

Research Article

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Effects of Foliar Applied Nano-Potassium Combined with Urea on Growth, Physiological Traits, and Yield of Wheat (*Triticum aestivum* L.) under Sandy Soils ConditionBilkess M. Salim ^{1*}, Abusif Sonousi ², Sherin M. A. Salim³^{1,2}Crops Department, Faculty of Agriculture, Sebha, Libya.³Botany Department, Faculty of Science, Sebha, Libya.

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Abstract

Wheat (*Triticum aestivum* L.) is an important cereal crop for global food security due to its high nutritional value. Improving wheat productivity is a priority, especially in arid and semi-arid regions with poor soil fertility, water scarcity, and temperature stress. The experiment was conducted in the experimental garden of the Faculty of Science, University of Sebha, during the 2025–2026 growing season. The objective of the present study was to evaluate the effect of different concentrations of foliar nano-potassium application (K NPs) (500, 1000, 1500, 2000 ppm) conjunction with urea on growth attributes, physiological traits, and grain yield of wheat cultivar Dhahab under sandy soil conditions. The experiment followed a completely randomized design (CRD) with five replicates. The results revealed that a dose-dependent response, with K NPs 1500 ppm + urea showing the highest leaf area, spike length, grain number per spike, 1000-grain weight, grain yield, straw yield, biological yield, and harvest index. Higher concentration (2000 ppm) led to reduced growth and yield. Foliar application of K NPs at 1500 ppm with urea is recommended to optimize wheat performance under resource-limited conditions.

Keywords: Biological yield; Dose–response optimum Nps; Spike architecture; Thousand-grain weight.

تأثيرات رش البوتاسيوم النانو مع اليوريا على نمو وخصائص وإنتاجية القمح (*Triticum aestivum* L.) في التربة الرملية

المستخلص: القمح (*Triticum aestivum* L.) يُعد من أهم محاصيل الحبوب في تحقيق الأمن الغذائي العالمي نظرًا لقيمته الغذائية العالية، ويُعد تحسين إنتاجية القمح أولوية خاصة في المناطق الجافة وشبه الجافة التي تعاني من انخفاض خصوبة التربة، ونُدرة المياه، والإجهاد الحراري، وتهدف هذه الدراسة إلى تقييم تأثير الرش الورقي بالبوتاسيوم النانو (K NPs) بتركيزات مختلفة (500، 1000، 1500، 2000 جزء في المليون) مع اليوريا على النمو والصفات الفسيولوجية ومحصول صنف القمح "دهب" تحت ظروف التربة الرملية، وقد تم إجراء التجربة في حديقة التجارب بكلية العلوم، جامعة سبها، خلال الموسم الزراعي 2025–2026 تحت ظروف حقلية مُتحكم بها، وقد نفذت التجربة وفق التصميم العشوائي الكامل (CRD) بخمسة مكررات، وقد أظهرت النتائج استجابة تعتمد على الجرعة، حيث أعطى تركيز 1500 جزء في المليون من K NPs مع اليوريا أعلى القيم لكل من مساحة الورقة، طول السنبل، عدد الحبوب في السنبل، وزن 1000 حبة، محصول الحبوب، محصول القش، المحصول البيولوجي، ودليل الحصاد، بينما أدى التركيز الأعلى (2000 جزء في المليون) إلى انخفاض في النمو والمحصول، وقد أوصت الدراسة بأن الرش الورقي ببوتاسيوم نانوي بتركيز 1500 جزء في المليون مع اليوريا هو الأفضل لتحسين أداء القمح تحت الظروف محدودة الموارد.

الكلمات المفتاحية: البوتاسيوم النانو، محصول القمح السنبل، وزن ألف حبة، المحصول البيولوجي، الاستجابة المثلى للجرعة.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops worldwide and serves as a staple food for nearly 40% of the global population. It is the second most important cereal crop after rice. Wheat is cultivated on approximately 222.27 million ha worldwide, produces 779.3 million tons and has an efficiency of 3.51 tons per ha (Singh *et al.*, 2023).



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Nanotechnology is seen as an “advanced fertilizer technology” as it will enhance nutrient use efficiency, especially N efficiency. It can improve plant growth, increase the macro- and micronutrient uptake, and lower the amount of fertilizer required, thus reducing environmental risks associated with excessive fertilizer use. The key differences between nano-fertilizers and conventional fertilizers include their extremely fine particle size, which allows them to penetrate the plant's foliage through the stomata, high re-activity, low nutrient losses and large surface area for interaction with the plant. (Seleiman *et al.*, 2020; Yaseen *et al.*, 2020; Kumar *et al.*, 2020; Hasan and Saad, 2020). Nano-potassium application improves biological yield, which was reflected in better bio-mass accumulation and crop growth efficiency of cereals (Noaema and Alha-sany 2020). indicated that nano-potassium application at 2 g L⁻¹ significantly enhanced grain yield, protein content and plant height in wheat, especially at the tillering and flowering stages Al-Zubade and Al-Uburi (2024), r. Nano-potassium application favoring spike fertility and reducing grain abortion under field conditions (Sheoran *et al.* 2024). In barley the Spike number, 1000-grain weight, grain yield and biological yield were significantly more than the control when sprayed with nano-potassium at 2000 mg L⁻¹ as (Noaema *et al.* 2023). where that Nano-potassium promotes canopy development and photosynthetic potential, which consequently increases the dry matter production in the vegetative tissues, nano-potassium boosts canopy development and photosynthetic ability, resulting in increased dry matter production in vegetative tissues (Beeresha and Jayadeva 2020). In light of these considerations, the present study was undertaken to evaluate the effectiveness of different nano-potassium concentrations combined with urea in improving growth, physiological traits, and yield of wheat cultivated in sandy soil.

MATERIALS AND METHODS

Experimental site and plant material: The experiment was conducted under controlled conditions in the Herbarium of the Faculty of Science, University of Sebha, Libya, during the 2025–2026 growing season. Seeds of wheat (*Triticum aestivum* L.) cultivar 'Dhahab' was obtained from a local farm in southern Libya, where it is widely cultivated and well known among farmers. The cultivar is commonly grown in the region and is considered a well-adapted and established variety in southern Libyan agricultural systems. A preliminary germination test was conducted prior to sowing to ensure seed viability. Thirty plastic pots (30 cm in height and 25 cm in diameter) were filled with sandy soil. Twenty seeds were sown in each pot, and after emergence, seedlings were thinned to ten healthy and uniform plants per pot to maintain equal plant density among treatments. All pots were irrigated regularly and maintained under similar environmental conditions throughout the experimental period.

Experimental design and treatments: The experiment was arranged in a completely randomized design (CRD) with six treatments and five replications. Thirty plastic pots (30 cm in height and 25 cm in diameter) were filled with approximately 8 kg of sandy soil. Nitrogen fertilizer was supplied as urea (46% N) at a rate equivalent to 150 kg N ha⁻¹. Based on the surface area of each pot (0.0491 m²), the corresponding amount of urea applied was 1.60 g pot⁻¹. Potassium nanoparticles (K NPs) were applied as foliar sprays at concentrations of 500, 1000, 1500, and 2000 ppm in combination with urea. Foliar applications were carried out at 15, 30, 45, and 60 days after sowing. Spraying was continued until complete wetting of the leaves to ensure uniform coverage. No surfactant was added to the spray solutions. All plants received the same irrigation and management practices throughout the experimental period.

Treatments:

Control

Urea

K NPs 500 ppm + urea

K NPs 1000 ppm + urea

K NPs 1500 ppm + urea

K NPs 2000 ppm + urea

Sampling and measured traits: Two plants per pot were sampled 15 days after each foliar application. The measured parameters included leaf number, leaf water content, spike weight and length, number of grains per spike, 1000-grain weight, grain yield, straw yield, biological yield, and harvest index.

Statistical

Data were analyzed using ANOVA appropriate for CRD, and mean comparisons were performed with LSD at $p \leq 0.05$.

analysis.

Table 1. Physical and chemical characteristics of experimental soil prior to sowing

Soil Property	Value
Clay (%)	20%
Sand (%)	60%
Silt (%)	20%
pH	7.8
Electrical Conductivity (EC)	2.2 dS/m
Potassium (K ⁺)	1.2 mg/kg
Calcium (Ca ⁺)	8.0 mg/kg
Magnesium (Mg ⁺⁺)	3.5 mg/kg
Sodium (Na ⁺)	1.2 mg/kg
Carbonates + Bicarbonates (CO ₃ ²⁻ + HCO ₃ ⁻)	2.6 meq/ L
Chloride (Cl ⁻)	1.6 mg/L
Sulfate (SO ₄ ²⁻)	2.0 mg/L
Calcium Carbonate (%)	4.0 %
Total Nitrogen (%)	0.12%
Available Phosphate (mg/kg)	30 mg/kg
Organic Matter (%)	2.5%

RESULTS

Effect of foliar nano-potassium on wheat growth and yield traits

Foliar application with nano-potassium (K NPs) combined with urea a significant effect on wheat growth and yield attributes. The response was concentration-dependent, with most growth and yield parameters reaching their maximum values at 1500 ppm nano-potassium (K NPs) followed by a reduction at the higher concentration of (2000 ppm) indicating that this level exceeded the optimum threshold for plant performance.

Leaf area: Leaf area was highly responsive to nano-potassium application (**Figure 2**). The highest leaf area (34.40 cm²) was recorded at 1500 ppm K NPs + urea, while the lowest value (17.78 cm²) was observed at 2000 ppm K NPs + urea. The control and urea-only treatments produced intermediate values.

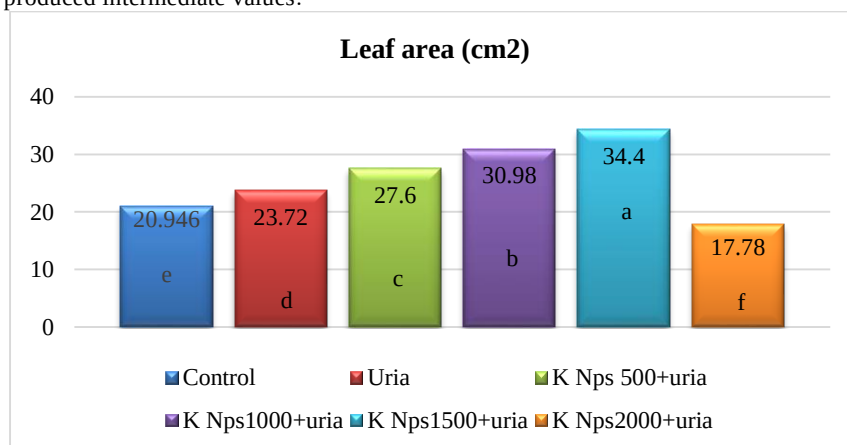


Figure (2): Effect of nano-potassium concentrations on the mean leaf area value.

Harvest index: Harvest index varied significantly with K NPs treatment (**Figure 3**). The maximum harvest index (45%) was observed at 1500 ppm K NPs + urea, followed by 1000 ppm (42%). The minimum values were recorded in the control (34%) and 2000-ppm treatment (37%).

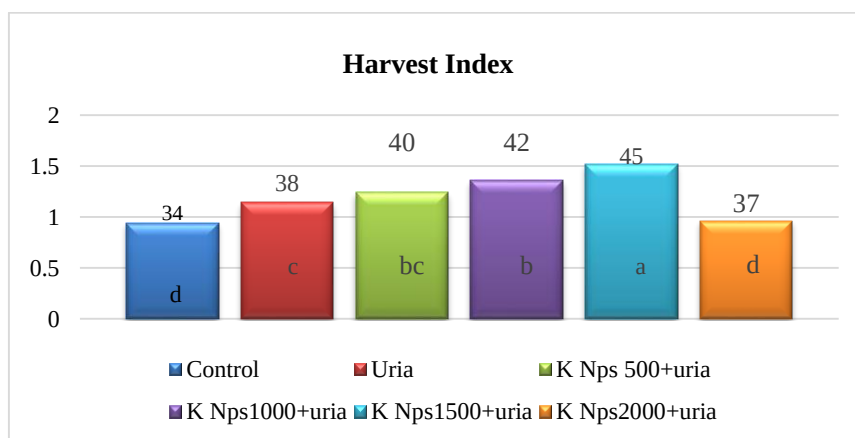


Figure (3): Effect of nano-potassium concentrations on the mean harvest index (HI) value.

Number of grains per spike: Grain number per spike increased with increasing nano-potassium concentration up to 1500 ppm (Figure 4). The highest number of grains per spike was 48.80, while the 2000-ppm treatment produced the lowest (23.40).

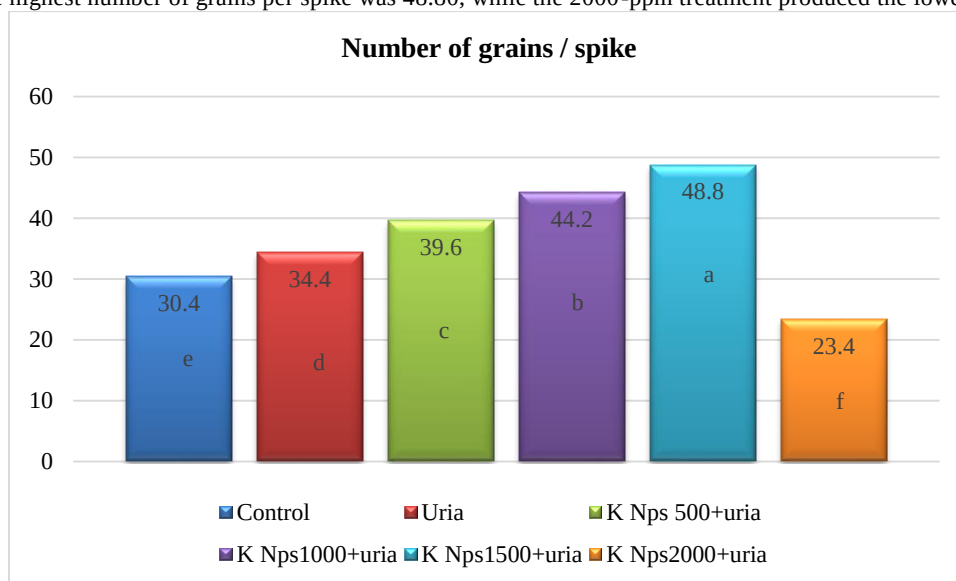


Figure (4): Effect of nano-potassium concentrations on the mean of number of grains per spike value.

1000 grain weight: Significant differences were observed among treatments (Figure 5). The maximum 1000-grain weight (49.00 g) occurred at 1500 ppm, followed by 1000 ppm (42.80 g), whereas the 2000-ppm treatment produced the lowest weight (22.80 g).

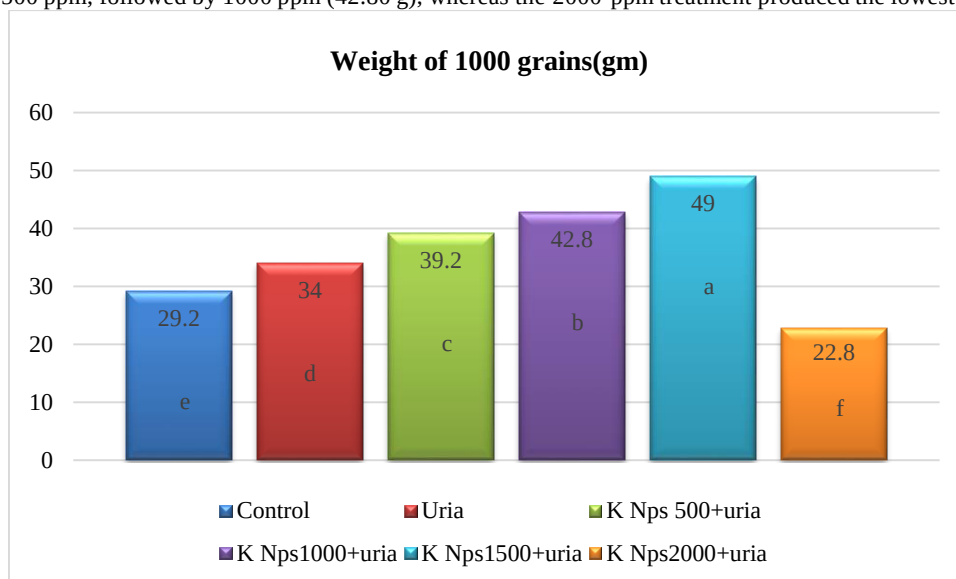


Figure (5): Effect of nano-potassium concentrations on the mean of the weight of 1000 grains value.

Grain yield per pot: Grain yield was greatly enhanced by the foliar application of K NPs (Figure 6). The highest yield (381.6 g) was recorded at 1500 ppm, followed by 1000 ppm (346.2 g), while 2000 ppm resulted in the lowest yield (188.4 g).

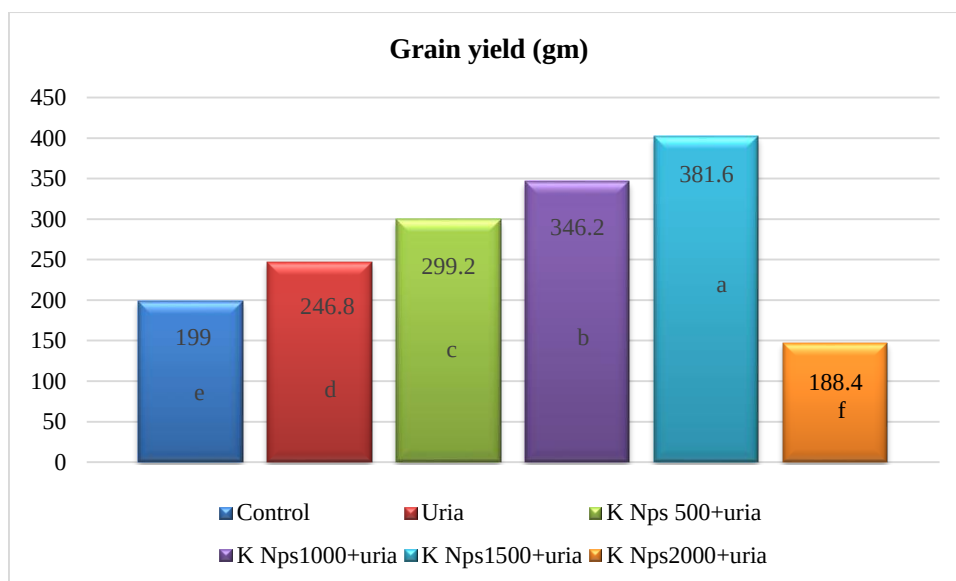


Figure (6): Effect of nano-potassium concentrations on the mean of the grain yield value.

Straw yield: Straw yield exhibited a trend similar to grain yield (Figure 7). The highest straw yield (401.8 g) was obtained at 1500 ppm, followed by 1000 ppm (375.1 g). The minimum was observed at 2000 ppm (203 g).

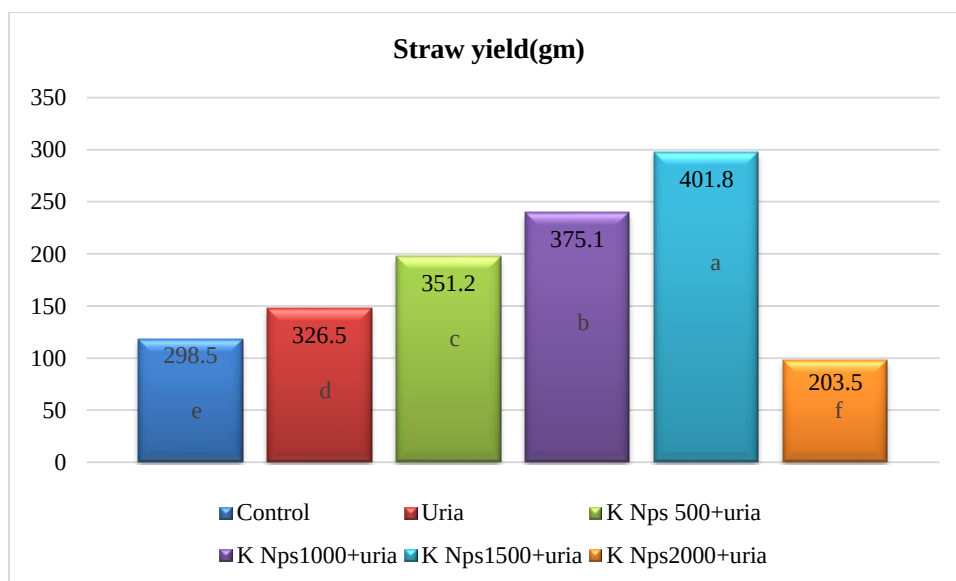


Figure (7): Effect of nano-potassium concentrations on the mean of the straw yield value.

Biological yield: Total biological yield significantly increased with K NPs up to 1500 ppm (Figure 8). The maximum biological yield was 730.5 g at 1500 ppm, while 2000 ppm resulted in the lowest yield (313.6 g).

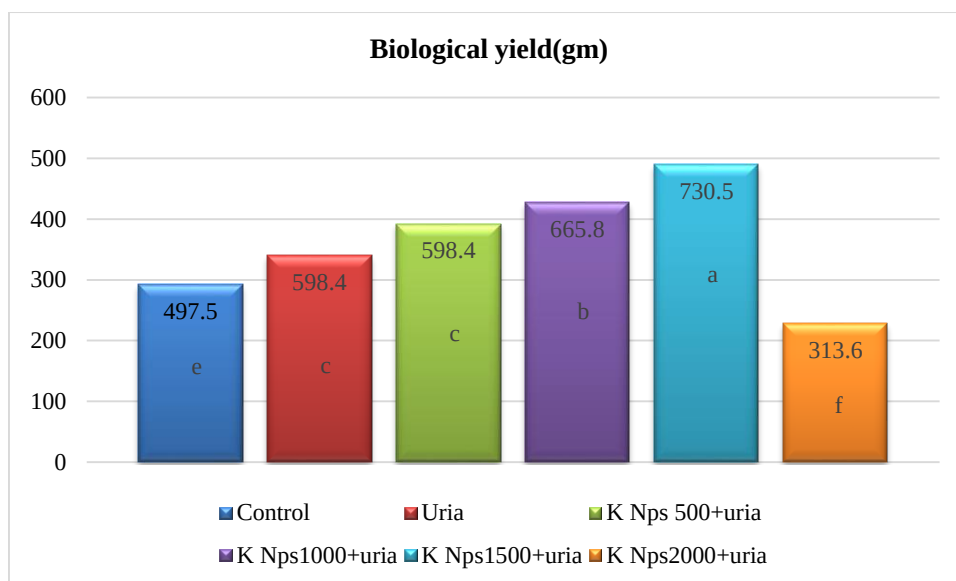


Figure (8): Effect of nano-potassium concentrations on the mean of the biological yield value.

Spike length: Spike length also responded positively to nano-potassium treatment (Figure 9), reaching a maximum of 20.40 cm at 1500 ppm, followed by 17.40 cm at 1000 ppm, and a minimum of 10.20 cm at 2000 ppm.

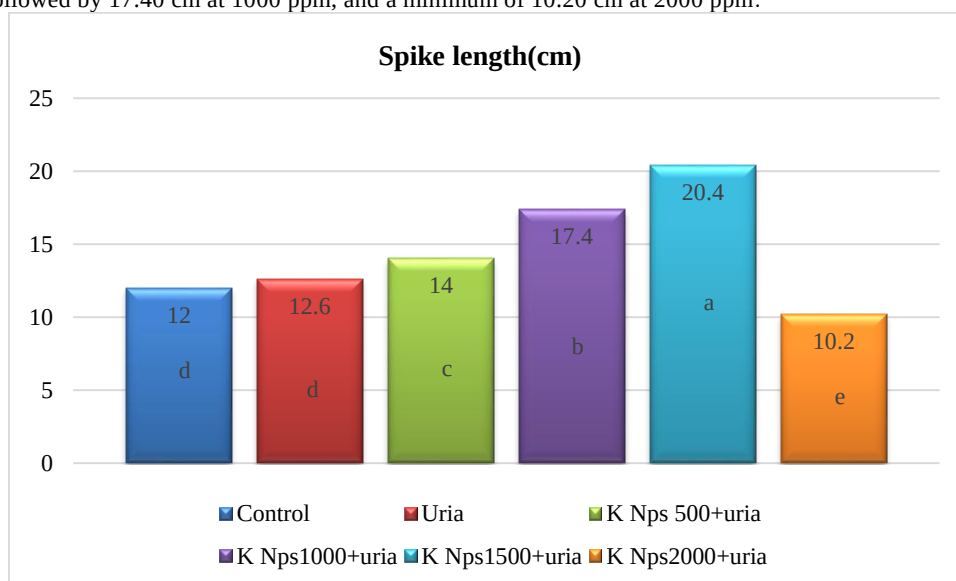


Figure (9): Effect of nano-potassium concentrations on the mean of the spike length value.

DISCUSSION

Conventional fertilization practices are often less efficient in sandy and semi-arid soils because wheat exhibits limited potassium uptake under these conditions, leading to reductions in leaf area expansion, spike development, grain yield, and harvest index. In the present study, the application of nano-potassium with Urea (K NPs 1500 ppm + urea) at the optimal rate improved plant water relations and promoted a better balance between vegetative growth and spike development. Consequently, this treatment achieved higher harvest index, grain yield and biomass production compared with both conventional fertilization treatment and untreated control. The results indicated that significantly higher leaf area was obtained with nano-potassium treatments with K NPs 1500 ppm + urea having the highest mean value. This is consistent with the results obtained by Alkhafagi *et al.* (2025) in wheat where leaf area was significantly enhanced by using nano-potassium at 3000 mg L⁻¹. Similarly, Al-Zubade and Al-Uburi (2024), Sheoran *et al.* (2024) who found that, foliar application of nano-potassium (2 g L⁻¹) enhanced the growth and productivity parameters of maize. The greater leaf area could be due to the improved cell division and cell expansion, better chlorophyll biosynthesis and nitrogen assimilation, that would improve the efficiency of photosynthesis and assimilative metabolism during the reproductive phase. Also, nano potassium treatments

improved harvest index (HI). Similar results were obtained by **Assad and Hindi (2025)**, **Soliman (2025)** who reported that harvest index was significantly elevated by foliar application of Nano-potassium at 8mL/L. Similarly, **Noaema and Alhasany (2020)** also showed nano-potassium's positive effect on yield performance, which reflected in the efficiency of, assimilate partitioning. An increase in HI may be attributed to a greater allocation of assimilates to grains rather than vegetative biomass. Physiologically, this suggests better source-sink coordination, greater sink strength of developing grains, and sufficient assimilate supply after anthesis for proper grain filling. A better co-ordination of the source and the sink, greater sink strength of the developing grains and an adequate supply of assimilates after anthesis for developing the grain properly. Additionally, an increase in the number of grains per spike was also found in the nano-potassium treatments. **Assad and Hindi (2025)**, **Hamrouni and Mohammed (2025)**, **Soliman (2025)**, **Sheoran et al. (2024)**, reported similar findings and **Ratnam et al. (2023)** who reported that application of nano-potassium significantly increased the number of grains per spike. This improvement can be attributed to improved floret fertility, better pollination and lower floret and kernel abortion due to sufficient availability of both carbohydrates and nitrogen during the critical growth stages of stem elongation to anthesis. Better water status and hormonal balance of plants may also promote the survival of spikelet's and grain set. Also, 1000-grains weight trait was also greatly improved with nano-potassium treatments. This was also recorded by **Assad and Hindi (2025)**, **Hamrouni and Mohammed (2025)**, **Soliman (2025)** and **Sheoran et al. (2024)**. This improvement may be due to higher rates of grain filling due to continued flag leaf and spike photosynthetic activity coupled with high phloem loading and unloading efficiency during the grain-filling period. Adequate potassium and nitrogen nutrition can also contribute to better osmotic regulation and enhancement of the enzyme system for endosperm assimilate transport and conversion. In addition, grain yield was significantly increased under nano-potassium treatments. **Assad and Hindi (2025)**, **Hamrouni and Mohammed (2025)**, **Soliman (2025)**, **Al Zubade and Al-Uburi (2024)**, **Ratnam et al. (2023)**, **Hussein et al. (2023)** and **Meena et al. (2021)** reported that application of nano-potassium in cereal crops resulted in an improvement in grain yield. The improvement in grain yield could be due to an improvement in key yield components (spikes per area, grains per spike, kernel weight) along with an improvement in leaf area, photosynthetic activity, and a more stable plant water status (RWC), and an improvement in reproductive development. In addition, application of fertilization at the right time and rate will help reduce the loss of yield due to crop stress at periods of demand. In addition, nano-potassium treatments also significantly increased straw yield. The same results were found in wheat **Soliman (2025)**, **Ratnam et al. (2023)** and in maize **Beeresha and Jyadeva (2020)** who reported that when the seeds were treated with nano-potassium, vegetative biomass production was enhanced. This increase could be due to increased radiation interception and photosynthetic conversion efficiency before and at anthesis, resulting in more biomass accumulation. Nutrient balance can be used to increase both straw and grain yield simultaneously by increasing the source capacity without limiting the sink development, although vegetative growth may decrease harvest index (HI). Moreover, biological yield trait was significantly increased under nano-potassium treatments. A similar result was obtained by **Assad and Hindi (2025)**, **Soliman (2025)** and **Noaema and Alhasany (2020)** who concluded that application of nano-potassium improved total biomass production. This improvement of biological production is indicative of better plant development, prolonged photosynthetic activity and less stress effects on the crop system during the growing season. Further, this was found to be true when coupled with the higher harvest index (HI), indicating that the total biomass production and partitioning of assimilates increased with a higher harvestable yield. Additionally, nano-fertilizer treatments significantly boosted spike length. **Soliman (2025)**, **Hussein et al. (2023)** and **Ratnam et al. (2023)** with nano potassium. Longer spikes may indicate improved inflorescence axis growth and higher spikelet capacity, which leads to more potential fertile florets. Proper nutrition in the differentiation of spikes also could promote meristematic activity and reduce spikelet abortion, leading to increased grain numbers per spike.

CONCLUSION

Foliar application of nano-potassium co-applied with urea had a substantial positive effect on wheat growth, plant development, physiological traits, and yield under sandy soil conditions. The optimum concentration was 1500 ppm K NPs + urea, providing maximum growth and yield. Supra-optimal levels (2000 ppm K NPs + urea) reduced wheat performance, suggesting the importance of precise dosing for physiological stability and nutrient use efficiency. Nano-potassium fertilization can therefore be recommended as an agro-nomical optimal approach to improve wheat production in resource-limited environments.

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Author contributions: Bilkess M. Salim designed the experiment and performed the statistical analysis. Abusif Sonousi supervised the experiment and collected the data. Sherin M. A. Salim performed the laboratory work. All authors contributed to the final version of the manuscript.

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