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RESEARCH ARTICLE

The effect of potassium fertilizer and planting dates on the growth and production of maize (*Zea mays* L.)

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Abstract

An agricultural field experiment was conducted in Ramadi City, Western Iraq, during the fall season of 2023 to evaluate the effects of 3 planting dates (25 March, 5 April and 15 April) and 3 potassium fertilizer levels (100, 150 and 200 kg K_2O ha^{-1}) on maize (*Zea mays* L.) variety Buhuth 106. Variations in planting dates significantly influenced plant height, leaf area, ear length, number of ears per plant, 300-grain weight and total grain yield. Among the tested dates, planting on 25 March resulted in the highest values for all measured traits, with plant height, leaf area, ear length, number of ears per plant, 300-grain weight and grain yield reaching 202.00 cm, 3990 cm^2, 15.138 cm, 1.824, 73.82 g and 4.372 t ha^{-1}, respectively. Significant differences were also observed among potassium fertilizer levels for the same traits. Application of potassium at 100 kg K_2O ha^{-1} produced the highest mean values across all measured parameters, recording 187.156 cm plant height, 3490 cm^2 leaf area, 13.413 cm ear length, 1.752 ears per plant, 71.15 g 300-grain weight and 3.301 t ha^{-1} grain yield. The combined effect of the experimental variables also demonstrated a clear influence on grain yield, as planting on 25 March combined with the application of 100 kg K_2O per hectare resulted in the highest recorded grain yield of 5.210 tonnes.

Keywords: grain yield; growth characteristics; planting dates; potassium fertilization; *Zea mays*

Introduction

Maize (*Zea mays* L.) occupies the third position worldwide, following wheat and rice, in terms of cultivated area and total production (1). Its grains are used in the manufacture of pastries and in the composition of concentrated poultry and animal feed, in addition to being used as human food in poor countries due to its high content of proteins, carbohydrates, minerals and oil, as well as some vitamins (1). Although this crop holds significant importance, its productivity per unit area remains low. In Iraq, the cultivated area of maize in 2017 reached approximately 57.2 thousand hectares, yielding a total production of 185.3 thousand tonnes (2). The significant gap in the productivity rate necessitates conducting scientific and applied studies to address this issue. Research has shown that potassium fertilization contributes significantly to enhancing plant growth and productivity, as potassium is one of the major nutrients that plants require in large quantities; second only to nitrogen-as the average content of plant tissues reaches 1.5 % and may rise to 8 % of the dry weight, as seen in tobacco tissues (3). Additionally, potassium has an effective role in improving water use efficiency required to produce 1 g of yield and in reducing overall water consumption (4). In addition, it enhances the plant's ability to tolerate drought conditions and increases its resistance to extreme cold, without negatively affecting growth, productivity, cell division, resistance to lodging or susceptibility to plant diseases. Pollen grains are greatly affected by high temperatures and lose their ability to pollinate within a short period at temperatures above 35 °C. Therefore, we see that the yield of maize in spring cultivation is less than that of autumn cultivation. It is known that spring cultivation begins in the second half of March, when the temperature ranges between 22–28 °C. Since the male organs mature within 2 months of cultivation, i.e., around mid-May, when the temperature has risen to between 35–40 °C. Therefore, we see that the pollination rate in spring cultivation is low and ranges approximately between 50–70 %, depending on the air temperature. Accordingly, the yield is less than that of the autumn crop (5). Therefore, this study aimed to identify the optimal potassium fertilizer level and the most suitable planting date to achieve maximum vegetative development and grain yield.

Materials and Methods

An agricultural field experiment was carried out during the 2023 spring growing season in a farmer's field located in Ramadi City, the administrative center of Al-Anbar Province Iraq. Three levels of potassium fertilizer were used in the experiment: 100, 150 and 200 kg K_2O. ha^{-1}, all of which were added mixed as basal. The plants were planted on three planting dates: March 25, April 5 and April 15. The experimental land was plowed, smoothed and leveled and then divided into experimental units with dimensions of 2 × 3

m. Each experimental unit was composed of 4 planting rows, with each row measuring 3 m in length, the spacing between rows was 50 cm and the distance between planting holes along each row was 25 cm (6). A spacing of 1.5 m was maintained between each experimental unit to ensure proper isolation and to prevent overlap or interference between treatments. Random soil samples were collected from the study site prior to planting, at a depth of 0–30 cm, to assess some of its physicochemical properties. Then, the phosphate fertilizer was incorporated into the soil in a single dose at a rate of 100 kg ha^{-1} in the form of triple superphosphate. The nitrogen fertilizer was applied uniformly at a rate of 200 kg N ha^{-1} in the form of urea (46 % N) in two batches, the first immediately after germination and the second at flowering. The experiment was conducted following a Randomized Complete Block Design (RCBD) to ensure the accurate evaluation of treatments under controlled field conditions. Immediately after planting, the experimental field was initially irrigated and subsequent irrigation was carried out as needed throughout the growing period. periodically depending on the soil moisture and plant condition. The experimental land was turfed twice during the growing season; the corn stalk borer (*Sesamia cretica*) was managed through the application of granular diazinon insecticide (6) (Table 1).

Ten randomly selected plants were taken from each experimental unit to assess the following traits:

1. Plant height (cm)
2. Leaf area (cm^2): Calculated using the following formula: (Leaf length below the upper ear leaf)^2 × 0.75 (7).
3. Ear length was recorded by counting ears per individual plant
4. Weight of 300 grains (g): A total of 300 grains were counted and weighed and the final weight was adjusted to a standard grain moisture level of 15.5 % (8).
5. Kernel yield (t ha^{-1})

The data for the studied traits were statistically analyzed based on the experimental design using the Gen Stat software. The Minimum Significant Difference (MSD) test was employed to determine statistically significant differences between means at the 5 % probability level.

Table 1. Physical and chemical properties of the experimental soil prior to planting (2023)

Traits	Value
pH	7.91
ECe (dS m^{-1})	2.38
Ready potassium (ppm)	132
Ready phosphorus (ppm)	8.1
Soluble nitrate (ppm)	19.01
Lime (%)	23.2
Gypsum (%)	8.7
Organic matter (%)	1.04
Sand g kg^{-1} soil	93
Clay g kg^{-1} soil	386
Green g kg^{-1} soil	515
Tissue	Silty clay mixture

Results and Discussion

Plant height

It is evident from Table 2 that a significant increase was observed in shoot height values with increasing fertilizer levels of potassium addition. The application rate of 100 kg K_2O ha^{-1} gave the highest rate for this trait, reaching 187.00 cm. In comparison with the application rate of 200 kg K_2O ha^{-1}, which achieved 182.00 cm. This increase in the trait may be due to the activation of factors growth. This increase in plant height may be attributed to the enhanced cell multiplication and extension, processes stimulated by the role of potassium in activating effective plant hormones, especially gibberellins and auxins (9). Regarding planting dates, the results of the same table showed that the difference in planting dates had a significant effect on the average of this trait, as planting on the date of March 25 recorded the highest mean plant height, reaching 202.00 cm when compared with the dates of April 5 and April 15, which gave 186.00 cm and 164.00 cm, respectively. This could be due to a reduction in temperature rates on the first date and the increase in relative humidity, which led to stimulating the division of plant cells and the elongation of internodes (6). As for the interaction of the factors studied, the treatment (100 kg K_2O ha^{-1} in addition the date of March 25) was characterized by the highest value for the same trait and perhaps the reason for this is the combined efforts of the individual factors with each other. Similar results were indicated by (9, 10) (Table 2).

Table 2. Effect of planting dates and potassium fertilizer levels on maize plant height

Sowing times	Potassium fertilizer			Mean sowing times
	100 K_2O kg ha^{-1}	150 K_2O kg ha^{-1}	200 K_2O kg ha^{-1}	
March 25	201.177	200.047	204.013	202.00
April 5	192.183	184.373	181.053	186.00
April 15	168.107	163.027	160.013	164.00
Mean potassium fertilizer	187.00	182.482	182.00	
LSD (0.05)	Potassium 0.213	Sowing times 0.2138	Sowing times × Potassium 0.3703	

Leaf area

A significant increase in average leaf area was observed with increasing potassium fertilizer levels, showing a direct positive relationship between potassium application and leaf area. The highest leaf area (3490 cm^2) was recorded at potassium levels exceeding 100 kg K_2O ha^{-1}, compared with 3303 cm^2 at the next highest concentration (Table 3). This is attributed to the role of potassium in increasing the division of leaf cells and the production of gibberellins and auxins hormones and its work with these hormones in increasing the flexibility and elasticity of the cell walls, which encourages the withdrawal of water and the formation of high swelling pressure that contributes to the elongation of leaf cells and thus increasing the leaf area (6). As for the planting dates, they were also significantly different from each other in terms of their effect on the rate of this trait. Planting on the first date yielded the greatest average leaf area, which reached 3990 cm^2, while a reduction in the average value of this trait was observed when the planting date was delayed to 2803 cm^{-2}. This may be due to the effective role of low temperatures in enhancing the activity of enzymes that stimulate leaf cell division. The interaction between the individual factors exerted a significant influence on increasing leaf area, as the combination of the first fertilizer level with the

Table 3. Impact of planting times and potassium fertilizer levels on leaf area of maize plants

Sowing times	Potassium fertilizer			Mean sowing times
	100 K_2O kg ha^{-1}	150 K_2O kg ha^{-1}	200 K_2O kg ha^{-1}	
March 25	4167	3700	4103	3990
April 5	3400.	3200.	3100	3233
April 15	2904	2800	2705.	2803
Mean Potassium Fertilizer	3490	3233	3303	
LSD (0.05)	Potassium 67.3	Sowing times 67.3	Sowing times × Potassium 116.5	

early planting date resulted in the highest average value for this trait, reaching 4167 cm^2. These results are consistent with the findings in previous works (11, 12).

Ear length

The experimental results indicate that the studied factors had a significant effect on the average ear length of maize plants (Table 4). The potassium fertilizer levels differed in their impact on this trait, with the highest ear length reaching 13.413 cm when fertilized with 100 kg K_2O h^{-1}, while the remaining levels of 150 and 200 kg K_2O h^{-1} gave 12.858 cm and 12.143 cm, respectively.

As for planting dates, the early planting date recorded the highest mean ear length of 15.138 cm, compared to the late planting date, which recorded 11.205 cm. The combined effect of the studied factors had a meaningful effect on the value of the trait as the highest average was 16.223 cm when fertilized with 100 kg K_2O h^{-1} and planted on 25/3. These results are consistent with previous studies (13, 14).

Table 4. Impact of planting dates and potassium fertilizer levels on ear length of maize plants

Sowing times	Potassium fertilizer			Mean sowing times
	100 K_2O kg ha^{-1}	150 K_2O kg ha^{-1}	200 K_2O kg ha^{-1}	
March 25	16.223	15.130	14.063	15.138
April 5	13.013	12.000	11.200	12.071
April 15	11.003	11.446	11.166	11.205
Mean Potassium Fertilizer	13.413	12.858	12.143	
LSD (0.05)	Potassium 0.040	Sowing times 0.040	Sowing times × Potassium 0.070	

Number of ears per plant

Potassium fertilizer levels had a significant effect on the number of ears per plant, with the application of 100 kg K_2O ha^{-1} resulting in the highest value (1.752 ears per plant) (Table 5).

In comparison, the application of 200 kg K_2O ha^{-1} resulted in 1.666 ears per plant. This response may be attributed to the role of potassium in improving the soil's physical and chemical properties, thereby enhancing root penetration and increasing nutrient uptake by the plant (15). The resulting increase in dry matter accumulation subsequently stimulates the development of secondary ears and promotes their progression to full ear formation (16). Also, planting dates differed significantly in their effect on the trait rate, as the date 25/3 recorded the highest mean value for the trait under investigation, reaching 1.824 ears per plant, when compared to the dates 5/4 and 15/4, which gave 1.686 ears plant and 1.608 ears per plant, respectively. The superiority of the first planting date in the number of ears per plant may be attributed to the fact that early planting promotes

Table 5. Impact of planting dates and potassium fertilizer levels on the number of ears per maize

Sowing times	Potassium fertilizer			Mean sowing times
	100 K_2O kg ha^{-1}	150 K_2O kg ha^{-1}	200 K_2O kg ha^{-1}	
March 25	1.910	1.803	1.7600	1.824
April 5	1.716	1.686	1.656	1.686
April 15	1.630	1.613	1.583	1.608
Mean potassium fertilizer	1.752	1.701	1.666	
LSD (0.05)	Potassium 0.005	Sowing times 0.005	Sowing times × Potassium 0.009	

the development of more ears per plant and late flowering, while the plants are still small due to the incompleteness of their natural physiological growth (17). Significant differences in the trait value were observed due to the interaction between the study factors, as the highest number of ears per individual plant was 1.910 ears per plant, which was recorded by plants planted at the first date and fertilized with the first level of potassium fertilizer. These results were consistent with what was stated in this table.

Grain weight per 300 seeds

Yellow corn plants showed significant variation in grain weight in response to different potassium fertilizer levels, with the highest average value (71.15 g) recorded at 100 kg K_2O ha^{-1}, while increasing the potassium level to 200 kg K_2O ha^{-1} reduced the grain weight to the lowest value of 68.62 g (Table 6).

This may be attributed to the role of potassium in transferring carbon metabolism products from the source to the sink, with plants sown on 25 March recording the highest mean value for the grain weight per plant, reaching 73.82 g, while delaying the planting date led to a decrease in the average of the trait to 66.00 g.

Table 6. Impact of planting dates and potassium fertilizer levels on the grain weight per 300 kernels of maize

Sowing times	Potassium fertilizer			Mean sowing times
	100 K_2O kg ha^{-1}	150 K_2O kg ha^{-1}	200 K_2O kg ha^{-1}	
March 25	75.80	73.45	72.21	73.82
April 5	70.28	69.21	69.00	69.50
April 15	67.36	66.00	64.64	66.00
Mean potassium fertilizer	71.15	69.55	68.62	
LSD (0.05)	Potassium 0.572	Sowing times 0.572	Sowing times × Potassium 0.990	

The interactions between the study factors also followed a similar trend to that of the individual factors, as the first fertilizer level with the earliest planting date gave the highest recorded value for the studied trait (75.80 g). This finding aligns with the results reported by previous researchers (13–15).

Grain yield

Potassium fertilization levels had a significant effect on grain yield, with the highest yield (3.301 t ha^{-1}) recorded at an application rate of 100 kg K_2O ha^{-1} (Table 7).

While the trait rate decreased when plants were treated with 200 kg K_2O ha^{-1}, which reached 2.296 t ha^{-1}. Potassium contributes significantly to enhancing cell division and elongation and it also facilitates the translocation of carbon metabolism products to the sites of leaf emergence, this was reflected in the expansion of the leaf area, which subsequently enhanced the supply of assimilates to the developing flowers, leading to an increase in grain weight and fullness, in addition to its contribution to increasing the number of ears per plant (6).

Table 7. Impact of planting dates and potassium fertilizer levels on grain yield

Sowing times	Potassium fertilizer			Mean sowing times
	100 K_2O kg ha^{-1}	150 K_2O kg ha^{-1}	200 K_2O kg ha^{-1}	
March 25	5.210	4.203	3.703	4.372
April 5	2.896	2.706	2.103	2.568
April 15	1.796	1.566	1.083	1.482
Mean potassium fertilizer	3.301	2.825	2.296	
LSD (0.05)	Potassium 0.0135	Sowing times 0.0135	Sowing times × Potassium 0.023	

From the same table, it is noted that a significant variation exists among planting dates regarding the rate of the studied trait. Early planting led to achieving the maximum grain yield of 4.372 t ha^{-1}, while delaying the planting date contributed to a decrease in the grain yield to 1.482 tonnes ha^{-1}. The reason is due to the favourable thermal conditions and elevated relative humidity during the flowering period, which positively influenced pollen viability and consequently enhanced the fertilization success, allowing for an extended grain filling period (17). The significance of the interaction in the trait rate shows the synergy of the two factors in increasing the grain yield rate, as the treatment 100 kg K_2O ha^{-1} in along with planting on 25 March resulted in the maximum grain yield of 5.210 tonnes. ha^{-1} (18). The results were consistent with findings of another study (19).

Conclusion

The results showed that planting dates and potassium fertilizer levels have two major effects on plant growth and yield. It was found that early planting allows the plant to benefit from the photoperiod, which contributes to the plant benefiting as much as possible from suitable climatic conditions, increasing flower setting and avoiding high temperatures that kill pollen grains. Also, low potassium fertilizer levels gave the best results. This indicates that low levels spare the plant the risk of toxicity and provide economic feasibility.

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Authors' contributions

FHM conceived the study, designed the experiment and supervised the manuscript preparation. MOM was responsible for field management and plant data collection. HIHEH contributed to the assessment of plant physiological traits. NMAF assisted in agronomic evaluations and data analysis. SSS contributed to reviewing the manuscript and coordinating logistics. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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