phosphorus fertilizer) was given the highest values for the pea growth coordinates in two consecutive seasons. The experimental treatment (humic acid at 2000 mgl^{-1} + 108 Kg P_2O_5 ha^{-1} of phosphorus fertilizer) resulted in the highest values of pea growth coordinates for two consecutive seasons.

Phosphorus, an essential macronutrient, plays an important role in plant growth and development. However, the limited availability of phosphorus in the soil poses serious challenges to crop productivity [15]. Afifi *et al.*, [16] showed that foliar application of humic acid improves nutritional status and increases legumes growth and productivity. Fouda [17] reported that spraying the leaves with humic acid increased the dry weight of faba bean plants at different phosphorus fertilization levels.

The results (Table 4 and Figure 1) show the effect of spraying humic acid at concentrations from 0 to 2000 mgl^{-1} overlapping with different rates of phosphorus fertilization (0 to 108 Kg P_2O_5 ha^{-1}) on the pea yield parameters during two successive growing seasons. As a result of increasing the amount of phosphorus fertilizer applied and enhancing the humic acid spraying effect, the growth effect and growth characteristics improved, and in particular, the growth index and growth characteristics improved significantly, especially with highest concentrations of humic acid and a highest rate of phosphorus fertilizer, this improved effect of the experimental treatments continued to have an effect on the yield and its various characteristics, during two successive growing seasons. It was noted that with increasing the concentration of humic acid spraying up to 2000 mg l^{-1}, it led to an increase in the efficiency of using phosphorous fertilizer, because the third rate of phosphorus fertilization (78 kg P_2O_5 ha^{-1}) gave the best values for the yield and its characteristics, with what was obtained for the yield p values when adding the higher rate of phosphorus fertilizer (108 kg P_2O_5 ha^{-1}), with a high spraying concentration of humic acid. Mesut *et al.*, [18] indicated that phosphate fertilization and humic acids enhanced the yield parameters of pepper plants grown under saline conditions.

Table 3. Effect of P fertilization and humic acid on pea growth at two season's growth (2022-2023).

P fertilization Kg P_2O_5 ha^{-1}	Humic acid mgl^{-1}	Plant height cm	No. of leaves plant^{-1}	Dry weight plant^{-1} g	Plant height cm	No. of leaves plant^{-1}	Dry weight plant^{-1} g
		2022			2023		
0	0	21.2	0.107	17.9	21.4	10.5	17.6
	1000	30.5	0.119	19.8	30.6	11.7	19.5
	2000	35.6	0.145	0.208	34.9	14.3	20.4
36	0	24.6	0.113	18.6	24.4	11.2	18.5
	1000	32.3	0.134	0.254	32.3	13.6	25.1
	2000	39.1	0.178	0.282	38.8	16.9	28.0
72	0	26.4	0.122	0.221	26.4	12.0	22.3
	1000	0.373	0.143	0.321	37.0	14.1	31.0
	2000	41.4	0.191	0.356	41.2	18.8	34.5
108	0	28.3	0.126	0.225	28.5	12.4	22.4
	1000	38.0	0.145	0.320	37.9	14.3	31.9
	2000	43.2	0.192	0.361	42.1	19.0	36.0
$LSD_{0.05}$		2.42	0.051	0.051	2.39	0.50	0.66

Forgac and Czimbalmos [19] reported that using of 1 g^{-1} humic acids increased yield components of pea plants. Phosphorus is the main component of ATP, which provides the "energy" to carry out processes such as photosynthesis and protein synthesis [20]. Gad El-Hak *et al.*, [21] indicated that application humic acid at of 2 gl^{-1} improves and increases the yield of pea plants grown in clay soil.

Nutrients content of pea seeds was improved as a result of spraying humic acid combined with addition of phosphorus fertilization, as shown in table 5. Increasing the application concentration of humic acid increased the content of nitrogen, phosphorus, and potassium in pea seeds along with increased phosphate fertilization rates during two consecutive growing seasons.

It has been established that foliar application of humic acids to plants improves the chemical composition of cowpea plant [22]. Ahmed and El-Abagy [23] found that the increase in the application of phosphorus fertilizers to bean plants led to an increase in the leaves content of nitrogen, phosphorus and potassium.

Conclusion

Attention must be paid to fertilizing pea plants grown in sandy soil with phosphorus because of its great importance in the stages of plant growth and for giving an abundant yield, as well as the importance of using humic acid, as it enhances the role of phosphorus fertilizer and also because of its importance in obtaining growth and high yield for pea plants grown in sandy soil.

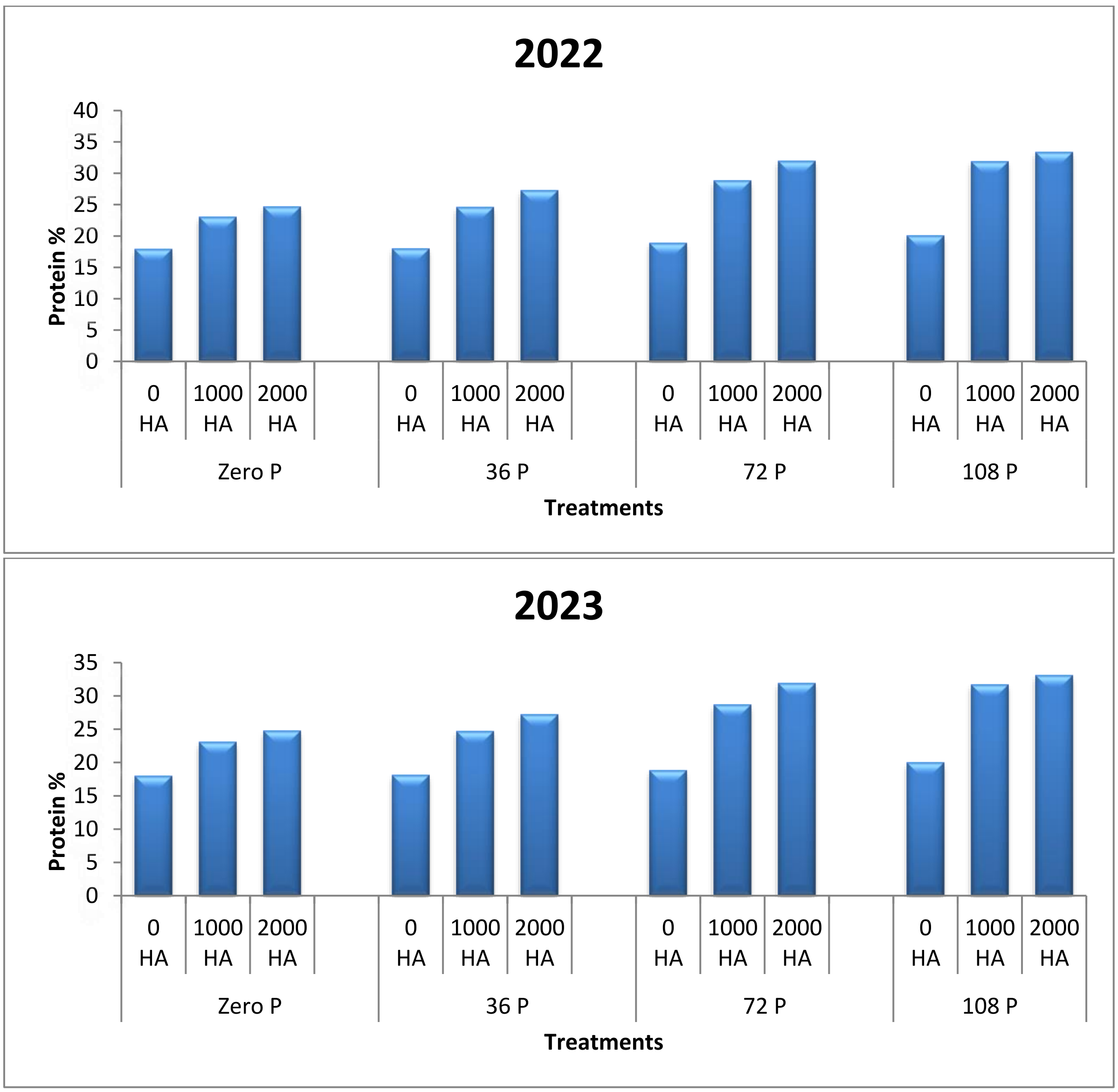

Figure 1. Effect of P fertilization (P) and humic acid (HA) on protein content at two season's growth (2022-2023).

Table 4. Effect of P fertilization and humic acid on pea yield at two season's growth (2022-2023).

P fertilization Kg P_2O_5 ha^{-1}	Humic acid mgl^{-1}	Pod length cm	No. of seeds pod^{-1}	Weight of 100 seeds g	Pod yield ton ha^{-1}
	2022				
0	0	4.89	5.44	18.0	4.25
	1000	5.44	6.89	21.2	5.06
	2000	6.78	7.10	23.0	5.35
36	0	5.56	6.11	19.0	4.68
	1000	6.22	7.29	23.4	5.45
	2000	8.00	7.68	25.6	6.12
72	0	6.63	6.55	20.2	5.11
	1000	7.82	7.54	27.4	6.24
	2000	8.92	7.82	27.6	6.89
108	0	7.01	6.77	20.6	5.33
	1000	8.66	7.69	27.6	6.46
	2000	9.56	8.00	28.0	6.91
$LSD_{0.05}$		0.76	0.33	0.26	0.20
2023					
0	0	4.88	5.39	17.9	4.32
	1000	5.39	6.88	21.0	5.11
	2000	6.74	7.11	22.9	5.52
36	0	5.53	6.08	19.1	4.78
	1000	6.20	7.28	23.5	5.52
	2000	8.01	7.69	25.5	6.24
72	0	6.61	6.54	20.3	5.14
	1000	7.80	7.53	27.6	6.22
	2000	8.91	7.81	27.8	6.89
108	0	7.00	6.72	20.5	5.38
	1000	8.59	7.68	26.8	6.43
	2000	9.49	8.01	27.9	6.89
$LSD_{0.05}$		0.75	0.35	0.30	0.25

Table 5. Effect of P fertilization and humic acid on N, P and K content on pea seeds at two season's growth (2022-2023).

P fertilization Kg P_2O_5 ha^{-1}	Humic acid mgl^{-1}	N	P	K	N	P	K
		%			%		
		2022			2023		
0	0	3.00	0.10	0.91	3.01	0.11	0.92
	1000	3.29	0.18	0.98	3.30	0.18	0.97
	2000	3.56	0.19	1.03	3.57	0.19	1.04
36	0	3.07	0.19	0.96	3.08	0.19	0.96
	1000	3.46	0.23	1.08	3.47	0.24	1.08
	2000	3.88	0.25	1.16	3.90	0.26	1.17
72	0	3.12	0.22	1.00	3.11	0.23	1.01
	1000	4.01	0.28	1.17	4.02	0.28	1.18
	2000	4.36	0.31	1.31	4.40	0.30	1.32
108	0	3.20	0.27	1.03	3.21	0.28	1.04
	1000	4.55	0.32	1.20	4.56	0.33	1.21
	2000	4.76	0.34	1.67	4.77	0.35	1.68
$LSD_{0.05}$		0.37	0.02	0.05	0.40	0.02	0.05

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Competing interests

The authors declare no competing interests.

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Ethics approval and consent to participate

As this study does not involve animal and patient experiments, the ethical approval and consent to participate are not applicable.

Data availability

All data generated or analyzed during this study are included in this published article.

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