Effect of potassium humate, phosphorus and copper on onionquantitative and qualitative yield

ABSTRACT

Previous research has been limited regarding the combined impacts of copper and potassium humate under various phosphorus fertilization levels on onion crops. So, a field trials were performed during two successive winter seasons of 2021-2022 and 2022-2023 aiming to evaluate three levels of calcium superphosphate (representing 100%, 75% and 50% of the phosphorus recommended dose) as main plot treatments, along with three levels of potassium humate soil addition (0.0%, 1.0% and 2.0%) as sub-plot treatments. Additionally, foliar spraying of copper was carried out at three different rates (0.0%, 0.1% and 0.2%) as sub-subplot treatments. These factors were examined individually or in combination to assess their impact on onion performance, quantitative yield, and qualitative attributes. Firstly, in terms of the individual effect of phosphorus recommended dose (PRD), the application of 100% of PRD demonstrated superior impacts on onion growth performance, quantitative and qualitative yield compared to 75% and 50% of PRD, respectively.Secondly, focusing on the individual effect of soil addition of potassium humate, all parameters related to growth performance, quantitative and qualitative yield, such as bulb weight and diameter, neck diameter, marketable bulb yield, total dissolved solids (TDS), total sugar (%), carbohydrates, and crude protein, exhibited an increase with higher rates of added potassium humate.Thirdly, the values of all parameters studied increased as the rate of copper application increased, indicating a positive correlation between copper application and onion crop performance.Lastly, the combined treatment of 100% of PRD with 2.0% potassium humate and 0.2% copper recorded the highest values across all measured parameters. Additionally, the combined treatment of 75% of PRD with potassium humate at rates of 1.0% or 2.0%, along with copper at rates of 0.1% and 0.2%, outperformed the individual application of 100% PRD in terms of the measured parameters.Therefore, it can be concluded that the combined addition of potassium humate (as soil addition) and Cu (as foliar application)

has a vital role in improving the quantitative and qualitative yield of the as well as raising the efficiency of phosphate fertilizers.

Keywords:Calcium superphosphate, Potassium humate, copperandonionplants.

INTRODUCTION

Phosphorus is one of the important macronutrients and its shortage limits higher plant growth **(Richardson *et al.,* 2009).** Plants can absorb P in two forms as $H_2PO_4^{-1}$ or HPO_4^{-2}, which are mostly present in very low concentrations in the soil. Even though phosphorus element is abundant in Egyptian soils in organic and inorganic forms, its availability is low. Also, the efficiency of the phosphatic fertilizers under most Egyptian soils is low due to the high pH values **(El-Agrodi *et al.,* 2011).** Although phosphorus is an essential element for crops, its uptake is greatly declined because of its fixation by mineral ions *e.g.,* calcium,where in most soil types, the activity of calcium element is high either in the soluble or exchangeable form (**Tirado and Allsopp, 2012**). This coupled with a high value of soil pH favours the precipitation of relatively insoluble dicalcium phosphate and other basic calcium phosphates like hydroxyapatite and carbonate apatite**(Bindraban *et al.,* 2020).** In other words, phosphorus is highly reactive with calcium, where a series of reactions occur between both calcium and phosphorus as a result,phosphorus solubility and availability to the plants reduce **(He *et al.,* 2021).**Thus, it can be said that Egyptian soils suffer from problems related to phosphatic fertilizers, where the added phosphorus turns from the available form into the unavailableone. Therefore, large percentage of P from phosphate fertilizers is not available to higher plants because at least 70–90% of it is fixed by Fe, Al, and Ca in soils **(El-Naqma *et al.,* 2022).**

Using humic substances as a soil conditioner hasa beneficial influence on the soil structure and plant performance**(Mayhew, 2004).**Humic acid is a commercial product containing many elements, which improve soil fertility **(Ghabbour and Davies, 2014).**Potassium humate has been found to enhance nutrient availability, including nitrogen (N), phosphorus (P), and potassium (K), leading to improved plant growth performance and yield. This observation is supported by studies conducted by**El-Shaboury and Ewais(2020) and El-shamly *et al.* (2024).** Their research indicates that the application of potassium humate can positively influence nutrient uptake by plants, resulting in increased growth vigor and ultimately higher yields. Such findings underscore the potential of potassium humate as a valuable tool for optimizing nutrient utilization in agriculture, with implications for improving crop productivity and sustainability.

In Egypt, most fertilization programs don't include copper element as a significant nutrient. However, fertilization with copper element is necessary due to its vital role in higher plants **(Zhu *et al.,* 2012).** The usage of the chelating compounds *i.e.,* EDTA, DTPA, CDTA and EDDHA is become common, where it plays a vital role in the production process **(Habiba *et al.,* 2015).** The chelate fertilizers make the nutrients easier to be absorbed by the plant without losing those (**Adamuchio-Oliveira *et al.,* 2020)**.

In Egypt, onion (*Allium cepa* L.) is one of the most important vegetable crops either for export or local market**(El-Sherpiny *et al.,* 2022;Mareyand Elmasry,2024).**Onion is one of the commercial vegetable crops having high nutritional value, as it contains oil (20.4%), protein (24.8%), fibre (22.4%), potassium (1010 mg 100 g^{-1}) and calcium (175.0 mg 100 g^{-1}) **(Chakraborty *et al.,* 2022).**

Therefore, the specific objectives of the present study were to evaluate the effect of soil application of potassium humate andfoliar addition of copper under different doses of calcium superphosphate on the sustainable performance, quantitative and qualitative yieldof onion.

MATERIALS AND METHODS

1. Experimental site.

The currentstudywas executedin a private farm located in El-Serw region, Damietta government, Egypt (31° 14`43.7" N&31° 48`14.3" E).

2. Soil Analyses.

The initial soil attributes were shown in Table(1). The sample was taken at depth of 0.0-25 cm. The analyses of initial soil were done according to **Dane and Topp (2020)** and **Sparks *etal.* (2020)**.

Table (1) : Mechanical and chemical analyses of the soils under investigation.

a) Mechanical analysis:

Season	Soil Particle distribution (%)			Texture class
	Sand	Silt	Clay	
1st	19.80	31.18	49.02	Clay
2nd	19.24	31.51	49.25	Clay

b) Chemical analysis:

Season	O.M.	$CaCO_3$	E.C (1 : 5) extract	PH (1 : 2.5)	CEC	Available nutrients (mg kg^{-1})		
	(%)	(%)	dSm^{-1}	soil : water suspension	m.e/100 g soil	N	P	K
1st	1.85	1.75	1.21	7.93	49.7	51.3	6.21	189
2nd	1.92	1.71	1.17	7.91	50.0	50.5	6.87	192

1st season = 2021/2022, **2nd season** = 2022/2023, **O.M.** = Organic matter, **CaCO3** = Calcium carbonate, **E.C** = Electrical conductivity, **CEC** = Cation exchange capacity.

3. Experimental Setup.

Two field trials were executed during two successive winter seasons of 2021 /2022 and 2022 /2023as sake of evaluating the effect of three levels of calcium superphosphate *i.e.,* 100, 75 and 50 % of phosphorus recommended dose(PRD) as main plots as well as assessing the effect of three levels of soil addition of potassium humate (KH) namely 0.0, 1.0 and 2.0 % as sub-plots as well as foliar spraying of Cu at rates of 0.0, 0.1 and 0.2 %Cu as sub-subplots on the performance, quantitative and qualitative yield of the onion .The above-mentioned factors were arrangement in split-split plot design with three replicates and were statistically analyzed according to **Gomez and Gomez (1984)** . Onion seedlings (**70 days old,** (**Cv. Giza Red**).) were obtained from the private nurseries andtransplanted on two sides of the ridges on 15 Novemberfor both seasons with a spacing of 10.0cm among each plants after soil irrigation by flood system immediately using Nile River.

Treatments of Calcium superphosphate (15.5% P_2O_5) were added at the soil preparation, where the rate of 300 kg fed^{-1} represented 100% of PRD. While 225 and 150 kg fed^{-1} represented 75 and 50% of PRD, respectively.Also, all plots received the compost at the rate of 20 m^3 fed^{-1} before a month from transplanting.

Potassium humate levels were applied twice; one was just before transplanting and the other was after 20 days from the first one with irrigation water.

Starting the 3rd irrigation event, the external application of Cu as EDTA-chelated copper at the rates under investigation was executed with repeating three times with three 15 days intervals.

Ammonium sulphate (20.5% N) was added at a rate of 90.0 Kg N fed^{-1}via three equal N doses starting after 15 days from transplanting to maturity. Potassium sulphate (48% K_2O) was applied at a rate of 200 $kgfed^{-1}$after 60 days from transplanting to the end of maturity. Other traditional agricultural practices for onion production were done according to MASR.

4. Potassium humatestudied.

Potassium humate sourced from soil &water and environment research institute(SWERI), Egypt was utilized for the study. Table (2) shows the attributes of potassium humate under investigation.

Table (2). Analysis of the studied potassium humate.

Humic acid,%	Moisture,%	Organic carbon,%	Hydroxyl,%	Water solubility,%	Potassium (K_2O),%
70	14.9	50	3	95	11

5. Studiedmeasurements.

At ages of 90 and 150 days (proper maturing stage) from transplanting, five onion plants (foliage at 90 days and bulb at 150 days) of each replicate were taken for measuringgrowth criteria ,photosynthetic pigments,nutrients as well asphysical and quality attributes of bulbs.Parameters measured and standard methods used are presented in Table(3).

Table (3). Parameters measured and standard methods used.

Stage		Parameters	Methods	References
At 90 days age from transplanting		Plant height (cm)	---------------------------	---------------------------
		Foliage fresh and dry weights (g plant^{-1})	---------------------------	---------------------------
		Chlorophyll (SPAD, reading)	A portable chlorophyll meter (SPAD-502, Soil-Plant Analysis Development (SPAD) Section, Minolta Camera, Osaka, Japan)	**Castelli *et al.* (1996)**
		Carotene content (mg g^{-1} in F.W)	Using organic solvent (methanol 100%).	**Costache *et al.*, (2012)**
		Nitrogen, (% in D.W of foliage)	Kejeldal method	**Walinga *et al.*, (2013)**
		Phosphorus (% in D.W of foliage)	Spectrophotometer	
		Potassium (% in D.W of foliage)	Flame photometer	
		Copper, manganese, zinc and iron (mg kg^{-1} (in D.W of foliage)	Plasma-mass spectrometry	
When bulbs of onion plants reached to the proper maturing stage (after 150 days from transplanting)	Physical and quality attributes of bulbs and yield	Bulb weight (g) and diameter (cm) and neck diameter (cm)	---------------------------	---------------------------
		Total bulb yield and marketable bulb yield (ton ha^{-1})	---------------------------	---------------------------
	Bulb nutrients	Uptake of N, P, K (**Kg ha^{-1}**), Cu, Mn, Zn and Fe (**g ha^{-1}**)	Element concentration x dry weight	
	Quality traits of bulbs	Vitamin C (mg 100g^{-1})	Via titration with 2.6 diclorophenol indophenol blue dye	**AOAC, (2000).**
		Carbohydrates (%), crude protein (%), total dissolved solids (TDS, %), fiber (%),and total sugar (%)	---------------------------	
		Anthocyanin pigment (mg 100g^{-1})	---------------------------	**Crecente-Campo *et al.*, (2012)**
		Pyruvic acid (µmol g^{-1})	---------------------------	**Anthon and Barrett (2003).**

6. Statistical Analysis.

Statistical Analysis of the obtained data was executed according to **Gomez and Gomez, (1984).**

RESULTS.

1. *Growth performance and chemical constituents at 90 days age from transplanting.*

Data presented in Table(4)show theimpact of copper and potassium humate under different levels of phosphate fertilization on growth parameters and photosynthetic pigments of onion plant at 90 days from transplanting*i.e.,*plant height (cm),foliage fresh and dry weights(g plant^{-1}), chlorophyll (SPAD, reading) and carotene contents (mg g^{-1} F.W)**.** Also,Table (5) shows the effect of the studied treatments on chemical constituents*i.e.*N,P,K (%), Fe, Zn, Mn and Cu (mg kg^{-1}) in onion leavesat 90 days from transplanting.

Individual effect of different levels of phosphate fertilization***.***

Data in table (4,5) indicated that the highest values for all growth performance and chemical constituents previously mentioned, at 90 days from transplanting, was attained at 100 % of PRD followed by 75 and 50 % of PRD in a descending order .

Individual effect of different levels of potassium humate***.***

Concerning the individual effect of soil addition of potassium humate, the values of all parameters related to growth performance and chemical constituents at 90 days from transplanting increased as raising the rate of added potassium humate .

Individual effect of different levels of copper

Concerning the individual effect of foliar application of Cu, the values of all aforementioned traits at 90 days from transplanting increased as the rate of Cu increased.

Table (4) : Impact of different levels of phosphate fertilization, potassium humate (KH) as well as copper (Cu) individually or in combinations on growth parameters and leaves photosynthetic pigments of onion plant at 90 days age from transplanting (combined analysis for the two investigated seasons).

Treatments			Plant height, cm	Fresh weight, g $plant^{-1}$	Dry weight, g $plant^{-1}$	Chlorophyll, SPAD value	Carotene, mg g^{-1}F.W
Levels of phosphate fertilization (% of PRD)							
100			78.44a	70.51a	8.50a	44.67a	0.511a
75			73.43b	67.90b	8.05b	43.63b	0.457b
50			63.34c	62.10c	7.06c	41.33c	0.372c
LSD $_{at 5\%}$			**0.28**	**0.45**	**0.05**	**0.05**	**0.005**
Levels of potassium humate (KH), %							
0.0			66.86c	64.23c	7.44c	42.18c	0.394c
1.0			73.75b	67.96b	8.04b	43.62b	0.469b
2.0			74.61a	68.33a	8.13a	43.83a	0.477a
LSD $_{at 5\%}$			**0.12**	**0.37**	**0.07**	**0.07**	**0.005**
Levels of copper (Cu), %							
0.0			70.34c	66.13c	7.73c	42.85c	0.432c
0.1			71.41b	66.76b	7.85b	43.22b	0.447b
0.2			73.46a	67.62a	8.03a	43.56a	0.461a
LSD $_{at 5\%}$			**0.14**	**0.48**	**0.04**	**0.11**	**0.003**
Interactions							
P % of	**HK (%)**	**Cu (%)**					
100	**0.0**	**0.0**	70.27	65.94	7.75	42.96	0.415
		0.1	70.58	66.52	7.86	43.23	0.425
		0.2	71.96	67.23	7.94	43.43	0.439
	1.0	**0.0**	81.32	71.81	8.58	44.82	0.532
		0.1	82.16	72.35	8.73	45.29	0.554
		0.2	82.75	72.92	9.04	45.76	0.565
	2.0	**0.0**	81.46	72.05	8.69	44.98	0.542
		0.1	82.52	72.52	8.82	45.57	0.558
		0.2	82.96	73.21	9.11	45.96	0.571
75	**0.0**	**0.0**	67.59	64.03	7.50	42.41	0.400
		0.1	67.75	64.64	7.62	42.67	0.406
		0.2	69.06	65.36	7.67	42.74	0.411
	1.0	**0.0**	72.50	67.83	8.03	43.68	0.451
		0.1	74.51	69.18	8.21	44.00	0.473
		0.2	78.84	70.47	8.41	44.47	0.502
	2.0	**0.0**	73.60	68.54	8.16	43.85	0.462
		0.1	76.55	69.84	8.31	44.21	0.490
		0.2	80.51	71.19	8.48	44.66	0.519
50	**0.0**	**0.0**	61.07	61.18	6.80	40.59	0.343
		0.1	61.29	61.37	6.87	40.75	0.352
		0.2	62.14	61.76	6.92	40.86	0.357
	1.0	**0.0**	62.49	61.83	6.99	41.05	0.376
		0.1	63.06	62.04	7.12	41.53	0.382
		0.2	66.12	63.17	7.26	41.96	0.390
	2.0	**0.0**	62.77	61.97	7.04	41.29	0.369
		0.1	64.25	62.34	7.15	41.74	0.385
		0.2	66.84	63.26	7.38	42.20	0.396
LSD $_{at 5\%}$			**0.42**	**1.44**	**0.15**	**0.32**	**0.008**
LSD $_{at 5\%}$			**0.42**	**1.44**	**0.15**	**0.32**	**0.008**

PRD = phosphorus recommended dose.

Table (5) : Impact of different levels of phosphate fertilization, potassium humate (KH) as well as copper (Cu) individually or in combinations onconcentrations macro- and micronutrients in onion leaves at 90 days age from transplanting (combined analysis for the two investigated seasons).

Treatments			Macronutrients concentration, %			Micronutrients concentration, mg kg^{-1}			
			N	P	K	Fe	Zn	Mn	Cu
Levels of phosphate fertilization (% of PRD)									
100			3.44a	0.328a	2.92a	43.56a	20.35a	32.20a	10.94a
75			3.04b	0.296b	2.62b	42.50b	19.31b	31.45b	10.63b
50			2.37c	0.230c	2.01c	39.49c	17.02c	29.73c	10.01c
LSD $_{at\ 5\%}$			**0.08**	**0.003**	**0.02**	**0.12**	**0.31**	**0.34**	**0.26**
Levels of potassium humate (KH), %									
0.0			2.58c	0.251c	2.21c	40.63c	17.87c	30.37c	10.42c
1.0%			3.12b	0.299b	2.65b	42.34b	19.30b	31.44b	10.53b
2.0%			3.15a	0.305a	2.70a	42.58a	19.50a	31.57a	10.62a
LSD $_{at\ 5\%}$			**0.02**	**0.003**	**0.02**	**0.04**	**0.11**	**0.30**	**0.05**
Levels of copper (Cu), %									
0.0			2.85c	0.276c	2.43c	41.43c	18.54c	30.86c	9.11b
0.1			2.96b	0.285b	2.53b	41.83b	18.89b	31.12b	11.21a
0.2			3.04a	0.293a	2.60a	42.29a	19.25a	31.39a	11.26a
LSD $_{at\ 5\%}$			**0.02**	**0.002**	**0.02**	**0.10**	**0.13**	**0.21**	**0.06**
Interaction									
P % of PRDPRD	**HK (%)**	**Cu (%)**							
100	**0.0**	**0.0**	2.81	0.270	2.41	41.73	18.75	30.98	9.56
		0.1	2.88	0.277	2.49	41.99	18.96	31.15	11.44
		0.2	2.96	0.286	2.55	42.26	19.16	31.36	11.47
	1.0	**0.0**	3.57	0.342	3.00	43.84	20.55	32.33	9.62
		0.1	3.73	0.353	3.16	44.21	20.93	32.66	11.59
		0.2	3.78	0.359	3.20	44.67	21.37	32.97	11.65
	2.0	**0.0**	3.64	0.350	3.09	44.07	20.77	32.45	9.65
		0.1	3.76	0.356	3.18	44.44	21.14	32.77	11.72
		0.2	3.81	0.363	3.23	44.84	21.50	33.13	11.77
75	**0.0**	**0.0**	2.54	0.247	2.20	41.08	18.08	30.52	9.38
		0.1	2.58	0.256	2.23	41.25	18.29	30.69	11.09
		0.2	2.70	0.264	2.34	41.53	18.53	30.81	11.13
	1.0	**0.0**	3.05	0.297	2.64	42.60	19.28	31.45	9.46
		0.1	3.23	0.312	2.79	43.02	19.68	31.81	11.18
		0.2	3.47	0.328	2.90	43.44	20.13	32.05	11.25
	2.0	**0.0**	3.12	0.305	2.73	42.77	19.47	31.65	9.48
		0.1	3.32	0.321	2.85	43.19	19.92	31.90	11.32
		0.2	3.39	0.336	2.94	43.67	20.39	32.17	11.36
50	**0.0**	**0.0**	2.22	0.217	1.86	38.29	16.10	29.10	8.23
		0.1	2.26	0.220	1.90	38.63	16.33	29.29	10.71
		0.2	2.30	0.223	1.92	38.92	16.62	29.43	10.77
	1.0	**0.0**	2.33	0.228	1.97	39.13	16.83	29.57	8.28
		0.1	2.42	0.234	2.05	39.69	17.27	29.87	10.85
		0.2	2.49	0.240	2.13	40.50	17.68	30.21	10.91
	2.0	**0.0**	2.38	0.231	2.01	39.40	16.99	29.70	8.32
		0.1	2.45	0.238	2.09	40.02	17.49	29.99	10.96
		0.2	2.52	0.243	2.17	40.79	17.84	30.38	11.02
LSD at 5%			**0.07**	**0.005**	**0.06**	**0.31**	**0.40**	**0.64**	**0.20**

PRD = phosphorus recommended dose.

Interaction effects

Data in table (4) also illustrated that the combination of 100% of PRD +2.0 % KH + 0.2 %Cu recorded the highest values of plant height (cm), foliage fresh and dry weights (g plant^{-1}), chlorophyll (SPAD, reading), carotene contents (mg g^{-1} F.W)as well as concentration of macro- and micronutrients namely N, Pand K (%) and Fe, Zn, Mn and Cu (mg kg^{-1}) in leaves for onion plants at period at 90 days from transplanting. In this respect,the combination of 75% of PRD + KH at both1.0 and 2.0% + Cu at rates of 0.1 and 0.2 % recorded values of all aforementioned traits better than those attained when the addition of 75% of PRD singly .

2. *Yield and bulb traits*

Data shown in tables (6, 7 and 8) illustrated the effect of the treatments under investigation on bulb physical and quality attributes as well as the yield of onion bulbs when onion plants reached the proper maturing stage. Average bulb weight (g), diameter (cm), neck diameter (cm), total and marketable bulb yield (ton h^{-1}) (**Table 6),** bulb uptake of N, P, K (**Kg ha^{-1}**), Fe, Zn, Mn and Cu (**g ha^{-1}**) (**Table 7),**carbohydrates, protein, TDS,fiber,total sugar (%), anthocyanin pigment (mg 100g^{-1}), vitamin C (mg 100g^{-1}), and pyruvic acid (μmol g^{-1}) (**Table 8)**were significantly affected as the addition of phosphate fertilizer ,KH or Cu individually or in combinations.

Individual effect of different levels of phosphate fertilization***.***

From these Tables, it can be noticed that the highest values of onion quantitative and qualitative yield were attained when the addition of 100 % of PRD followed by 75 and 50 % of PRD in a descending order.

Individual effect of different levels of potassium humate.

Regarding the individual impact of soil addition of potassium humate, the values of all traits related to onion quantitative and qualitative yield increased as raising the rate of added potassium humate up to 2.0 % .

Table (6) : Impact of different levels of phosphate fertilization, potassium humate (KH) as well as copper (Cu) individually or in combinations on physical traits of bulbs and total marketable yield of onion at harvest stage(combined analysis for the two investigated seasons).

Treatments			Average bulb weight, g	Bulb diameter, cm	Neck diameter, cm	Total bulb yield, ton ha^{-1}	Marketable bulb yield, ton ha^{-1}
Levels of phosphate fertilization (% of PRD)							
100			107.72a	6.76a	2.13a	41.02a	36.87a
75			97.91b	5.83b	1.40b	37.28b	34.73b
50			82.16c	3.87c	1.02	31.29c	29.13c
LSD $_{at\ 5\%}$			**0.61**	**0.33**	**0.04c**	**0.23**	**0.19**
Levels of potassium humate (KH), %							
0.0			87.37c	4.54c	0.89c	33.27c	31.23c
1.0			99.56b	5.84b	1.76b	37.91b	34.48b
2.0			100.86a	6.09a	1.91a	38.41a	35.02a
LSD $_{at\ 5\%}$			**0.96**	**0.23**	**0.03**	**0.37**	**0.25**
Levels of copper (Cu), %							
0.0			93.33c	5.11c	1.33c	35.54c	32.77c
0.1			96.10b	5.54b	1.49b	36.59b	33.65b
0.2			98.37a	5.82a	1.74a	37.46a	34.31a
LSD $_{at\ 5\%}$			**0.87**	**0.22**	**0.03**	**0.33**	**0.23**
Interactions							
P % of PRDPRD	**HK (%)**	**Cu (%)**					
100	**0.0**	**0.0**	92.24	5.10	0.86	35.13	33.30
		0.1	94.09	5.21	0.97	35.83	33.92
		0.2	96.31	5.51	0.97	36.67	34.29
	1.0	**0.0**	110.24	7.04	2.27	41.98	37.39
		0.1	113.79	7.45	2.70	43.33	38.03
		0.2	117.35	7.76	3.02	44.69	38.77
	2.0	**0.0**	111.98	7.35	2.49	42.64	37.78
		0.1	115.53	7.55	2.81	44.00	39.10
		0.2	117.95	7.86	3.13	44.91	39.25
75	**0.0**	**0.0**	83.16	4.60	1.51	31.67	31.92
		0.1	88.09	4.80	0.76	33.55	32.46
		0.2	90.19	5.01	0.86	34.34	32.90
	1.0	**0.0**	98.31	5.83	1.08	37.44	34.83
		0.1	102.38	6.53	1.41	38.99	35.70
		0.2	106.21	6.63	1.95	40.44	36.52
	2.0	**0.0**	100.27	6.02	1.30	38.18	35.22
		0.1	104.34	6.33	1.73	39.73	36.14
		0.2	108.23	6.74	2.05	41.22	36.89
50	**0.0**	**0.0**	79.63	3.26	0.54	30.32	26.77
		0.1	81.16	3.58	0.65	30.90	27.44
		0.2	81.49	3.78	0.86	31.03	28.03
	1.0	**0.0**	81.86	2.71	0.97	31.17	28.53
		0.1	82.49	4.08	1.19	31.41	29.77
		0.2	83.41	4.50	1.30	31.76	30.81
	2.0	**0.0**	82.23	4.08	0.97	31.31	29.20
		0.1	82.99	4.29	1.19	31.60	30.26
		0.2	84.19	4.59	1.51	32.06	31.31
LSD $_{at\ 5\%}$			**2.60**	**0.65**	**0.08**	**0.99**	**0.68**

PRD = phosphorus recommended dose.

Table (7) : Impact of different levels of phosphate fertilization, potassium humate (KH) as well as copper (Cu) individually or in combinations onthe uptake of macro- and micronutrients by onion bulbs at harvest stage(combined analysis for the two investigated seasons).

Treatments			Macronutrients uptake, Kg ha^{-1}			Micronutrients uptake, g ha^{-1}			
			N	P	K	Fe	Zn	Mn	Cu
Levels of phosphate fertilization (% of PRD)									
100			154.87a	21.77a	157.70a	151.21a	78.02a	114.11a	57.18a
75			119.45b	17.08b	118.52b	123.68b	64.54b	93.56b	48.74b
50			65.52c	9.85c	58.62c	80.27c	43.30c	60.85c	34.06c
LSD $_{at\ 5\%}$			**1.65**	**0.12**	**1.14**	**2.64**	**0.12**	**0.26**	**0.16**
Levels of potassium humate (KH), %									
0.0			82.01c	12.26c	78.00c	94.97c	50.24c	71.31c	39.48c
1.0%			126.07b	17.86b	125.24b	127.95b	66.75b	96.91b	48.43b
2.0%			131.76a	18.58a	131.62a	132.23a	68.87a	100.31a	52.07a
LSD $_{at\ 5\%}$			**0.70**	**0.07**	**0.29**	**1.79**	**0.04**	**0.08**	**0.05**
Levels of copper (Cu), %									
0.0			104.02c	15.01c	101.05c	111.60c	58.35c	83.96c	38.50c
0.1			113.29b	16.23b	111.20b	118.06b	62.03b	89.62b	50.32b
0.2			122.54a	17.47a	122.61a	125.50a	65.47a	94.94a	51.16a
LSD $_{at\ 5\%}$			**0.67**	**0.06**	**0.76**	**1.67**	**0.01**	**0.01**	**0.02**
Interaction									
P % of PRDPRD	**HK (%)**	**Cu (%)**							
100	**0.0**	**0.0**	98.70	14.38	94.42	107.12	56.75	80.84	37.71
		0.1	103.85	15.22	102.18	112.41	58.98	84.69	49.20
		0.2	110.53	16.00	109.39	117.73	61.37	88.60	51.41
	1.0	**0.0**	161.70	22.66	164.86	157.16	80.83	118.96	51.71
		0.1	176.20	24.67	180.80	168.00	86.41	126.78	68.71
		0.2	190.85	26.57	198.91	179.26	91.64	135.13	56.61
	2.0	**0.0**	169.48	23.59	173.21	162.61	83.62	122.97	53.31
		0.1	184.56	25.52	190.07	173.26	88.83	131.01	71.39
		0.2	197.92	27.34	205.50	183.31	93.74	138.03	74.59
75	**0.0**	**0.0**	79.74	11.54	74.64	89.85	48.03	68.20	31.66
		0.1	87.07	12.79	81.60	97.42	51.94	73.74	42.59
		0.2	92.39	13.57	88.26	102.25	54.19	77.26	44.49
	1.0	**0.0**	118.46	17.05	117.86	123.60	64.20	92.86	41.40
		0.1	132.76	18.79	132.12	134.30	69.84	101.53	55.61
		0.2	146.17	20.70	148.90	145.82	75.20	109.97	59.56
	2.0	**0.0**	125.17	17.97	125.17	128.70	67.11	97.22	43.13
		0.1	139.66	19.66	140.98	139.79	72.48	106.83	58.05
		0.2	153.66	21.64	157.18	151.40	77.89	114.47	62.17
50	**0.0**	**0.0**	51.79	8.61	48.60	79.56	39.24	54.38	30.32
		0.1	55.72	9.01	50.40	73.18	40.40	56.25	33.60
		0.2	58.30	9.24	52.47	75.24	41.27	57.80	34.35
	1.0	**0.0**	64.52	9.48	53.98	76.80	42.17	59.29	28.16
		0.1	68.84	10.02	60.12	80.99	44.17	62.12	36.29
		0.2	75.12	10.80	69.60	85.64	46.28	65.53	37.83
	2.0	**0.0**	66.58	9.79	56.70	78.95	43.21	60.96	29.08
		0.1	67.97	9.87	58.05	79.60	43.51	61.18	33.60
		0.2	77.88	11.36	73.24	88.87	47.70	67.64	39.45
LSD at 5%			**2.01**	**0.19**	**2.27**	**4.97**	**0.02**	**0.04**	**0.08**

PRD = phosphorus recommended dose.

Table (8) : Impact of different levels of phosphate fertilization, potassium humate (KH) as well as copper (Cu) individually or in combinations onthe biological constituents of onion bulbs at harvest stage, as indicators of quality (combined analysis for the two investigated seasons).

Treatments			Carboh-ydrates	Protein	TDS	Fiber	Total sugar	Anthocy-anin	Vitamin C	Pyruvic acid
			(%)					(mg/100g)		(πmol.g^{-1})
Levels of phosphate fertilization (% of PRD)										
100			17.88a	8.49a	11.59a	3.77a	6.11a	27.73a	12.69a	6.65a
75			16.79b	7.97b	10.72b	3.20b	5.82b	26.66b	11.69b	5.80b
50			14.58c	7.11c	9.03c	2.20c	5.20c	24.71c	9.45c	3.98c
LSD $_{at\ 5\%}$			**0.12**	**0.06**	**0.29**	**0.05**	**0.01**	**0.03**	**0.21**	**0.15**
Levels of potassium humate (KH), %										
0.0			15.34c	7.38c	9.61c	2.55c	5.42c	25.31c	10.22c	4.63c
1.0%			16.85b	8.04b	10.80b	3.26b	5.82b	26.81b	11.71b	5.82b
2.0%			17.05a	8.15a	10.94a	3.35a	5.90a	26.98a	11.91a	5.98a
LSD $_{at\ 5\%}$			**0.08**	**0.08**	**0.06**	**0.02**	**0.05**	**0.05**	**0.09**	**0.03**
Levels of copper (Cu), %										
0.0			16.08c	7.70c	10.20c	2.89c	5.62c	26.07c	10.93c	5.21c
0.1			16.43b	7.85b	10.45b	3.05b	5.71b	26.38b	11.30b	5.48b
0.2			16.73a	8.01a	10.69a	3.22a	5.80a	26.65a	11.61a	5.74a
LSD $_{at\ 5\%}$			**0.02**	**0.06**	**0.06**	**0.02**	**0.03**	**0.06**	**0.09**	**0.02**
Interaction										
P % of PRDPRD	**HK (%)**	**Cu (%)**								
100	**0.0**	**0.0**	16.13	7.66	10.16	2.87	5.64	25.82	11.00	5.25
		0.1	16.32	7.76	10.39	3.01	5.70	26.10	11.25	5.46
		0.2	16.60	7.86	10.59	3.11	5.74	26.40	11.47	5.66
	1.0	**0.0**	18.12	8.62	11.79	3.85	6.17	28.02	12.77	6.84
		0.1	18.53	8.80	12.12	4.08	6.32	28.47	13.34	7.17
		0.2	18.95	8.99	12.44	4.34	6.41	28.84	13.74	7.49
	2.0	**0.0**	18.31	8.69	11.95	3.96	6.23	28.21	13.16	7.00
		0.1	18.75	8.89	12.28	4.20	6.35	28.68	13.55	7.32
		0.2	19.19	9.11	12.62	4.47	6.46	29.04	13.96	7.66
75	**0.0**	**0.0**	15.33	7.33	9.50	2.54	5.45	25.17	10.24	4.76
		0.1	15.63	7.43	9.71	2.65	5.53	25.40	10.52	4.92
		0.2	15.83	7.56	9.95	2.73	5.57	25.58	10.75	5.10
	1.0	**0.0**	16.85	7.99	10.82	3.23	5.83	26.77	11.78	5.84
		0.1	17.34	8.19	11.14	3.41	5.86	27.21	12.21	6.17
		0.2	17.67	8.38	11.47	3.63	6.06	27.62	12.57	6.45
	2.0	**0.0**	17.11	8.09	10.99	3.30	5.96	26.98	11.96	6.01
		0.1	17.48	8.30	11.29	3.53	6.01	27.40	12.40	6.33
		0.2	17.86	8.49	11.62	3.74	6.11	27.79	12.77	6.66
50	**0.0**	**0.0**	14.02	6.84	8.65	1.97	4.99	24.37	8.66	3.40
		0.1	14.08	6.94	8.72	2.04	5.04	24.40	8.92	3.49
		0.2	14.15	7.00	8.79	2.07	5.09	24.54	9.15	3.64
	1.0	**0.0**	14.35	7.03	8.89	2.13	5.15	24.61	9.32	3.83
		0.1	14.75	7.15	9.17	2.26	5.25	24.84	9.67	4.14
		0.2	15.11	7.20	9.32	2.39	5.38	24.97	9.97	4.42
	2.0	**0.0**	14.52	7.09	9.04	2.19	5.21	24.72	9.49	3.98
		0.1	14.97	7.18	9.24	2.32	5.32	24.90	9.81	4.31
		0.2	15.24	7.54	9.46	2.46	5.42	25.07	10.08	4.59
LSD at 5%			**0.36**	**0.19**	**0.17**	**0.07**	**0.11**	**0.19**	**0.26**	**0.09**

PRD = phosphorus recommended dose, **TDS** = total dissolved solids.

Individual effect of different levels of copper

Regarding the foliar application of Cu, data shown in table(6, 7 and 8) indicated that all aforementioned parameters related onion quantitative and qualitative yield were recorded with the plantsfoliar sprayed with copper at a rate of 0.2 % followed by those treated with copper atarate of 0.1 %, while control treatment gave the least values . In other words, the highest values of all aforementioned traits increased as the rate of copper increased.

Interaction effects

Data presented in table (6, 7 and 8)elucidated that the best quantitative and qualitative yield of onion plants at the harvest stage was observed when the plants were treated with a combination of 100% of PRD +2.0%HK + 0.2 %Cu. On the other hand, it can be noticed that a combination of 75% of PRD + KH at both studied rates (1.0 and 2.0%) + Cu at 0.1 and 0.2 % recorded values of quantitative and qualitative yield better than those recorded under the treatment of 75% of PRD singly.

DISCUSSION

Results obtained herin indicated that theaddition of 100% PRD attained the highest values for all parameters under investigationfollowed by 75 and 50 % of PRD , respectively . This could be attributed to the essential structural role of Pin the nucleus and cell membrane **(El-Agrodi *et al.,* 2011).** Besides, P also has roles in photosynthesis, energy storage and transfer, metabolism of sugars, cell enlargement, cell division and transfer of genetic information **(Tirado and Allsopp, 2012**).In other words, it is a vital component in the process of onion plants converting the sun's energy into food. In addition, it might promote healthy onion root growth and early shoot growth as well as it may speed up ground cover for erosion protection **(Bindraban *et al.,* 2020).**. Also, adequate phosphorus might increase onion plant water use efficiency and might improve the efficiency of other nutrients *e.g.,* nitrogen **(El-Naqma *et al.,* 2022).**

Although P is considered essential nutrient for onion plants , its uptake is greatly decreased due to its fixation in the soil by calcium. The ability of potassium humate in raising phosphorus availability appeared where the phosphorus availability increased as raising the rate of potassium humate. Generally,it could be concluded that the increases in plant growth characteristics as well as onion quantitative and qualitative yield by increasing added rate of potassium humate may be due to increasing the nutritional elements in the rooting region and also increasing availability of phosphorus and other nutrients *e.g.,* N, K, Zn and Fe even from the early stage of crop growth. Thus, more nutrients were absorbed so more improvement in the performance of the onion plant. Also, it can be said that the soil addition of humic acid might increase the synthesis and activity of IAA that plays a major role in promoting onion plant growth.These results are in agreement with those of **Mayhew, (2004) andGhabbour and Davies, (2014).**

The combined addition of 75% of PRD+ KH recorded values for growth performance as well as onion quantitative and qualitative yield better than those recorded when the addition of 100% of PRD singly . This impact may be due to the role of potassium humate in raising the soil P availability and releasing of significant amounts of phosphorous after removing the effect of calcium. Generally, it can be said that potassium humate helps to dissolve the tricalcium phosphate and turn it into di calcium ($HPO4^{-2}$) or a highly soluble form ($H_2PO_4^{-}$), which is the most convenient form of the onion plant. Also, it can be said that potassium humate might be reducing the soil pH and thereby raising the efficiency of phosphorus fertilizer via increasing the availability of phosphorus and this effect is positively reflected on onion growth performance.These findings are in agreement with those obtained by **El-Shaboury and Ewais (2020)**.

The present study also indicated that foliar addition of copper enhanced the growth traits, quantitative and qualitative yield of the onion plants compared to the corresponding plants grown under control treatment (without copper) .The pronounced promotional effect of copper may be due to that it is required for many enzymatic activities as well as for chlorophyll. In addition , Cu activates some enzymes in plants which are involved in lignin synthesis , essential for several enzyme systems, required in the processes of photosynthesis and respiration.P is also assists in plant metabolism of carbohydrates and proteins. Copper also serves to intensify flavour and color of onion. On the other hand, the chelating compound form (EDTA) may be led to the translocation of Cu away from the treated leaf to other plant parts under the EDTA form being fast. The obtained results are in harmony with those of **Zhu *et al.,* (2012); Habiba *et al.,* (2015) and Adamuchio-Oliveira *et al.,* (2020)**.

CONCLUSION

The results of the current investigation increase our knowledge about the efficacy of a combination of potassium humate, phosphorus and copper. The obtained results confirmed that the combined treatment of 100% of PRD + 2.0 % KH + 0.2 % Cu is the best for obtaining the highest values of growth performance, quantitative and qualitative yield ofonion. Taking into consideration, the combined treatment of 75% of PRD +KH at 2.0 or 1.0% + Cu at rate of either 0.1 and 0.2 %recorded values of onion growth performance, quantitative and qualitative yield betterthan those recorded when the addition of 100%of PRD individually .

Generally, it can be concluded that the combined addition of potassium humate (as soil addition) and copper (as foliar application) has a vital role in improving the onion quantitative and qualitative yield as well as raising the efficiency of phosphate fertilization.

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