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Effect of different Phosphorus Fertilizers sources on Growth, Productivity, and Bulb Quality of Onion Plants

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Onion is regarded as a highly valuable vegetable crop due to its rich nutritional content; however, insufficient phosphorus application remains a major limiting factor in achieving optimal yields. Investigation into how onions respond to different phosphorus sources can help enhance fertilizer formulations, promoting more sustainable agricultural practices with reduced environmental impact and improved market competitiveness. Therefore, two open field experiments were conducted to assess the impact of various phosphorus sources (Phosphoric Acid, Brandt Reaction P DS, and Monoammonium phosphate) on the growth and production of onion plants in a randomized complete block design (RCBD) with four replications and four treatments. The obtained findings showed that maximum vegetative growth traits, like plant height, bulb diameter, fresh bulb, and dry bulb values were recorded to be higher in plants fertilized with Brandt Reaction P DS and Monoammonium phosphate, followed by phosphoric acid, while the minimal values were observed in unfertilized plants. Comparable trends were observed in the nutritional values of blub. Compared with the control treatment, the higher nutrients (N, P, K, Fe, and Zn), TSS, carbohydrate, protein content, and total phenol in bulbs of plants fertilized with Brandt Reaction P DS and Monoammonium phosphate, followed by phosphoric acid. The Principal component analysis showed that the exogenous addition of phosphorus has positive effects on the bulb yield and quality.
Keywords: *Allium cepa*, Agro-physiological properties, phosphorus application, nutritional quality.

INTRODUCTION

Onion (*Allium cepa* L.) is a significant vegetable crop in Egypt, due to its economic relevance (Hassan *et al.*, 2023; Ali *et al.*, 2025). In 2020, around 154.17 thousand feddans were dedicated to onion cultivation in Egypt (Fangary and Adam, 2020). It is considered one of the most exported crops in Egyptian trade. Based on its geographic distribution, Saudi Arabia ranked as the leading importer of Egyptian onions, receiving approximately 256.2 thousand tons. It was followed by Russia and the Netherlands, with imports of around 58.8 and 31.3 thousand tons, respectively (Fangary and Adam, 2020). The application of fertilizers is crucial in onion growing, particularly through fertigation, as it significantly influences on the plant growth, in addition to bulb yield and quality of onions in semiarid environments. The production manner is crucial as it suggestively influences growth, development, and yields (Geisseler *et al.*, 2022). An important limitation to crop productivity in numerous tropical soils is the deficiency of phosphorus (P), primarily due to its naturally low availability and the rapid immobilization of P within the soil matrix (Rinasoa *et al.*, 2022). A main trait of the onion plant concerning phosphorus (P) is its limited capacity to absorb this nutrient from the soil, primarily due to the relatively short length of its root hairs, which are often shorter than the diffusion distance of phosphate ions. A lack of phosphorus delays crop growth, root development and maturation, especially in alkaline soils rich in Ca and Mg and in acidic soils where Fe and Al predominate (Gong *et al.*, 2022). As a result, growers must carefully manage soil phosphorus levels and make informed choices regarding the sources and formulations of phosphate-containing fertilizers (Brewester, 1994; Gerke, 2024). The reaction of onions to phosphorus fertilization varies based on the genotype

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employed, phosphorus levels in the soil, type of phosphorus source, as well as soil and weather conditions (Lindi *et al.*, 2024). Costa *et al.* (2009) documented that applying as much as 90 kg ha^{-1} of P_2O_5 led to a yield of 33.4 t ha^{-1}. Tekalign *et al.* (2012) achieved greater yields when they applied 120 kg ha^{-1} of P_2O_5. Resende *et al.* (2016) noted improved yields for onion varieties when an application rate 132 kg ha^{-1} of P_2O_5 was used, which was similar to the economic dose of 130 kg ha^{-1} of P_2O_5.

Sustainable P management in agricultural systems is very complex. It is associated with crop production, rock phosphate exploitation, and mineral P fertilizer manufacturing. The effects of different mineral P fertilizers on P use efficiency must be quantitatively determined and analyzed from a supply chain perspective. Therefore, slow and controlled-release chemical fertilizers, such as Brandt Reaction P DS, can efficiently improve nutrient use efficiency, minimize nutrient leaching, and reduce environmental pollution. The controlled chemical contents of the fertilizers can promote sustainable agriculture and enhance agricultural productivity (Gong *et al.*, 2022). Brandt Reaction P DS fertilizers are considered one of slow-release chemical fertilizers. Because it protects the negative charges on the surface of the phosphate molecule, so that the calcium and magnesium in the soil cannot react to inactivate it. This protected phosphate is much more mobile in the soil solution than conventional orthophosphate. Fertigation allows for the application of water-soluble fertilizers and various chemicals simultaneously with irrigation water in a more uniform and efficient manner. This technique reduced the water losses and nutrient leaching from the soil as well as improves crop productivity, especially in arid and semi-arid regions (Kurtz *et al.*, 2013). Research conducted on vegetables has demonstrated their strong positive response to fertigation. For instance, studies have shown effective results in melon (Abdeldaym *et al.*, 2014), potato (Mahmoud *et al.*, 2022; Xu *et al.*, 2025), pepper (Sabli *et al.*, 2010; EL-Mogy *et al.*, 2024), cucumber (He *et al.*, 2025; Abdeldaym *et al.*, 2024), tomato (Alveno *et al.*, 2024), and certain leafy vegetables (Zohar *et al.*, 2024; Abdel-Hakim *et al.*, 2023). In the case of onions, Rumpel *et al.* (2004) noted that utilizing a 50 kg ha^{-1} nitrogen rate via drip fertigation led to a significant increase in marketable onion yields (41% higher), while applying 150 kg ha^{-1} nitrogen via fertigation resulted in the highest yield increase (79% higher) when compared to a control group that did not use fertigation or irrigation. Kale *et al.* (2024) demonstrated that drip fertigation led to an increase in onion seed productivity by 12 to 74% when compared to traditional methods. Wale *et al.* (2025) found that daily fertigation resulted in the highest yield of onions, while alternate day fertigation followed in terms of yield. In addition, several researchers confirmed that an increase in NPK fertigation level significantly increased the number of leaves, relative leaf water content, marketable yield of onion, and benefit cost ratio, but decreased fertilizer expense efficiency (Kurtz *et al.*, 2013; Wale *et al.*, 2025).

For the purposes of this research study, onion (*Allium cepa*) was selected as a test crop due to its high demands in P and sensitivity in P shortage. Therefore, this research study was aimed to estimate the impact of different sources of phosphorus on morphological characteristics and on the quantity and quality of onion yield.

MATERIALS AND METHODS

***Description of study site*:** The field experiment was performed from September to April 2024 at the private farm, located in Aiate, Giza, Egypt (29°24'04.3"N 31°16'40.2"E). Table 1 presents the physicochemical characteristics of the experimental soil using techniques described by Bashour and Sayegh (2007). The experimental soil was identified as a clay loam soil. During the experimentation, the average of precipitation, from September to April in Giza Governorate-Egypt, was 24.01 mm, and the mean temperature was 26.4°C.

***Treatments and experimental design*:** An evaluation of three phosphorus fertilizer sources was executed through a randomized complete block design comprising four replications. Each experimental plot was sized at 3.0 × 0.8 m and contained eight rows of plants arranged with a spacing of 0.10 × 0.10 m. The usable plants were harvested from the six central rows, omitting the border plants.

***Planting and agronomic practices*:** The experimental soil was tilled over a single round of ploughing and harrowing. After that, beds were established. The onion variety used in the current study was Giza 20. Onion seeds were sown in seed beds that measured 0.2 m in height and 1.0 m in width, at a density of 10 g for every square meter, arranged in channels 0.01 m deep with a spacing of 0.1 m between them throughout the length of the bed. Before transplanting the seedling, 12 ton of botanical compost per hectare were added to soil. The compost's chemical analysis is displayed in Table 2.

Transplanting took place 53 days following sowing, once the seedlings attained heights of 15 to 20 cm. Irrigation's drip was utilized to provide water to the beds. Fertigation started 10 days following transplanting (DAT) and continued until 70 DAT. Across this period, nitrogen was provided in the form of urea and ammonium sulfate at a rate of 135.0 kg ha^{-1} N, while potassium was supplied using potassium chloride at 135 kg ha^{-1} K_2O. Moreover, the phosphorus fertilizers were adding Moreover, the different phosphorus treatments, including 1) Phosphoric Acid, 2) Brandt Reaction P DS, and 3) and Monoammonium phosphate also applied via irrigation at a rate of 20 L, 6 kg, and 20 per hectare), respectively. Table 3 presents the chemical analysis of the fertilizers employed.

Control treatment was without phosphorus fertilizers. Mancozeb was utilized weekly at a concentration of 2.5 g L^{-1} to control diseases like purple stain. Mospilan 20% SP and

Table 1. Physical and chemical properties of the experimental soil.

Physical analysis				Chemical analysis								
Sand %	**Silt %**	**Clay %**	**Texture**	**OM**	**pH**	**E.C mmhos/cm**	**N %**	**P ppm**	**K ppm**	**Fe ppm**	**Mn ppm**	**Zn ppm**
17.33	33.22	49.45	Clay loam	1.72	7.85	1.08	0.07	24.21	355.4	29.1	17.6	5.14
18.20	34.26	47.54	Clay loam	1.89	7.91	1.06	0.09	27.25	374.5	30.0	18.9	5.71

Table 2. Chemical analysis of applied compost.

pH	EC (dS /m)	O.M (%)	N (%)	P (%)	K (%)	C/N	Humidity (%)
6.5	1.7	56	1.3	0.64	0.82	18: 1	25

Table 3. Chemical analysis of used fertilizers.

Chemical properties	Phosphoric Acid	Brandt Reaction P DS	Monoammonium phosphate
Chemical formula	H_3PO_4	$NH_4H_2PO_4$	$NH_4H_2PO_4$
P_2O_5	61%	58.0%	48-61%
N	---	12.0% Ammoniacal nitrogen	10-12%
Solution pH	2.3		4 to 4.5

lambda-cyhalothrin were alternately administered every two weeks to manage thrips. Weeds were addressed as needed through hoeing. Over 70% of the onion crop was harvested at 150 DAP. Fewer than 25% of the remaining sample was gathered 7 days later to allow for further healing.

Data recorded**:** After 120 days of transplanting, a sample of 6 plants and their bulbs was selected randomly and harvested from each plot to evaluate morphological and physicochemical properties characteristics.

1. Plant height of onion plants was measured using graded meter. The bulb diameter was assessed using the digital feet.
2. Total soluble solids (TSS) were detected utilizing a digital refractometer (model PR101, Co. Ltd., Tokyo, Japan)
3. Blub nutrient content: samples were then dried in an air-forced oven at 75ºC for 3 days and ground. Approximately 20 mg of ground sample was digested by adding the mixture containing sulfuric acid (5 mL) and perchloric acid and heating were maintained until a clear solution appeared. The modified micro-Kjeldahl technique, as outlined by AOAC (1970), was employed to establish the total nitrogen (TN) content in the dried bulb. The phosphorus (P) concentration was determined calorimetrically utilizing the chlorostannous molybdophosphoric blue color method in sulfuric acid, as documented by Watanabe and Olsen (1965). The potassium (K), was measured utilizing the flame photometer apparatus (CORNINGM410, Halstead, UK). The concentration of Zinc (Zn), iron (Fe), and copper (Cu) was estimated using an atomic absorption spectrophotometer (PyeUnicam, model SP 1900, Cambridge, UK).
4. The total protein content in the bulb was computed using total N content, measured by Kjeldahl's method, and subsequently multiplied by 5.7 (Abdeldaym *et al.*, 2018).
5. Bulb phenol content: The extract of the fertilized fresh bulb was acquired via the procedures stated by Hernández *et al.* (2007) with minimal modifications.

Summarizing, 30 g of the bulb sample was homogenized with 10 mL of 80% ethanol utilizing a homogenizer (IKA Works, Wilmington, NC, USA). Then homogenate was centrifuged at 15,000 rpm for 12 min. The supernatant was gathered, and the precipitate was re-extracted using 5 mL of 80% ethanol, maintaining the same conditions as before. The filter paper (Whatman No. 1) was used to filter the obtained supernatants. The filtrate was kept at 5°C until it was used for determining the total phenolic content. The total phenolic content in the bulb extract was quantified spectrophotometrically by employing the Folin-Ciocalteu reagent, with gallic acid serving as the reference standard. The findings were presented as mg. gallic acid/100 g for fresh bulb.

1. The phosphomolybdic acid method, as per AOAC (1990), was used to determine the total carbohydrates in bulbs. Around 2 grams of the sample were ground with 10 mL of 80% ethanol utilizing a mortar and pestle, and the mixture was then strained via Whatman filter paper. The residue and filter were gathered separately. The alcohol residue was transferred into a 250 mL conical flask. Five milliliters of concentrated HCl and 150 mL of distilled water were introduced into the flask. The sample was subjected to hydrolysis for 30 minutes and then allowed to cool to ambient temperature. Na_2CO_3 was gradually introduced till the pH of the extract reached neutrality (pH = 7). The filtrate was passed through a filter. Then, 20 mL of the filtrate was transferred into a 150 mL conical flask, to which 2 mL of concentrated HCl was introduced. The sample was subjected to hydrolysis

for 30 minutes and subsequently allowed to cool to ambient temperature. Na_2CO_3 was gradually incorporated until the solution reached a neutral pH of 7. A 0.5 mL aliquot of the sample was moved into a test tube, subsequently 1 mL of Somogy's reagent was added. The blend was completely combined and diluted with water to a final volume of 10 mL. The absorbance of the resulting solution was then assessed using a spectrophotometer at 560 nm.

2. Total fresh bulb yield of each treatment was computed by weight the onion bulb after harvesting directly using the digital balance. The results were expressed as a ton/ hectare (T/ha)

***Statistical analysis*:** The data of experiment were exposed to the one-way analysis of variance (ANOVA). The Tukey test at a 5% level of significance (LSD) was employed to compare the means, utilizing Statistical Software (version 2004). The principal component analysis of the different sources of phosphorus supplementation on agro-physological properties of onion plants.

RESULTS AND DISCUSSION

***Plant height, yield and its components*:** Data in Figure 1 (A, B, C & D) shows the plant height and onion production were significantly affected different sources of phosphorus fertilizer. Maximum plant height was noted in onion plants fertilized with Brandt Reaction, succeeded by Monoammonium phosphate and Phosphoric acid compared to the control treatment. In addition to their improvement ratio was reached 31.39%, 21.438% and 13.16%, respectively, compared with control treatment (Figure 1A). Such results were observed in total yield, bulb yield of onion plants significantly augmented by 25.56%, 24.15% and 19.6% for plants fertilized with Brandt Reaction, followed by Monoammonium phosphate and Phosphoric acid, respectively (Figure 1B), compared with untreated plants (control).

A similar trend was found in the fresh blub weight. Compared with the untreated plants (30.43g, Control), maximum fresh bulb weight was achieved in the plots treated Brandt Reaction (38.06g), and with Monoammonium phosphate fertilizers (37.5 g) followed by plots treated and Phosphoric acid fertilizers (35.1). Furthermore, result of current study exhibited that a different sources of phosphorus fertilizer (Brandt Reaction, Monoammonium phosphate, Phosphoric acid and Control) with 5.1, 4.77, 4.1, and 3.2 cm respectively has significant difference on bulb diameter of onion (Figure 1D), at 5% probability level. Lowest value of bulb diameter (3.2 cm) was recorded in the control treatment (no phosphorous) while highest values were noted in bulbs of plants fertilized with Brandt Reaction fertilizers (5.1 cm). the improvement in the plant growth and bulb yield could be attributed to increasing phosphorus application. Hence, Phosphorus is crucial for cellular functions, such as preserving membrane integrity, synthesizing biomolecules, and producing high-energy compounds. It also contributes to the process of cell division, the regulation of enzyme activity, and the metabolism of carbohydrates (Malhotra *et al.*, 2018; Khedr *et al.*, 2024). At the overall plant level, it promotes seed sprouting, enhances root growth, strengthens stems and stalks, supports flower and seed production, increases crop yield, and improves quality. Other researchers confirmed that the phosphorus supplementation increase the nutrient and water absorption which consequently improved the photosynthesis rate and the accumulation of photosynthates (Wang *et al.*, 2021), that play a vital role in the plant growth and blub yield (Arunachalam *et al.*, 2024; Hassan *et al.*, 2023).

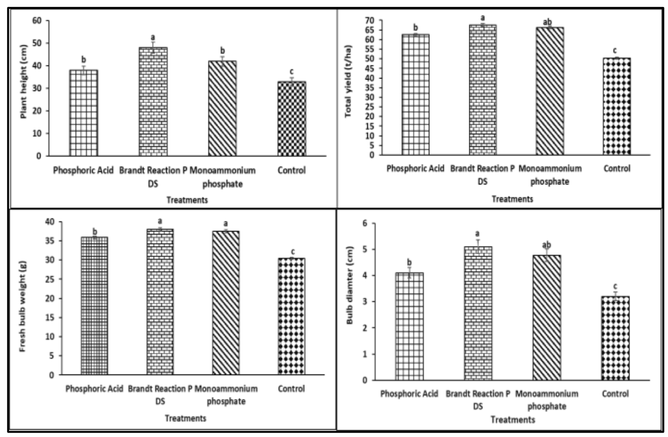

Figure 1. Influence of various sources of phosphorus on the Plant height, yield, and its components.

***Bulb nutrient content*:** The application if exogenous phosphorus significantly influenced on the concentration of endogenous nutrient, including K, P, N, Fe and Zn in the bulb tissues, as presented in Table 4. The maximum concentration of K, P, N, Fe and Zn was recorded in the plots fertilized with

Table 4. Influence of various sources of phosphorus on the endogenous nutrient concentrations in blub tissues.

Treatment	N (%)	P (%)	K (%)	Fe (ppm)	Zn (ppm)	Cu (ppm)
Phosphoric Acid	1.5b	0.17b	1.38a	140.3b	23.2b	6.95a
Brandt Reaction P DS	1.8a	0.21a	1.42a	145.6a	26.6a	7.80a
Monoammonium phosphate	1.7a	0.19a	1.39a	142.6a	24.5ab	7.31a
Control	1.2c	0.12c	1.36a	137.5c	21.8c	6.42a

Brandt Reaction and Monoammonium phosphate followed by Phosphoric Acid in comparison to the untreated plots (Control). In contrast, there isn't significant changed in the concentration of Cu between the treatments. The improvement in the accumulation of plants supplied with extra phosphors fertilizers could be linked to enhancing the root growth and development (Zhang *et al.*, 2023). Zhang *et al.* (2024) reported that the concentration of available P in the soil influences on organic acid exudation, shoot development, formation of cluster roots, root architecture, and alternative glycolytic and respiratory pathways. Under suitable P supply conditions, total root length, the total root volume, and total root surface area are upgraded, which consequently improve nutrient uptake and water absorption (Rajamanickam *et al.*, 2024). In conditions of phosphorus deficiency, there is a marked reduction in root growth, root length density, and specific root length, resulting in a proportional reduction in nutrient absorption (Kaur *et al.*, 2023).

***Bulb quality*:** Data in the Figure 2 showed that the nutritional quality of bulb significantly affected the different sources of phosphorus. The highest TSS, carbohydrate, total phenol content and protein content was observed in the bulbs grown in the plots fertilized with Brandt Reaction and Monoammonium phosphate and the lowest value were noted in the blubs grown in the control treatment. increasing the TSS, carbohydrate, total phenol content and protein content in the blubs suppled with extra phosphorus (P) probably is related to capability of P to improve nutrient uptake, enhance the photosynthesis rate energy transfer, and synthesis of metabolic compounds (Wang *et al.*, 2021).

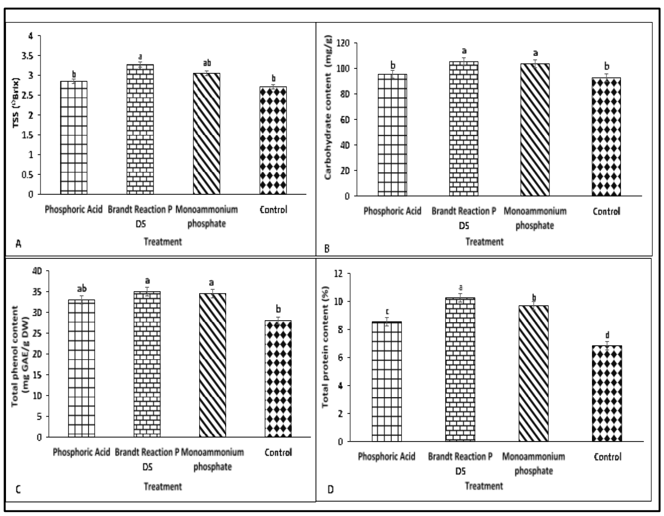

Figure 2. Effect of various sources of phosphorus on the bulb nutritional quality.

***Correlation study*:** Principal component analysis (PCA) of alterations in morphological and physicochemical properties of onion were presented in Figure 3. Considering the changes in plant growth and bulb quality, treated with different sources of phosphorus, 14 indexes of onion plants post receiving different sources of phosphors were integrated employing two-dimensional principal component analysis (PCA) with the SPSS 20.0 software. PCA was applied to further combine and examine the results of the onion plant's bulb quality indicators. The primary components (PCs) account for 99.1% of the overall variance in the dataset. The data set's variance was explained by PC1 and PC2 at rates of 95.29% and 3.81%, respectively. PC1 had strong positive loading for bulb diameter, total yield, TSS, total carbohydrate, total phenol content (TPC), N, K, and Zn.

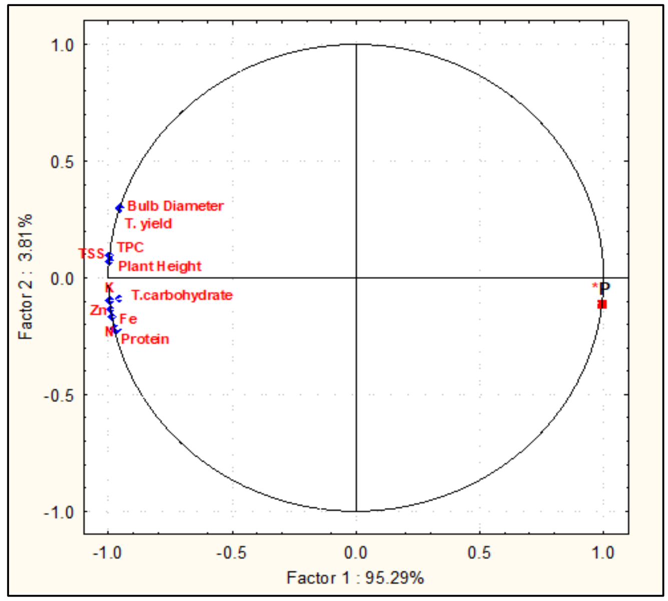

Figure 3. Principal component analysis of the main agro-physiological characteristics of fertilized onion plants with different sources of phosphorus.

***Conclusion*:** Our results suggested that the soil use of Brandt Reaction at a rate of 6Kg/ha improves the growth performance and bulb yield of onion plants. Furthermore, the previous fertilizer improves the nutritional quality of onion blub by increasing TSS, total carbohydrate, total phenol content (TPC), protein content, K, Fe, and Zn. Therefore, the positive supplementation of Brandt Reaction might be recommended to onion growers seeking to increase production and quality.

***Authors contributions statement*:** M.A. Gaafer, E.A. Abdeldaym, H.A. Hassan, designed, completed the experiments M. Ali, A.M. Ismail1, and E.A. Abdeldaym prepared the draft; EL-Mogy M. M., and E.A. Abdeldaym reviewed and finalized the draft.

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***Consent for publication*:** All authors submitted consent to publish this research article in JGIAS.

***SDGs addressed*:** Zero Hunger, Responsible Consumption and Production, Climate Action.

***Policy referred*:** Sustainable Fertilizer Management Policy; Food Security and Export Competitiveness Policy; Climate-Resilient Agricultural Policy.

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