https://doi.org/10.70882/tet3mz71
SCIENCE FORUM (JOURNAL OF PURE AND APPLIED SCIENCES) 26, (5 Special) (2026), 594 - 600

Science Forum (Journal of Pure and Applied Sciences)

Journal Homepage: https://atbuscienceforum.com.ng/index.php/jpas

Response of Phosphorus Availability in Phosphate Rock to the Type and Timing of Potassium Source Application, and Its Effect on Sorghum Growth and Yield

Douaa Hafedh Mousa
Al-Musayyib Polytechnic College, Al-Fur at Al-Awsat Technical University, Iraq

Abstract
A field experiment was conducted during the 2025–2026 autumn season at a private farm in the Al-Jabla district of Babil Governorate to evaluate the response of grain sorghum (white sorghum) grown in silty clay soil. The study investigated the influence of potassium—specifically the type of potassium source, application rate, and timing—on the availability of phosphorus from phosphate rock, as well as its effects on the growth and yield of the sorghum. The experiment involved two factors: the source of potassium (potassium nitrate, potassium chloride, and potassium sulfate) and the timing of its application (15, 30, and 45 days after sowing, as well as various combinations: 15+30 days, 15+45+30 days, and 15+30+45 days). Phosphate rock was also applied, and the overall experimental design comprised 63 experimental units. The results indicate that the optimal timing for fertilizer application is 15, 30, and 45 days after planting. For certain traits, potassium nitrate performed comparably to other fertilizer sources. Furthermore, the application of potassium fertilizer and phosphate rock influenced most of the soil's chemical properties; specifically, the cation exchange capacity ranged from 20.50–20.65 cmol(+)/kg, electrical conductivity from 2.51–2.62 dS/m, and soil pH from 7.28–7.45. Regarding physiological indicators, leaf area under different potassium fertilizer treatments measured 250.43, 240.42, and 245.17 cm^2/plant, respectively. In terms of yield, the use of potassium nitrate resulted in a significant increase, with total yield reaching 54.77 [units]. Moreover, for several of the yield-related traits studied, significant differences were observed in relation to the timing of fertilizer application, the type of fertilizer used, and the interaction between these two key factors.

Keywords
sorghum,
potassium,
phosphorus derived from phosphate rock

EISSN: 3156-5190 (Online)
ISSN: 1119-4618 (Print)
JPAS
Faculty of Science, ATBU Bauchi

Corresponding Author: Douaa Hafedh Mousa, Al-Musayyib Polytechnic College, Al-Fur at Al-Awsat Technical University, Iraq
. Email: douaa.mousa.ims@atu.edu.iq © 2026 Faculty of Science, ATBU Bauchi. All rights reserved

Introduction

White sorghum is the fifth most important crop within the Poaceae (grass) family, ranking as a significant global food crop in terms of both cultivation area and production volume. In Iran, white sorghum is cultivated over an area of 136,152 dunums, with a total production of 64,627 tonnes (Ministry of Agriculture of Iraq, 2014). Its importance stems from its versatility: it is used for the production of bread and baked goods, while its high protein content also makes it a primary ingredient in poultry feed (Attia et al., 2001) Its importance lies in its use in the production of bread and pastries, where it accounts for 30% of the ingredients. Furthermore, due to its high protein content (nearly 12%), it serves as a key component in poultry feed (Attia et al., 2001).

Moreover, the crop offers substantial yields within a single growing season. As a C4 (four-carbon) plant, it is capable of producing high yields of dry matter (Abu Dahahi, 2004). Phosphorus is an essential nutrient for plants, participating in all vital biological processes, such as respiration, energy metabolism, and cell division and development. It plays a crucial role in seed germination, as well as the development of root systems, stems, and buds (Teusuch, 2002). Typically, phosphorus is supplied through chemical fertilizers; however, due to the high cost of these fertilizers and their negative impact on the soil, alternative, more cost-effective sources of phosphorus are being explored. Phosphate rock is one such option—a naturally occurring substance composed of tricalcium phosphate. It has low solubility in water and a total phosphorus content of 30%, of which only 3% is in a form directly available for plant uptake.

It is characterized by a slow release of nutrients and presents certain challenges in terms of processing., The application of phosphate rock is somewhat limited; therefore, researchers have attempted to mix it with potassium to improve its solubility, thereby enhancing the availability of phosphorus. Potassium is an essential element for plants; it participates in photosynthesis, plays a role in various biological processes, and is capable of activating enzymes and regulating stomatal function (SUN, et al., 2024).

Materials and working methods

This experiment was conducted during the 2024-2025 autumn season in the Al-Jabla area of Babylon Governorate (32° N, 44° E), involving the cultivation of white sorghum in soil. The study aimed to investigate the effects of foliar potassium application on the yield and harvest components of two white sorghum varieties The study involves several factors. The first factor concerns the type of potassium fertilizer—specifically comparing potassium nitrate, potassium chloride, and potassium sulfate—with an application rate of 120 units for each.

The second factor is the timing of fertilizer application, which encompasses seven distinct schemes: 1) applying the entire amount of fertilizer at 15 days after planting; 2) applying the entire amount at 30 days after planting; 3) applying the entire amount at 45 days after planting; 4) splitting the fertilizer into two portions, applied at 15 and 30 days after planting; 5) splitting the fertilizer into two portions, applied at 15 and 45 days after planting; 6) splitting the fertilizer into two portions, applied at 30 and 45 days after planting; and 7) splitting the fertilizer into three portions, applied at 15, 30, and 45 days after planting., All experimental plots received an application of phosphate rock at a rate of 10 tonnes per hectare. The field soil was subsequently tilled, involving both plowing and harrowing (thorough seedbed preparation).

The experimental site was divided into three blocks, and autumn crops were sown on July 25, 2025. Each block was further subdivided into 21 experimental plots, resulting in a total of 63 plots; the experiment followed a randomized complete block design (RCBD) with three replications. Additionally, soil samples were collected at random from a depth of 0–30 cm for analysis, following the methods described by Black (1965) and Page (1982).

Table 1: Some physical and chemical properties of the study soil

Soil separates	Sand	g·kg⁻¹ 310
	Silver	g·kg⁻¹ 389
	Clay	g·kg⁻¹ 301
Soil texture		Clayey mixture
EC Electrical conductivity		DC Siemens.M-1 2.5
Cation exchange capacity (CEC)		19,3
Organic matter		8.79
Carbonate minerals		222.3
Soil reaction (pH)		7.62
Calcium (Ca^{2+})		mmol/L⁻¹ 7.41
Magnesium (Mg^{2+})		mmol/L⁻¹ 3.72
$^{2-}$ SO4		mmol/L⁻¹ 2.56
Cl^-		mmol/L⁻ 5.02
Sodium		2.82
$HCO3^-$		mmol/L⁻¹ 1.56
Available nitrogen		23.11
Available phosphorus		11.5
Available potassium		145.3

Regarding the preparation of phosphate rock: The raw material was sourced from the Akashat region in the western part of the province. Following grinding and crushing (for specific technical parameters, please refer to other Phosphate Fertilizer Manufacturing Plant / Ministry of Industry - Akashat sections), the phosphate rock was applied to each experimental unit at a rate of 10 tonnes per hectare.

Table 2/ Some chemical properties of phosphate rock

Chemical compounds	Weigh t percentage
Phosphorus pentoxide P205	21.47
Calcium oxide Ca	50.98
Magnesium oxide MgO	0.60
Silica SiO3	2.24
Iron and aluminum oxides R2RO3	0.67
Sulfur trioxide SO3	1.70
Fluorine F	2.88
Chlorine Cl	0.125

Results and discussion

1/ Cation exchange capacity

The results for Cation Exchange Capacity (CEC) (Table 3) indicate that the rate of potassium fertilizer application, the timing of application, and the interaction between these two factors all led to significant differences. Regarding the application rate, the mean CEC was highest at the A2 level (20.71 cmol(+)/kg) and lowest at the A3 level (20.55 cmol(+)/kg). In terms of application timing, the CEC value was highest at the B4 level (20.90 cmol(+)/kg) and lowest at the B1 level (19.46 cmol(+)/kg.

As for the interaction between these two factors, the A1B4 treatment combination yielded the highest mean value (22.07 cmol(+)/kg), while the A3B1 combination resulted in the lowest value (19.40 cmol(+)/kg) This leads to an increase in exchange capacity, thereby enhancing the soil's ability to retain potassium (Havlin .ed,2005). Consequently, there is a direct relationship between the soil's clay content and its potassium-(Gezahegn.eat,2025

Table 3: Effect of different potassium fertilizer sources and their application timing on ion-exchange capacity traits

Sources of Potassic Fertilizers	Application Timing							
	B1	2 .B	B3	B4	B5	B6	B7	Average
.A1	19.56	20.02	20.23	20.96	20.52	21.24	22.07	20.56
.A2	19.42	19.92	20.16	20.92	20.42	22.13	22.00	20.71
A3	19.40	20.13	20.13	20.83	20.50	21.03	21.86	20.55
Average	19.46	20.02	20.17	20.90	20.48	21.46	21.97	
LSD.0. B05	Potassium		Application Timing			Interaction		
	n.s		0.560			n.s		

Degree of interaction2/

The results in Table 4 indicate significant differences in the response levels based on the fertilizer application rate and the timing of application; furthermore, a significant interaction effect between these two factors was observed. Regarding the application rate, Level **(A** 1) yielded the highest response 7.44. while Level (A3) yielded the lowest. In terms of application timing 7.29, Level(B3) proved most effective 7.48, resulting in the highest response, whereas Level(B 6) was the least effective, resulting in the lowest response 7.22, Regarding the interaction between these two factors, the(B3A2) treatment yielded the best results, with a value of 7.53, while the(B6A3) treatment resulted in a value of 7.10. These differences are attributed to root exudates—specifically the release of hydrogen ions and carbonate ions—which influence soil pH. Furthermore, a higher calcium carbonate content in the soil enhances its buffering capacity, thereby preventing significant shifts in soil pH (Awwad, 1986).

Table 4: Effect of different potassium fertilizer sources and their timing of application on soil reaction (pH)

Sources of Potassic Fertilizers	Application Timing							
	B1	2 .B	B3	B4	B5	B6	B7	Average
.A1	7.51	7.46	7.48	7.42	7.47	7.36	7.40	7.44
.A2	7.32	7.46	7.53	7.40	7.38	7.22	7.27	7.36
A3	7.36	7.44	7.43	7.26	7.33	7.10	7.16	7.29
Average	7.39	7.43	7.48	7.36	7.39	7.22	7.27	7.29
LSD.0. B05	Potassium			Application Timing			Interaction	
	0.090			0.137			n,s	

The results in Table 5 indicate significant differences based on the timing of addition. Specifically, the value (A2) reaching 2.63 (in dS/m) is highest for Level 2 and lowest for Level (A1), reaching 2.45 (in dS/m). During the improvement phase, the B7 level yielded the highest value at 2.78 dS/m (compared to the B1 treatment), with an effective range of 2.31 dS/m.

Regarding interaction effects, the B7A2 combination produced the highest value at 2.86 dS/m, while the A1B1 combination yielded the lowest at 2.26 dS/m. This is attributed to the leaching effect of water on salts, which causes salts to migrate below the root zone; this process alters the salinity profile and improves soil salt concentrations, thereby creating a more favorable environment for plant growth (Al-Zaidi, 1989).

Table 5: Effect of different potassium fertilizer sources and their timing of application on electrical conductivity

Sources of Potassic Fertilizers	Application Timing							
	B1	2 .B	B3	B4	B5	B6	B7	Averag
.A1	2.26	2.30	2.46	2.36	2.37	2.72	2.72	2.45
.A2	2.42	2.50	2.60	2.66	2.52	2.85	2.86	2.63
A3	2.26	2.32	2.56	2.42	2.50	2.76	2.77	2.51
Average	2.31	2.37	2.54	2.48	2.46	2.78	2.78	
LSD.0. B05	Application Timing			Potassium			Interaction	
	n.s			0.196			n.s	

Paper Space /4

The results (Table 6) indicate significant differences in the trait of leaf area. Treatment (A 1) yielded the highest value248.99 (cm²/plant), while Treatment (A 2) yielded the lowest value 240.44. Regarding the application stage, Treatment (B 7) showed the highest value 259.8 (cm²/plant), and Treatment (B 2) showed the lowest 22.44. In terms of interaction effects, Treatment (A 1B7) produced the highest value 264.76(cm²/plant), whereas Treatment (A 1B2) produced the lowest value 215.96

Table 6: Effect of different potassium fertilizer sources and their timing of application on leaf area

Sources of Potassic Fertilizers	Application Timing							
	B1	2 .B	B3	B4	B5	B6	B7	Average
.A1	254.44	215.96	241.86	259.52	254.88	261.6	264.72	248.99
.A2	237.96	233.90	227.1	242.10	246.17	247.1	248.76	240.44
A3	240.40	235.46	231.52	250.06	250.57	248.30	259.8	245.15
Average	244.26	228.44	233.49	250.56	250.54	246.33	269.76	
LSD.0. B05	Potassium			Application Timin			Interaction	
	5.206			7.951			13.773	

Total plant yield (ton/ha) /5

The results presented in Table 7 indicate significant differences in total plant yield. Treatment (A 1) performed best, with a yield of 7,78, while Treatment (A 2) yielded the lowest, at 4.82. Regarding the timing of application, Treatment (B 7) resulted in the highest yield 8.12 whereas Treatment (B 1) produced 5.03 the lowest, In terms of the interaction between factors (B7), Treatment 8. 12 performed best, with a (B1) yield of 5.03, Regarding the trading impact of the individual components, (A1B7) performed the best, with a value of 10.80, while (A2B1) recorded the lowest overall value, at 4.41,.

The increase in yield is attributed to the application of potassium fertilizer. Potassium promotes photosynthesis, increases leaf area, enhances enzyme activity, and facilitates the transport of synthesized compounds to storage sites within the grains (Abu Al-Dahi and Al-Younis, 1988),

Furthermore, this is attributed to the significant role phosphorus plays in enhancing and promoting root branching, which helps plants absorb more nutrients from the soil (et al., 2005). By acquiring essential nutrients, plants are able to develop a robust vegetative growth system, thereby effectively carrying out their various critical biological functions.

Additionally, an increase in potassium concentration leads to the displacement of calcium within phosphate rock; this process, in turn, facilitates the decomposition of the phosphate rock and increases the concentration of phosphorus (Onikata et al., 1999).

Table 7: Effect of different potassium fertilizer sources and their timing of application on the total plant yield trait

Sources of Potassic Fertilizers	Addition schedules							
	B1	2 .B	B3	B4	B5	B6	B7	Average
.A1	5.63	6.26	6.71	7.82	8.66	8.90	10.80	7.78
.A2	4.41	4.55	4.80	4.87	4.90	5.02	5.25	4.82
A3	5.06	5.41	5.41	6.52	6.50	7.63	8.31	7.33
Average	5.03	5.40	5.64	6.40	6.68	7.18	8.12	
LSD.0. B05	Potassium		Addition schedules				Interaction	
	0.03		0.04			0.08		

References

Abu Dahi, Y. (2004). *Soil–water–plant relationships*. Department of Soil and Water Sciences, College of Agriculture, University of Baghdad.

Abu Dahi, Y. M., & Al-Younis, M. A. (1988). *Plant nutrition guide*. College of Agriculture, University of Baghdad, Ministry of Higher Education and Scientific Research.

Al-Younis, A. A. (1993). *Production and improvement of field crops*. University of Baghdad, Ministry of Higher Education and Scientific Research.

Al-Zubaidi, B. M. (2010). *Effect of organic and potassium fertilizers on potassium availability, growth, and yield of maize* [Master's thesis, College of Agriculture, Iraq].

Atya, H. J., Khudair, A. J., & Dhafer, Z. (2001). Effect of plant density and nitrogen fertilization on the growth and yield of sorghum. *Iraqi Journal of Agricultural Sciences, 32*(5), 143–150.

Awad, K. M. (1986). *Principles of soil science* (pp. 15–31). University of Basrah, Ministry of Higher Education and Scientific Research.

Gezahegn, A., Selassie, Y. G., Agegnehu, G., Addisu, S., Mihretie, F. A., Kohira, Y., & Sato, S. (2025). Synergistic effect of aquatic weed biochar and inorganic fertilizer on soil properties, maize yield, and nitrogen use efficiency on Nitisols of northwestern Ethiopian highlands. *Journal of Agriculture and Food Research*.

Havlin, J. L., Beaton, J. D., Tisdale, S. L., & Nelson, W. L. (2017). *Soil fertility and fertilizers: An introduction to nutrient management* (8th ed.). Pearson.

Ministry of Agriculture, Planning Department. (2014). *Statistics of sorghum cultivation in Iraq*. Ministry of Agriculture, Iraq.

Onikata, M., Kondo, M., Hayashi, N., & Yamanaka, S. (1999). Complex formation of cation-exchanged montmorillonites with propylene carbonate: Osmotic swelling in aqueous electrolyte solutions. *Clays and Clay Minerals, 47*(5), 672–677.

Page, A. L., Miller, R. H., & Keeney, D. R. (Eds.). (1982). *Methods of soil analysis: Part 2. Chemical and microbiological properties* (2nd ed.). American Society of Agronomy.

Phosphate Fertilizer Manufacturing Plant, Ministry of Industry. (n.d.). *Phosphate fertilizer manufacturing plant, Akashat, Iraq*.

Sun, K., Zhang, J., Wang, Y., Qian, W., Gong, S., Li, Z., et al. (2024). Foliar spraying of KH_2PO_4 promotes shoot development by inducing stomatal opening and sugar transport in tea leaves. *Scientia Horticulturae*.

Teutsch, C. (2002). *Warm-season annual grasses for summer forage* (Publication No. 418-004). Southern Piedmont Agricultural Research and Extension Center, Virginia Cooperative Extension.