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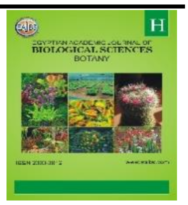

Productivity of Wheat under Different Methods and Times of Potassium Application Grown in Sandy Soil

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ABSTRACT

Egypt's primary food staple is wheat, and as the country's population to grow, wheat production must increase to meet the rising demand. In this regard, two field experiments were carried out at Rosetta City, El-Beheira Governorate conditions (Latitude: 30° 54' 36'' N and Longitude: 30° 10' 27'' E), Egypt, to study the effect of different methods and timing of application for potassium (K) on wheat (*Triticum aestivum* L. cv Sakha 95) during the growing seasons 2022/2023 and 2023/2024 seasons. The experimental design was a randomized complete block design (RCBD) in three repetitions in both seasons, where T1= One time, soil K application (K) with planting, T2=Twice, soil application of K with planting and with the first irrigation, T3= Three times, Soil application of K with planting, with the first and second irrigation, T4=One time, foliar application of K after 30 days after sowing (DAS), T5=Twice, foliar application of K after 30 and 50 DAS, T6=Three times, foliar application of K after 30, 50 and 70 days after sowing (DAS), T7= Soil application with planting + Twice, foliar application of K after 30 and 50 DAS, T8=Soil application with planting and the first irrigation + Twice, foliar application of K after 30 and 50 DAS, and T9=Soil application of K with planting and the second irrigation + Twice, foliar application of K after 30 and 50 DAS in both seasons. The findings result revealed that application of K as soil + foliar application enhanced wheat growth and yield characteristics significantly under the studied region conditions and the similar regions.

INTRODUCTION

The Poaceae family includes wheat (*Triticum aestivum* L.), which is the main food supply for many countries worldwide, especially emerging nations like Egypt. especially emerging nations. Thus, wheat contributes around 20% of the calories consumed worldwide. Even if animals may be fed wheat. Around 1.425 million hectares of wheat were grown in Egypt, and the country produced around 9.279 million tonnes of wheat overall (FAO, 2024).

Approximately 40% of the country's imports from overseas markets came from the ratio of wheat output to consumption. The focus of efforts should be on increasing and improving wheat output to reduce the gap between production and consumption. To increase the amount of wheat grown, it is necessary to relocate to freshly restored soils.

Nutrient application to the soil entails the danger of overfertilization, which can result in significant financial loss and a decline in soil fertility. According to reports, nitrogen

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sprayed on leaves may improve wheat crop development and production. Additionally, foliar fertilizer treatments in addition to soil application led to increased crop yield and quality by reducing common nitrogen losses such as denitrification, leaching, and immobilization in the soil (Pradeep *et al*. 2013; Rahman *et al.*, 2014).

Despite not being an essential constituent of any plant's cellular organic or structural components, K is one of the key nutrients thought to be necessary for crop growth and yield improvement. It is linked to or engaged in several physiological processes that promote the growth and development of plants, making it the most prevalent cation in plants. Potassium can affect water relations, photosynthesis, assimilate transport, and enzyme activation (Pettigrew 2008). Furthermore, because stress adversely impacts plant physiological processes like root and shoot elongation, enzyme activity, water and assimilate transport, protein synthesis, photosynthetic transport, and chlorophyll content, K is essential for plant survival under abiotic stress conditions (Gerardeaux *et al*., 2010 and Kanai *et al.*, 2011). While in sandy soil the plants' response to the foliar treatment persisted with all soil applied P only up to the second level, in sandy loam soil the combination of soil and foliar fertilization increased wheat yield parameters, NPK concentration, and wheat uptake during the two seasons (Fawy 2014). The greatest record was achieved by low levels of Fe alone or in combination with K. K applications had a substantial impact on the growth, yield, and nutritional content of wheat leaves, straw, and grains (Hamouda *et al.*, 2015).

Growth, yield, and its components characteristics, as well as total NPK absorption, were the lowest for wheat plants that did not get potassium treatment (Sarhan and El-Hamed, 2018). K significantly affects wheat quality and output. Because of the constraints imposed by manufacturing costs and irrigation. Even when wheat has adequate amounts of nitrogen and phosphorus (N/P), K shortage can still arise in the late growth stage; therefore foliar spraying is required to provide potassium.

Grain yield gains for the 5 g/L foliar treatment of K and the 60 kg/ha soil treatment of K ranged from 34–120% in the first season to 80–170% in the second season. It seemed possible that sandy soils might benefit more from this combined treatment (Arabi *et al*., 2002). K was applied as a potash fertilizer spray at a concentration of 60 mmol/L during the flowering stage to significantly increase the protein content, wet gluten content, and gluten protein content in grains. According to Gu *et al*. (2021), gluten protein levels, as well as dough development time, rose when potassium fertilizer was applied at the K_2 concentration during the blooming stage.

The treatments with the longest duration to heading and maturity phases were those that applied 12 kg of K_2O/feddan as a soil application pre-sowing, followed by another 12 kg of K_2O/feddan two months later, or 12 kg of K_2O/feddan as a soil application with 2% potassium sulphate as a foliar spraying twice. Conversely, the lowest growth metrics, yield and its constituents, and total NPK absorption were found in wheat plants treated without potassium (Sarhan and Abd El-Hamed, 2018). Potassium addition (pre-sowing) quite reduced the quantity and dry weight of weeds (combined analysis) while increasing wheat yields and most of their characteristics (Salama, 2024).

The primary aim of this research is to thoroughly investigate the variations observed in the grain and its various components of bread wheat. This study specifically focuses on how these variations are influenced by the different methods and timing of potassium application, under the specific conditions set for the research. By examining these factors in detail, the study aims to provide a clear understanding of their effects on the quality and characteristics of bread wheat.

MATERIALS AND METHODS

Two field experiments were conducted at Rosetta city, El- Behira governorate, Egypt, during the 2022/2023 and 2023/2024 seasons to study the effect of timing and method K application on the yield and its components of wheat cultivar Sakha 95.

In both seasons of this study, maize (*Zea may*s L.) was the preceding crop as summer crop.

Soil samples were collected from various locations at a depth of 0 to 60 cm before planting and analyzed for specific physio-chemical properties. Soil texture was determined using the hydrometer method (Topp *et al*., 1993). Organic matter content was assessed via the modified Walkey-Black method (Nelson and Sommers, 1996). Available phosphorus and potassium were measured as described by Olsen (1982), and nitrogen was estimated following Jackson (1973). Some physical and chemical analyses of the experimental site are shown in Table 1.

During soil preparation and pre- planting, mono calcium superphosphate (15.5% P_2O_5) was applied at a rate of 24 kg P_2O_5/fed. Urea (46.5 percent N) was provided as nitrogen fertilizer at a rate of 70 kg N/fed in two equal doses; the first dose, and the second dose before to the first watering. The recommendations of Egypt's Ministry of Agriculture and Land Reclamation were adhered to in all other agricultural practices.

Potassium was applied to the leaves in a foliar spray at a rate of 1 kilogram per fed, utilizing the commercially available compound known as Naturwin K. This specific product contains a composition of 38.64% potassium, along with additional ingredients such as 2% Ceteric acid and 2% Glucose.

A randomized complete blocks design (RCBD) with three replications was used. Each experiment plot size was 10.5 m^2 (3.5 m x 3 m). Sakha 95 variety grains were sown at the rate of 60 kg/fed (one feddan = 4200 m^2) was used. Sowing dates were November 20th in the first season and November 25th in the second one.

The treatments randomly were distributed as follows;

- T1 One time, soil application of K (K) at the rate of 24 kg K_2O/fed with planting.
- T2 Twice, soil application of K at the rate of 24 kg K_2O/fed with planting and with the first irrigation.
- T3 Three times, soil application of K at the rate of 24 kg K_2O/fed with planting, with the first and second irrigation.
- T4 One-time, foliar application of K at the rate of 1 kg /fed after 30 days after sowing (DAS).
- T5 Twice, foliar application of K at the rate of 1 kg /fed after 30 and 50 DAS.
- T6 Three times, foliar application of K at the rate of 1 kg /fed after 30, 50 and 70 days after sowing (DAS).
- T7 Soil application of K at the rate of 24 kg K_2O/fed with planting + Twice, foliar application of K at the rate of 1 kg /fed after 30 and 50 DAS.
- T8 Soil application of K at the rate of 24 kg K_2O/fed with planting and the first irrigation + Twice, foliar application of K at the rate of 1 kg /fed after 30 and 50 DAS.
- T9 Soil application of K at the rate of 24 kg K_2O/fed with planting and the second irrigation + Twice, foliar application of K at the rate of 1 kg /fed after 30 and 50 DAS.

Table 1. The experimental soil's physical and chemical characteristics over both seasons.

Soil characteristics	Seasons	
Particle size distribution	2022/2023	2023/2024
Soil texture (%)	Sandy loam	Sandy loam
Sand %	59.90	60.03
Silt %	9.60	9.55
Clay %	28.50	28.92
pH (1: 2.5 water suspension)	8.20	8.05
EC (dSm^{-1})	3.50	3.45
Soluble Cations (meq/L.)		
Ca^{++}	7.20	7.00
Mg^{++}	5.00	4.50
Na^{+}	5.50	5.30
K^{+}	0.53	0.55
Soluble Anions (meq/L.)		
HCO_3^{-}	3.40	4.00
Cl^{-}	4.50	3.10
SO_4^{--}	10.30	10.20
O.M. (%)	1.86	1.90
$CaCO_3$ (%)	22.50	23.70
Available Mineral N(mg/kg)	19.40	20.60
Available P (mg/kg)	6.12	6.50

Studied Characteristics:

1. Plant height at harvest (cm): was measured from the soil surface to the top of the plant using 20 plants randomly selected from each plot at harvest time.
2. Grain yield (t/fed): determined by harvesting specific area (m^2) from each plot in terms of kg and converted to t/fed.
3. Biological yield: determined from the harvested area (m^2) of each plot in terms of kg and converted to t/fed.
4. Straw yield (t/fed): calculated by separating straw and spikes of biological yield then weight the yield of the straw in kg/m^2 and converted to t/fed.
5. 1000- kernel weight (g): was expressed as an average weight of 1000 clean grains in gram taken randomly from each plot.
6. Grains number/spike: counted as an average number of grains of twenty random spikes samples from each plot.
7. Spikes number/m^2: counted as the number of fertile tillers/m^2 from each plot at harvest time.
8. Harvest index (HI %) estimated according to the following equation:

$$\text{Harvest index (HI \%)} = \frac{\text{Grain yield}}{\text{Biological yield}} x100$$

All the data that was collected throughout both seasons of the study were then carefully analyzed using a statistical software package known as CoStat, 2005. To assess the significance of differences observed among the mean values for each treatment, we employed the Least Significant Differences test, commonly abbreviated as L.S.D. This statistical test was conducted at a probability level of 0.05, which is widely regarded as a standard threshold for determining statistical significance. The methodology follows the guidelines established by Gomez and Gomez 1984, ensuring a rigorous approach to data analysis and interpretation.

RESULTS AND DISCUSSION

The results presented in Table (2) clearly demonstrate a significant effect on various parameters related to plant growth and yield. These parameters include plant height measured in centimeters (cm), the number of spikes per square meter, the count of kernels per spike, the weight of 1000 kernels expressed in grams (g), as well as the overall grain yield measured in tons per feddan (t/fed). Moreover, the analysis also covers straw yield (t/fed), biological yield (t/fed), and the harvest index (HI%). These effects were observed under varying timings and methods of potassium application throughout the growing seasons of 2022/2023 and 2023/2024.

The results obtained from the experiments are presented in Table 2, which clearly reveals that the K application fertilizer—whether applied to the soil directly or as a foliar treatment, either as a one-time application or multiple times—significantly enhanced all the measured characters associated with wheat growth. This includes characters such as plant height measured in centimeters (cm), the number of spikes per square meter (spike/m2), the number of kernels per spike, the weight of 1000 kernels expressed in grams (g), grain yield measured in tons per fed (t/fed), straw yield also measured in tons per fed (t/fed), biological yield in tons per fed (t/fed), and the harvest index (HI %) of wheat when compared to the control treatments that did not receive potassium fertilization. Among the various treatments, the results indicated that T9, which involved soil application at the time of planting along with the first irrigation, followed by a twice-performed foliar treatment of potassium after 30 and 50 DAS, yielded the highest plant height. In the second place, T7, which also involved soil application at planting combined with two instances of foliar treatment of potassium after the same intervals of 30 and 50 DAS, recorded impressive results for plant height as well. This was subsequently followed by treatments T3 and T2, which also noted significant growth increases. Moreover, T4, which consisted of a single foliar treatment of potassium after 30 days after sowing (DAS), resulted in the highest number of spikes and kernels produced. This was followed closely by T3, reinforcing the observed trends across the various treatments. Consistently, similar enhancements were noted in yield and its corresponding components of wheat, signifying a clear positive impact. The observed increase in yield and its related components is likely attributable to the vital role that potassium plays in promoting growth and development, as well as facilitating nutritional absorption within both the soil and the plants. Thus, the K application fertilizer appears to be crucial for maximizing wheat production.

Also, the results indicated that HI increased by T9=Soil application with planting and the second irrigation + Twice, spraying of K after 30 and 50 DAS. In the second place, T4= One time, spraying of K after 30 DAS recorded the highest HI %. This was subsequently followed by treatments T3, which also noted significant HI increases. Similar enhancements were noted in yield and its corresponding components of wheat, signifying a clear positive impact. The observed increase in HI is likely attributable to the vital role that K had important role in encouraging growth as well as development, as well as facilitating nutritional absorption within both the soil and the plants. Thus, the application of potassium fertilizer appears to be crucial for maximizing wheat production.

Potassium plays a crucial role in wheat production by enhancing grain yield through several mechanisms. It increases both the number and size of seeds, which can positively affect overall yield. Additionally, potassium improves photosynthetic efficiency and plant performance, and its adequate presence in plant tissue is essential for proper biochemical functioning. Potassium also helps mitigate the effects of deficiency, which can lead to oxidative stress and reduced plant vitality. Like this, potassium (K) is an essential inorganic nutrient for plant growth and development. It is involved in several physiological processes, including osmoregulation, stomatal regulation, cell expansion, and enzyme activation (Marschner *et al*., 2012; de Bang *et al*., 2021). The similar results were obtained by Arabi *et al*. (2002); Fawy (2014); Gomaa *et al.* (2015); Sarhan *et al.* (2018); Gu *et al*. (2021); Chowdhury *et al*. (2024).

Table 2. Effect of potassium application methods and timings on yield and its components of wheat in the 2022/2023 and 2023/2024 seasons.

Treatments	Plant height (cm)		Number of spike/m^2		Number of kernels/spike		1000- kernel weight (g)		Grain yield (t/fed)		Straw yield (t/fed)		Biological yield (t/fed)		Harvest index (HI %)	
	Seasons															
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
T1	90.00	96.00	277.00	281.67	48.67	47.67	38.33	37.50	2.40	2.34	3.47	3.54	5.87	5.88	40.89	39.80
T2	102.40	102.67	327.00	334.00	52.33	54.33	47.50	47.37	2.50	2.58	3.90	3.92	6.40	6.50	39.06	39.69
T3	106.60	108.00	341.67	348.67	52.33	53.00	53.00	53.03	2.81	2.93	4.11	4.21	6.92	7.14	40.61	41.04
T4	97.67	98.60	349.33	356.33	53.67	54.33	46.67	46.33	2.97	3.05	4.27	4.25	7.24	7.30	41.02	41.78
T5	101.00	102.40	318.67	325.67	42.33	45.33	49.43	51.20	2.90	2.97	4.20	4.27	7.10	7.24	40.85	41.02
T6	94.73	96.33	312.67	321.00	44.00	47.00	43.50	46.10	2.67	2.89	4.13	4.33	6.80	7.22	39.26	40.03
T7	106.73	108.13	325.67	329.00	51.33	52.67	53.50	54.90	3.07	3.02	4.60	4.43	7.67	7.45	40.03	40.54
T8	106.40	106.80	343.33	351.67	53.33	53.00	54.27	56.20	2.70	2.62	4.43	4.33	7.13	6.95	37.85	37.77
T9	111.40	112.67	349.00	357.33	58.00	58.67	54.33	56.07	3.79	3.87	5.03	5.02	8.82	8.89	42.97	43.53
LSD@0.05	3.15	3.46	24.37	24.04	3.91	6.97	6.73	6.19	0.42	0.35	0.51	0.31	0.80	0.79	3.13	2.75

T1= One time, soil K application (K) with planting, T2=Twice, soil application of K with planting and with the first irrigation, T3= Three times, Soil application of K with planting, with the first and second irrigation, T4=One time, foliar application of K after 30 days after sowing (DAS), T5=Twice, foliar application of K after 30 and 50 DAS, T6=Three times, foliar application of K after 30, 50 and 70 days after sowing (DAS), T7= Soil application with planting + Twice, foliar application of K after 30 and 50 DAS, T8=Soil application with planting and the first irrigation + Twice, foliar application of K after 30 and 50 DAS, and T9=Soil application with planting and the second irrigation + Twice, foliar application of K after 30 and 50 DAS.

Conclusion

It was confirmed through the research findings that the K application fertilizer, both through soil and foliar methods, led to a significantly greater yield, as well as improvements in its various components, when compared to the control treatments that did not receive this fertilizer. The combination of applying K-fertilizer to the soil along with foliar treatment resulted in a marked increase in wheat growth and yield characteristics, demonstrating substantial effects under the specific conditions present in the studied region. Furthermore, similar positive outcomes were observed in regions with conditions comparable to those being investigated, reinforcing the effectiveness of this dual application method in enhancing wheat productivity overall.

Declarations:

Ethical Approval: Not applicable.

Conflict of interest: The authors declare no conflict of interest.

Authors Contributions: I hereby verify that all authors mentioned on the title page have made substantial contributions to the conception and design of the study, have thoroughly reviewed the manuscript, confirm the accuracy and authenticity of the data and its interpretation, and consent to its submission.

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ARABIC SUMMARY

إنتاجية القمح تحت طرق ومواعيد مختلفة لإضافة البوتاسيوم المزروع في تربة رملية

محمود عبد العزيز جمعة[1] ، صبحي فايد لملوم[2] ، صلاح ياسر عبود[1] ، عصام إسماعيل قنديل[1]

1- قسم الإنتاج النباتي، المحاصيل ، كلية الزراعة، سابا باشا، جامعة الإسكندرية، مصر.

2- الإنتاج النباتي، التكنولوجيا الحيوية للمحاصيل، كلية الزراعة، سابا باشا، جامعة الإسكندرية، الإسكندرية، مصر

القمح هو الغذاء الأساسي في مصر، ومع زيادة عدد سكان البلاد، يجب زيادة إنتاج القمح. وفي هذا الصدد، أجريت تجربتان حقليتان في مدينة رشيد بمحافظة البحيرة (خط العرض: 30° 54' 36" شمالاً وخط الطول: 30° 10' 27" شرقًا)، مصر، لدراسة تأثير طرق ومواعيد مختلفة لتطبيق البوتاسيوم (K) على القمح صنف سخا95 خلال موسمي 2023/2022 و2024/2023. تم تصميم التجربة بتصميم القطاعات الكاملة العشوائية (RCBD) بثلاث تكرارات حيث T1= إضافة أرضية للبوتاسيوم مرة واحدة مع الزراعة، T2= إضافة أرضية للبوتاسيوم مرتين مع الزراعة ومع الري الأول، T3= إضافة البوتاسيوم ثلاث مرات إلى التربة مع الزراعة ومع الري الأول والثاني، T4= رش البوتاسيوم ورقياً مرة واحدة بعد 30 يوماً من الزراعة، T5= الرش البوتاسيوم ورقياً مرتين بعد 30 و50 يوماً من الزراعة، T6= الرش البوتاسيوم ثلاث مرات ورقياً بعد 30 و50 و70 يوماً من الزراعة، T7= إضافة البوتاسيوم في التربة مع الزراعة + رش البوتاسيوم ورقياً مرتين بعد 30 و50 يوماً من الزراعة، T8= الإضافة الأرضية للبوتاسيوم مع الزراعة والرية الأولى + الرش الورقي للبوتاسيوم مرتين بعد 30 و50 يوماً من الزراعة، T9= الإضافة الأرضية للبوتاسيوم مع الزراعة والرية الثانية + ، الرش الورقي مرتين أظهرت نتائج الدراسة هناك تأثير معنوي لمعاملات الإضافة الأرضية والرش الورقي للبوتاسيوم حيث وجد أن إضافة البوتاسيوم إلى التربة + الرش الورقي أدى إلى تحسين نمو وانتاجية القمح ومكونات المحصول بشكل ملحوظ تحت ظروف المنطقة المدروسة والمناطق المماثلة.