Effect of Sources and Application Timings of Potassium Fertilizer on the Growth and Yield of Maize (*Zea mays L.*)

Amna J. H. Al-Mamouri [1*], Sabah Latif Assi[2]

[1,2]Department Of Soil and Water Techniques- Al-Musayyab Technical College- Al-Furat Al-Awsat Technical University -Babylon--Iraq.

*Corresponding author's email: [1]amna.jassim.tcm41@student.atu.edu.iq

Email addresses of coauthors: [2]com.sbh1@atu.edu.iq

Abstract

A field experiment was conducted during the autumn season of 2024 in Al-Wutayfiyah area, 6 km from Al-Mussaib Technical College, Babylon Governorate, Iraq, to evaluate the effects of different potassium fertilizer sources and application timings on the growth and yield of maize (Zea mays L.). The study consisted of two factors. The first factor was potassium fertilizer sources: potassium nitrate, potassium chloride, and potassium sulfate (A1, A2, and A3, respectively). The second factor was the application timing: a single dose at 15, 30, or 45 days after planting, or split doses at 15 + 30, 15 + 45, 30 + 45, and 15 + 30 + 45 days after planting, denoted as B1, B2, B3, B4, B5, B6, and B7, respectively.

The results showed that potassium fertilizer sources significantly affected maize growth and yield parameters. Potassium nitrate consistently gave the highest values for chlorophyll content, leaf area, plant height, vegetative dry weight, and 500-grain weight, especially when applied in three equal splits (B7). These findings emphasize that selecting the appropriate source of potassium fertilizer and optimizing its application timing are effective strategies to overcome challenges related to nutrient availability in calcareous soils. Under the conditions of central Iraq, split application of potassium nitrate in particular improved nutrient use efficiency and contributed to better growth and yield performance of maize.

Keywords: Potassium fertilizers, application timings, rock phosphate.

This study is extracted from the M.Sc. thesis of the first author.

Introduction

Maize (Zea mays L.) is one of the most important cereal crops worldwide, providing food for people and feed for livestock. In Iraq, it plays a growing role in food security and the livelihood of farming families, yet production often falls short of its potential due to limitations in soil fertility and crop nutrition .[2,3,8]

Among the essential nutrients, potassium (K) is required in relatively large amounts and ranks third after nitrogen and phosphorus in crop nutrition. It plays key roles in photosynthesis, stomatal regulation, enzyme activation, and carbohydrate translocation [12,18,22]. For maize, these physiological functions translate into practical benefits for farmers: stronger stems, greener leaves, improved grain filling, and higher yields that directly affect family income and food availability [19,20]. When potassium is deficient or mismanaged, the result is poor crop vigor, reduced grain weight, and lower harvests.

Although potassium makes up about 2.59% of the Earth's crust, most of it is bound in mineral forms unavailable to plants [10,14]. In the calcareous soils that dominate central and southern Iraq, the problem is more severe: potassium is easily fixed or lost through leaching, reducing its availability for maize

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growth [7,13]. Farmers often respond by applying fertilizers, but efficiency remains low, raising production costs and environmental concerns.[6,11]

Research suggests that splitting potassium application across crop growth stages enhances nutrient use efficiency and yield [1,13]. Furthermore, differences among potassium fertilizer sources—such as nitrate, chloride, and sulfate—affect plant growth and yield because of variations in solubility, accompanying anions, and their interactions with soil pH [8,19,23]. However, limited studies in Iraq have jointly addressed both fertilizer source and application timing under local soil and climatic conditions. This leaves farmers uncertain about the most effective practice.

Therefore, this study was designed to evaluate the effects of potassium fertilizer sources (nitrate, chloride, sulfate) and application timings (single and split doses) on the growth and yield of maize under calcareous soils in central Iraq. The objective was to identify the best management strategy that improves nutrient use efficiency, increases maize productivity, and offers practical recommendations for farmers in the region.

Materials and Methods

A field experiment was conducted in one of the fields of the Al-Wutayfiyah area, located 6 km from the Al-Mussaib Technical College, within the Al-Mussaib Project area, approximately 36 km north of Babylon Governorate. The experiment aimed to evaluate the growth and yield of maize (Zea mays L.) during the autumn 2024 season using the Dutch hybrid cultivar, focusing on the effects of potassium fertilizer sources and application timings under calcareous soil conditions. The soil was classified as clay loam in texture and, according to the USDA Soil Taxonomy [14], was identified at the great group level as Typic Torrifluvent.

Field preparation involved cross plowing with a rotary plow, followed by leveling operations. The experimental area was divided into three blocks (replicates), with a 1 m buffer between blocks. Each block was subdivided into 21 experimental units, each consisting of two planting rows, with 10 plants per row. The spacing between plants within a row was 0.25 m, and the row spacing was 0.75 m, giving an experimental unit area of 6 m^2. A 1 m buffer was maintained between experimental units to prevent treatment interference.

The experiment included two factors:

Factor 1 – Potassium fertilizer source:

Potassium nitrate (A1)

Potassium chloride (A2)

Potassium sulfate (A3)

Each applied at a rate of 120 kg K_2O ha^{-1}.

Factor 2 – Potassium application timing:

B1 – Full dose applied 15 days after planting

B2 – Full dose applied 30 days after planting

B3 – Full dose applied 45 days after planting

B4 – Dose split into two equal parts applied at 15 and 30 days after planting

B5 – Dose split into two equal parts applied at 15 and 45 days after planting

B6 – Dose split into two equal parts applied at 30 and 45 days after planting

B7 – Dose split into three equal parts applied at 15, 30, and 45 days after planting

The experiment comprised 63 experimental units, arranged in a randomized complete block design (RCBD) with three replications. The total number of treatments was (3 × 7) = 21 treatments, each replicated three times. Potassium fertilizers (potassium chloride and potassium nitrate) were applied according to the designated schedules. Urea fertilizer was applied at half the recommended rate (100 kg

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N ha^{-1}) after germination according to the treatment schedule.

After harvest, plant growth and yield traits were measured, including chlorophyll content (SPAD units) on fully expanded leaves using a SPAD chlorophyll meter at the tasseling stage, leaf area (cm^2 plant^{-1}) calculated as Leaf Length × Leaf Width × 0.75 for selected fully expanded leaves, plant height (cm) measured from soil surface to the tip of the tassel at physiological maturity, shoot dry weight (g plant^{-1}) determined by harvesting above-ground parts and oven-drying at 70°C until constant weight, weight of 500 grains (g) obtained by randomly selecting and weighing 500 grains from each plot, and grain yield (t ha^{-1}) harvested from each plot and adjusted to 14% moisture content. The data were statistically analyzed, and differences between treatment means were evaluated using the Least Significant Difference (LSD) test at a significance level of 0.05 with the Statistical Analysis System [17].

Table 1: Selected physical and chemical properties of the experimental soil before planting.

Attributes		Values	Units of measurement
Electrical conductivity (ECe)		2.5	ds m-1
Soil pH (pH)		7.62	
Organic matter		8.81	gm kg-1 soil
carbonate minerals		223.3	
Cation exchange capacity (CEC)		19.4	cmol kg-1
Dissolved ions in the soil solution	Ca++	7.43	mmol L^{-1}
	Mg++	3.75	
	Na+	2.83	
	K+	0.34	
	Cl-	5.03	
	HCO3-	1.97	
	SO4--	2.57	
Available nitrogen		3.14	mg kg-1 soil
Available phosphorus		11.5	
Available potassium		165.4	
Soil horizons	Sand	310	%
	Silt	301	
	Clay	389	
soil texture		Clay Loam	

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Results and Discussion

Chlorophyll Content in Plants

The results presented in Table (2) indicate significant differences among the levels of the rock phosphate addition factor, the potassium application stage factor, and their interaction in terms of chlorophyll content.

For the potassium fertilizer source factor, treatment A1 (potassium nitrate) recorded the highest mean chlorophyll value (44.03 SPAD units), compared with A2 (potassium chloride), which recorded the lowest mean (40.50 SPAD units).

Regarding the potassium application timing factor, treatment B7 (application in three equal splits at 15, 30, and 45 days after planting) achieved the highest mean chlorophyll value (48.26 SPAD units), while B2 (single application at 30 days) recorded the lowest mean (35.97 SPAD units).

For the interaction between the two factors, the combination A1B7 (potassium nitrate applied in three equal splits) produced the highest mean chlorophyll content (48.90 SPAD units), whereas A2B2 (potassium chloride applied as a single dose at 30 days) recorded the lowest mean (30.20 SPAD units).

Table 2. Effect of different potassium fertilizer sources on rock phosphate dissolution and chlorophyll content (SPAD units).

Application Timing								
Fertilizers	B1	B2	B3	B4	B5	B6	B7	Average
A1	42.93	40.13	44.23	46.53	45.00	40.50	48.90	44.03
A2	36.77	30.20	40.93	39.87	45.10	41.87	48.73	40.50
A3	48.03	37.57	41.47	37.43	41.57	42.17	47.13	42.20
Average	42.58	35.97	42.21	41.28	43.89	41.51	48.26	
LSD 0.05		Potassium		Application Stage		Interaction		
		2.22		3.40		5.88		

.*Leaf Area (cm² plant⁻¹)*

The results in the table (3) reveal that leaf area characteristics were significantly affected by the rock phosphate addition factor levels, potassium application stage factor levels, and interaction between the two factors.

he potassium source factor recorded the highest value for treatment A1 (potassium nitrate) with a mean leaf area of 250.44 cm^2 $plant^{-1}$ and the treatment with lowest value for A2 (potassium chloride), which recorded 240.43 cm^2 $plant^{-1}$. The parameter B7 (three equal splits at 15, 30, and 45 days after planting) had the highest mean leaf area (257.77 cm^2 $plant^{-1}$) among potassium application timings, while B2 (single application at 30 days) had the lowest mean area (228.44 cm^2 $plant^{-1}$).

For interaction, combination A1B7 (three equal splits using potassium nitrate), with a mean leaf area of 264.37 cm^2 $plant^{-1}$, was the best treatment, while A2B3 (single application using potassium chloride at 45 days) had the lowest mean leaf area of 227.00 cm^2 plant.

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Table 3. Effect of different potassium fertilizer sources on rock phosphate dissolution and leaf area (cm^2

Application Timing								
Fertilizers	B1	B2	B3	B4	B5	B6	B7	Average
A1	254.43	215.97	241.87	259.53	254.87	261.7	264.73	250.44
A2	237.97	233.90	227	242.10	246.17	247.1	248.77	240.43
A3	240.40	235.47	231.53	250.07	250.7	248.30	259.8	245.18
Average	244.27	228.44	233.47	250.57	250.58	252.37	257.77	
LSD 0.05		Potassium		Application Stage		Interaction		
		5.21		7.95		13.77		

$plant^{-1}$).

Plant Height (cm)

The analysis of variance showed results in Table (4) to indicate that plant height differed significantly with respect to the levels of rock phosphate addition, potassium application timing, and their interaction.

The growth of plants in centimeters is influenced by the potash source factor. Among the sources, A1 (potassium nitrate) showed a plant mean height of 196.65 cm, while the shortest height was produced by A2 (potassium chloride) at 165.98 cm mean.

In potassium time of application, B7 (three equal splits at 15, 30, and 45 days after planting) achieved the highest mean plant height of 207.50 cm; whereas B3 (single application at 45 days) recorded the least mean of 169.53 cm.

For the interaction of two factors, A1B7 (potassium nitrate applied in three equal splits) gave the highest mean plant height of 236.20 cm, while A2B3 (potassium chloride applied single dose at 45 days) recorded the lowest mean of 155.93 cm.

Table 4. Effect of different potassium fertilizer sources on rock phosphate dissolution and plant height (cm).

Application Timing								
Fertilizers	B1	B2	B3	B4	B5	B6	B7	Average
A1	180.40	179.80	177.40	208.77	201.47	192.50	236.20	196.65
A2	160.77	161.63	155.93	169.23	170.53	170.00	173.73	165.98
A3	177.83	172.47	175.27	199.80	186.60	182.63	212.57	186.74
Average	173.00	171.30	169.53	192.60	186.20	181.71	207.50	
LSD 0.05		Potassium		Application Stage		Interaction		
		1.75		2.67		4.63		

Dry Weight of the Vegetative Part (g plant^{-1})

The results shown in Table (5) indicate significant differences among the levels of the rock phosphate addition factor, the potassium application stage factor, and their interaction in terms of plant dry weight.

For the potassium fertilizer source factor, treatment A1 (potassium nitrate) recorded the highest mean dry weight (176.72 g plant^{-1}), compared with A2 (potassium chloride), which recorded the lowest mean (157.73 g plant^{-1}).

Regarding the potassium application timing factor, treatment B7 (application in three equal splits at 15, 30, and 45 days after planting) achieved the highest mean dry weight (172.84 g plant^{-1}), while B3 (single application at 45 days) recorded the lowest mean (163.04 g plant^{-1}).

For the interaction between the two factors, the combination A1B7 (potassium nitrate applied in three equal splits) produced the highest mean dry weight (181.90 g plant^{-1}), whereas A2B3 (potassium chloride applied as a single dose at 45 days) recorded the lowest mean (151.73 g plant^{-1}).

Table 5. Effect of different potassium fertilizer sources on rock phosphate dissolution and dry weight of the vegetative part (g plant^{-1}).

Application Timing								
Fertilizers	B1	B2	B3	B4	B5	B6	B7	Average
A1	171.70	174.27	174.63	178.27	178.93	177.33	181.90	176.72
A2	156.83	153.63	151.73	160.37	160.17	160.33	161.07	157.73
A3	162.17	162.13	162.77	167.00	162.37	166.10	175.57	165.44
Average	163.57	163.34	163.04	168.54	167.16	167.92	172.84	
LSD 0.05		Potassium		Application Stage		Interaction		
		1.68		2.57		4.45		

Weight of 500 Grains (g)

The results presented in Table (6) reveal significant differences among the levels of the rock phosphate addition factor, the potassium application stage factor, and their interaction in terms of the weight of 500 grains.

For the potassium fertilizer source factor, treatment A1 (potassium nitrate) recorded the highest mean value (140.97 g), compared with A2 (potassium chloride), which recorded the lowest mean (132.21 g).

Regarding the potassium application timing factor, treatment B7 (application in three equal splits at 15, 30, and 45 days after planting) achieved the highest mean value (141.42 g), while B3 (single application at 45 days) recorded the lowest mean (130.80 g).

For the interaction between the two factors, the combination A1B7 (potassium nitrate applied in three equal splits) produced the highest mean value (150.13 g), whereas A2B1 (potassium chloride applied as a single dose at 15 days) recorded the lowest mean (121.07 g).

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Table 6. Effect of different potassium fertilizer sources on rock phosphate dissolution and the weight of 500 grains (g).

Application Timing								
Fertilizers	B1	B2	B3	B4	B5	B6	B7	Average
A1	135.33	133.37	135	145.53	148.6	138.8	150.13	140.97
A2	124.07	128.27	132.47	135.10	133.23	133.97	138.37	132.21
A3	133.07	133.9	126.57	134.73	132.3	132.97	135.77	132.76
Average	130.82	131.84	131.34	138.46	138.04	135.24	141.42	
LSD 0.05		Potassium		Application Stage		Interaction		
		2.14		3.26		5.65		

Discussion

According to the results in Tables (2–6), potassium nitrate along with rock phosphate ranked very high for improvement in growth parameters measured and named chlorophyll content, leaf area, plant height, shoot dry weight, and weight of 500 grains. Potassium sulfate was the second-best treatment, while potassium chloride always registered the least values .

On comparing among timings of application, treatment B7 (potassium nitrate applied in three equal splits at 15, 30, and 45 days after planting) recorded the highest mean values for all studied growth parameters: chlorophyll content (48.90 SPD), leaf area (246.73 cm^2 $plant^{-1}$), plant height (236.20 cm), shoot dry weight (181.90 g $plant^{-1}$), and weight of 500 grains (150.13 g) .

For potassium sulfate also, the highest means were associated with B7: chlorophyll content (47.13 SPD), leaf area (259.80 cm^2 $plant^{-1}$), plant height (212.57 cm), shoot dry weight (175.57 g $plant^{-1}$), and weight of 500 grains (135.77 g). In contrast, potassium chloride was again at the bottom; for B7, chlorophyll content (48.73 SPD), leaf area (248.77 cm^2 $plant^{-1}$), plant height (173.73 cm), shoot dry weight (161.07 g $plant^{-1}$), and weight of 500 grains (138.37 g).

The superiority of potassium nitrate with rock phosphate may be attributed to the nitrification of ammonium ions released from the fertilizer, which increases hydrogen ion release and reduces soil pH, thereby enhancing rock phosphate dissolution. This agrees with findings reported by [9] and [6] . The increased availability of phosphorus plays a key role in the synthesis of tryptophan, an amino acid responsible for cell elongation and division in stem tissues, thus promoting plant height consistent with [21].

Nitrogen is a fundamental component in the synthesis of essential biomolecules within plant cells and is directly involved in physiological and biochemical processes related to growth and yield. Similar observations were reported by[2], who highlighted the role of biofertilizers and organic fertilization in enhancing soil characteristics that support crop growth. It is a primary constituent of amino acids, proteins, and chlorophyll, and it enhances vegetative cell expansion and proliferation. The added phosphorus also contributes to leaf area facilitating energy transfer for biochemical processes, thereby enhancing leaf expansion. This aligns with the observations of [15]

Higher potassium ion concentrations in the soil can displace calcium bound in rock phosphate, promoting phosphate dissolution and increasing phosphorus availability [14]. Phosphorus, in turn, strengthens root branching, improves nutrient uptake, and enhances photosynthetic performance, leading to better carbohydrate transport to grains and increased 500-grain weight, as noted by [12] and [5].

In the case of potassium sulfate, its sulfate ions contribute to carbonic acid formation, lowering soil pH and promoting rock phosphate dissolution, albeit to a lesser extent than potassium nitrate [23]. This is consistent with [11], who reported that improved phosphorus availability enhances maize growth and yield.

Potassium also plays a significant role in CO_2 exchange, stomatal regulation, and water conservation, especially under moisture stress, thereby increasing chloroplast development and chlorophyll concentration [20]. Increased development by increasing its uptake and leaf area and plant height (Tables 3 and 4) enhance photosynthetic capacity, resulting in higher assimilate production and improved translocation to developing grains, which boosts grain weight—findings supported by [8].

The improvement in yield attributes (plant height, dry matter yield, and grain weight) with potassium fertilizers (nitrate, sulfate, and chloride) can also be linked to their role in stimulating photosynthesis, activating enzymes, and strengthening stem tissues via sclerenchyma cell development, which improves structural integrity and biomass accumulation [1,7,13].

The greater efficiency of potassium nitrate compared with potassium sulfate and chloride may be due to its high solubility and its provision of both nitrate (NO_3^-) and potassium (K^+) ions—two essential nutrients required in relatively large quantities by plants. Nitrate is the preferred nitrogen form for uptake, enhancing endosperm development and protein synthesis in grains, thus increasing grain weight. This is in agreement with[19,3], who reported that KNO_3 application improved maize yield and quality.

Conclusions

The application of different potassium fertilizer sources (nitrate, sulfate, and chloride) at varying timings significantly influenced maize growth and yield. Potassium nitrate consistently outperformed other sources, especially when applied in three equal splits at 15, 30, and 45 days after planting, resulting in the highest chlorophyll content, leaf area, plant height, shoot dry weight, and 500-grain weight. Split application of potassium nitrate also enhanced nutrient use efficiency and promoted better phosphorus availability through improved rock phosphate dissolution. These findings indicate that selecting the appropriate potassium source and optimizing its application timing is a practical strategy to maximize maize productivity under calcareous soil conditions in central Iraq.

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