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Influence of Sodium Potassium Niobate ($Na_{0.5}K_{0.5}NbO_3$) Nanoparticle on Yield and Yield Attributes of Sugar Beet (*Beta vulgaris*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during RABI 2024 at Karguanji Research Farm, Department of Soil Science and Agriculture Chemistry, Bundelkhand University, Jhansi (Utter Pradesh). The soil texture of experimental site was loamy sand, with a pH of 8.1, low organic carbon (0.58%), available Nitrogen (208.14 kg/ha), available Phosphorus (12.57 kg/ha), available potassium (232.14 kg/ha)

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and Ec (0.29 d Sm-1). The experiment was laid out in completely randomized design with five treatments to evaluate the performance of sodium potassium niobate nanoparticles on Yield and yield attributes of sugar beet. The treatments consist moistened with deionized water (0.0, 200, 400, 600 and 800 ppm). The results reveled that plant height was recorded significantly higher 56.30 cm, maximum number of bulb diameter (13.02 cm), maximum number of leaf fresh weight (59.21 gm), maximum leaf dry weight (6.46 gm), maximum bulb fresh weight (130.00 gm), maximum bulb dry weight (11.03 gm) were recorded with the treatment of Sodium potassium niobate nanoparticles 200 ppm + 400 ppm as compared to other treatments.

Keywords: Influence; nanoparticles; sodium potassium niobate; sugar beet; yield.

1. INTRODUCTION

“Sugar beet (*Beta vulgaris*) is one of the most important vegetable belonging to Chenopodiaceae family, having a high concentration of sucrose, and it is used for the production of sugar” (Zicari *et al.,* 2019). “The sugar extracted from sugarcane and sugar beet is used as a sweetener in our domestic food and as an ingredient in the food industry for sweet-flavored substances. Sugar is mainly referred to as sucrose and, to some extent, as glucose and fructose” (Duraisam *et al.,* 2017). “Sugar beet was considered a productive and good rotational crop in Mediterranean regions, and its growth also started in the northern coastal areas” (Sánchez -Sastre *et al.,* 2020). “Sugar extraction was started from fodder beet containing high sugar content in the 18th century; it was a great achievement in the agriculture field in northern Europe. The sugar beet industry was established in Germany as a consequence of sufficient experimental work and flourished during the Napoleonic Wars when sugarcane was replaced by sugar beet as an alternative for sugar production. Its adaptation was especially progressed in France due to France’s better policies. The average sugar beet yield of 50–60 t ha^{-1} has been recorded during 2003– 2004 when experiments were conducted in 16 countries at 55 different locations” (Hoffmann *et al.,* 2009). “Sugar beet contains a sugar content of 16%, while sugarcane contains a sugar content of 8–10%. Twenty percent of the world’s sugar production has been obtained from sugar beet” (Wimmer *et al*., 2020). “Extraction of the raw juice, purification of the thin juice, evaporation, and then crystallization are the main steps for processing sugar beet in the sugar industry. Raw juice is the main product extracted from the cassettes, a strip or slice of sugar beet. After evaporation, the juice becomes thick and contains 60% of dissolved solids” (Bahrami *et al.,* 2020). “It is also used for the production of energy such as ethanol, bioethanol, molasses, cattle feed, pulp, and pectin. Being a short-duration (5–6 months) crop in comparison with that of sugarcane (long duration, i.e., 12–14 months) sugar beet can be considered a better crop. The sucrose content in sugar beet is higher, 14–20%, compared to 10–12% in sugarcane. In addition, inputs such as the water and fertilizer requirements for the cultivation of beet crops are 30–40%, much lower compared to those in sugarcane cultivation, and beet crops have the capability of adaption in a wide range of climatic conditions” (Pan et al., 2019; Mioduszewska *et al*., 2020). There is a dire need to increase sugar production by cultivating sugar beet on saline–sodic soils without reducing the sugar quality. To date, little literature is available to help us better understand the cultivation and large-scale adaptation of sugar beet on these poor quality soils to fulfil the sugar requirement of the rising population. Thus, the main objective of this review is to increase sugar production with a low input cost, particularly in hostile soils and under unfavourable growth conditions. This review presents a comprehensive story of the challenges in and opportunities for the large-scale cultivation of sugar beet in tropical and subtropical regions.

2. MATERIALS AND METHODS

The experiment was laid out in the Organic Farm Karguwan ji, Bundelkhand University, Jhansi Uttar Pradesh situated between the two rivers Pahuj and Betwa at an average elevation of 225 meters above mean sea level at 78°34’11’E longitude and 25°26’55’N latitude. The Bundelkhand region falls under agro-climatic zone VI. The soil was loamy red in texture and slightly basic (pH 8.1). The experiment was laid out in completely randomized design with five treatments to evaluate the performance of sodium potassium niobate nanoparticles on seed germination, Yield and Yield attributes of sugar beet. The treatments consisted of moistened with deionized water with Sodium potassium niobate

Table 1. The treatment combinations

Symbols	Treatments
T_0	Control (priming with deionized water)
T_1	200 ppm Sodium potassium niobate nanoparticles (Seed priming)
T_2	400ppm Sodium potassium niobate nanoparticles (Seed priming)
T_3	600ppm Sodium potassium niobate nanoparticles (Seed priming)
T_4	800ppm Sodium potassium niobate nanoparticles (Seed priming)

nanoparticles having concentrations of 0.0 ppm (control), 200, 400, 600 and 800 ppm respectively before sowing. The treatment combinations are given in Table 1.

The sugar beet seeds of the variety RUBY QUEEN were planted on 30-11-2024 in lines and 3 seeds in every pot. The crop was raised adopting standard cultural practices and the observation were recorded on one randomly selected plants from each pot on different on Yield and Yield attributes of sugar beet. The experimental data on observation were statistically analysed by adopting the procedure of Panse and sukhatme. The critical difference was calculated at five per cent probability level to draw statistical calculations.

3. RESULTS AND DISCUSSION

The yield qualities and yields of sugar beet were significantly affected by the use of sodium potassium niobate nanoparticles (Table 2). Plant height was observed lowest 13.18 cm in in 0.0 ppm and highest 17.51 cm in 400 ppm KNN application at 30 days. However, at 60 days after sowing the plant height ranged from 25.04 cm to 29.65 cm 0.0 ppm and 400 ppm respectively and 90 DAS ranged from 40.01 cm to 43.08 cm 800ppm and 400 ppm and120 DAS ranged from 56.30 cm to 51.40cm 0.0ppm and 400 ppm. Plant height reviled at 60, 90, 120 day after showing were significantly (p <0.05) except 30 DAS non significantly (p <0.05) in influenced by KNN application during the crop session and 400 ppm recorded significantly taller plant as compared to other treatments during the growth period on the basis of mean data. As regard to influence of different treatment plant height was found to deviate significantly at the stay of observation. Among the all treatments 400 ppm recorded taller plant at 30, 60, 90, 120 days after sowing (DAS). However 800 ppm fount lower plant growth at 30, 60, 90 and 120 DAS.

The result revealed that the bulb diameter was observed highest in 400 ppm and lowest in 800 ppm followed by 200 ppm and 600 ppm at 30, 60, 90 and 120 days after sowing. Bulb diameter reviled at 60, 90, 120 day after showing were significantly (p <0.05) except 30 DAS non significantly (p <0.05) in influenced by KNN (*Sodium Potassium Niobate Nanoparticles*) application during the crop session. Overall, bulb diameter was observed lowest 1.08 cm in 0.0 ppm and highest 1.70 cm in 400 ppm. However, at 60 DAS the bulb diameter ranged from 2.85 cm to 3.70 cm in 0.0 ppm and 400ppm, and 90DAS bulb diameter ranged from 4.35cm to 6.24cm in 0.0 ppm and 400 ppm.

The overall data for leaf fresh was observed lowest 1.81 gm 0.0 ppm and highest 2.73gm 400 ppm at 30 days and ranged from 42.75 gm to 59.21 gm in 600 ppm and 200 ppm at 120 days. Leaf fresh weight reviled at 60, 90, 120 day after showing were significantly (p <0.05) except 30 DAS non significantly (p <0.05) in influenced by KNN application during the crop session. The mean data of leaf dry weight was observed lower in 0.0 ppm (0.22 gm) and highest in 400 ppm (0.29 gm) at 30 days. However, at 120 days leaf dry weight ranged from 4.19 to 6.46 gm in 200 ppm and 400 ppm treatment. Leaf dry weight reviled at 60, 90, 120 day after showing were significantly (p <0.05) except 30 DAS non significantly (p <0.05) in influenced by KNN application during the crop session. Among the all treatment 400 ppm recoded best dry weight at 30, 60, 90, 120 DAS.

The mean data of bulb fresh weight elongation was observed at 30 days lowest 3.04gm in 800 ppm and highest 4.64 gm in 400 ppm. However at 120 days ranged 65.00 gm to 130.00 gm in 800ppm and 400 ppm respective. Bulb fresh weight reviled at 60, 90, 120 day after showing were significantly (p <0.05) except 30 DAS non significantly (p <0.05) in influenced by KNN application during the crop session and 400 ppm recorded significantly highest fresh bulb weight as compared to other treatments during the growth period on the basis of mean data As regard to influence of different treatment bulb fresh weight was found to deviate significantly at the stay of observation. Among the all treatments 400 ppm recorded bulb fresh weight at 30, 60, 90, 120 days after sowing (DAS). However 800 ppm found lower plant growth at 30, 60, 90 and 120 DAS.

The mean data of bulb dry weight was observed lowest 0.24 gm 0.0 ppm and highest 0.46gm in 400ppm KNN application at 30 days. However, at 120 days after sowing the plant highest ranged from 6.86gm to 11.00 gm in 0.0 ppm and 400 ppm respectively. Bulb dry weight reviled at 60, 90, 120 day after showing were significantly (*p* <0.05) except 30 DAS non significantly (p <0.05) in influenced by KNN application during the crop session and 400 ppm recorded significantly highest dry bulb as compared to other treatment during the growth period on the basis of mean data. As regard to influence of different treatment bulb dry weight was found to deviate significantly at the stay of observation. Among the all treatments 400 ppm recorded bulb dry weight at 30, 60, 90, 120 days after sowing (DAS). However 800 ppm found lower plant growth at 30, 60, 90 and 120 DAS.

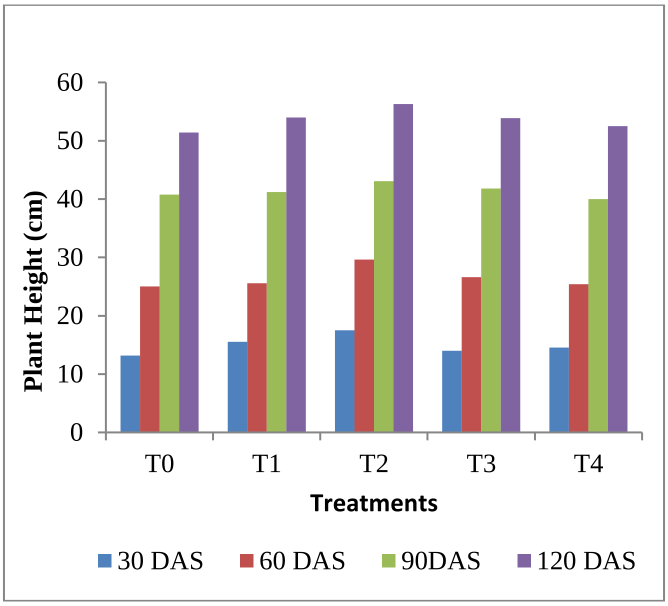

Fig. 1. Effect of KNN on plant height (cm) under different treatments combination

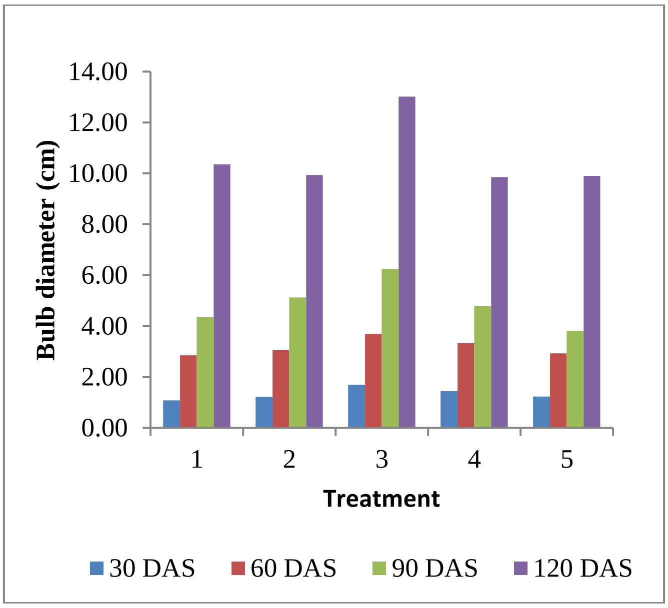

Fig. 2. Effect of KNN on bulb diameter (cm) under different treatments combination

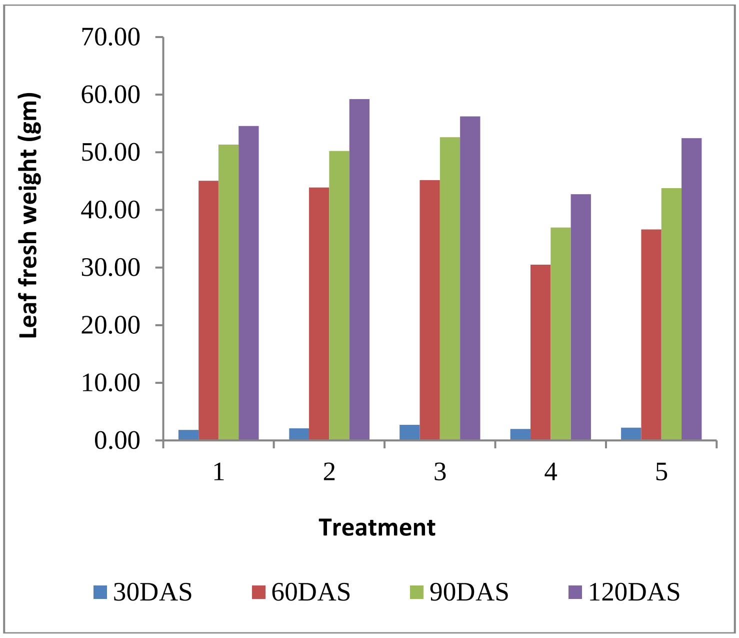

Fig. 3. Effect of KNN on leaf fresh weight (gm) under different treatments combination

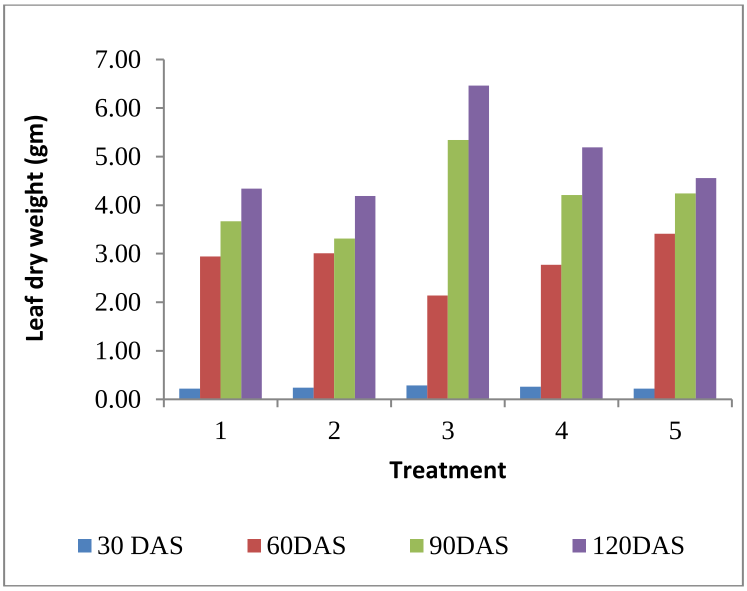

Fig. 4. Effect of KNN on leaf dry weight (gm) under different treatments combination

“The use of nano-fertilizers improves the growth of sugar beet plants” (Mohamed *et al.* 2022). A study by (Ghasemi *et al.* 2020) revealed that nanofertilizer with nanoiron containing NPK fertilizer improves the production of dragon’s head *Lallemantia iberica* L. Some study reported that silver nanoparticles on the growth of plants (Khan *et al.* 2023). “Therefore, increasing the concentration of KNN we observe toxic effect on sugar beet plant at higher conentration (800ppm). However, nanoparticles as sources of macro- and microelements for plant crop growth” (Semenova *et al.* 2024). “This result also confirms the well-known reduction on primary root growth observed in plants subjected to low phosphate availability, as described in Arabidopsis” (Al-Ghazi *et al.* 2003). “The possible reason for the improvement in the growth characteristics with HAP NPS nano-fertilizer is that nanoparticle size can inter the leaves following foliar application via stomatal openings or trichomes and then translocate to other tissue” (Elsoyed *et al.* 2022). “Furthermore, increased readily available fraction of P stimulated root elongation, which is the necessary for plant growth" (George *et al.* 2021). "Effect of Nano micronutrients and nitrogen foliar applications on sugar beet of quantity and quality traits in marginal soil in Egypt" (Dewdar *et al.* 2018). "Agriculture policy of Egypt supports sugar beet cultivators, to increase the cultivated area so increase sugar production and decrease the gap between production and consumption of sugar). Nanoparticles (NPs) can modulate cell fate, induce or prevent mutations, initiate cell–cell communication, and modulate cell structure in a manner dictated largely by phenomena at the nano–bio interface" (Behzadi *et al*.2017). Rouached *et al.* 2010, Nitrogen metabolism plays a major role in the adaptation of the halophytic forage species Sulla carnosa to water deficit and upon stress recovery.

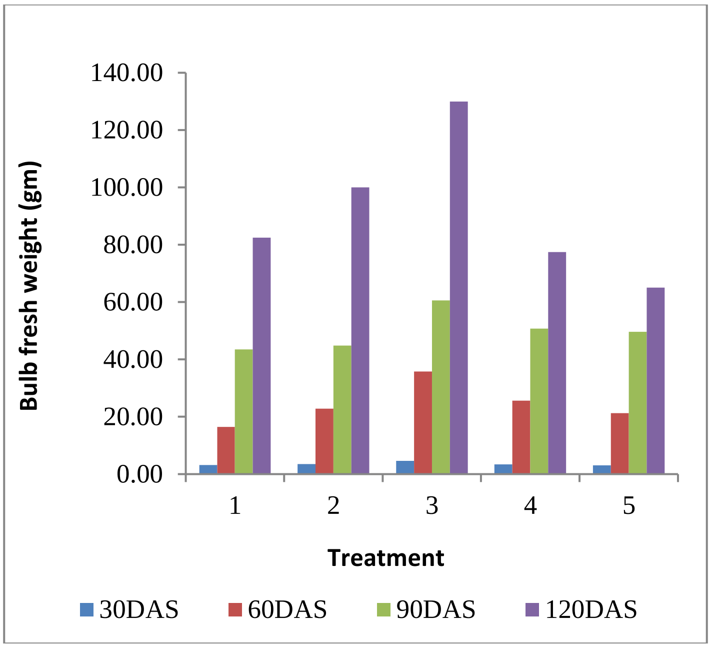

Fig. 5. Effect of KNN on bulb fresh weight (gm) under different treatment combination

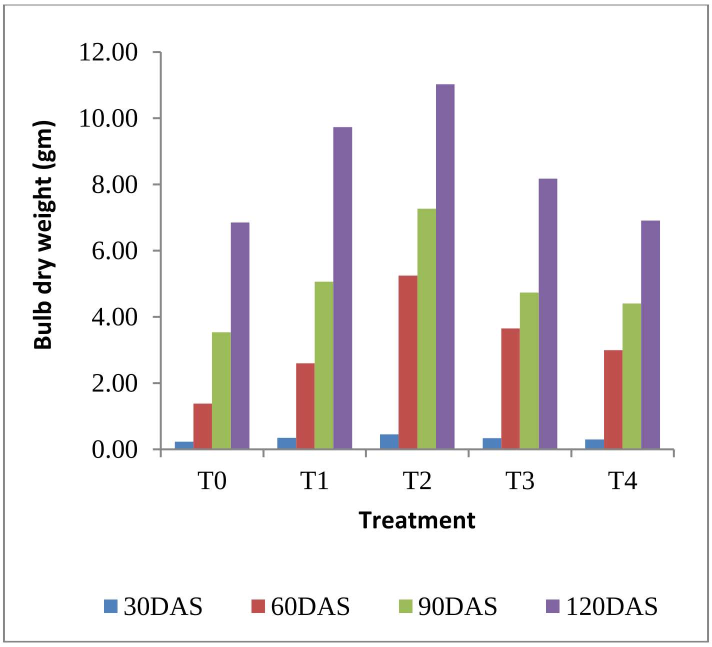

Fig. 6. Effect of KNN on bulb dry weight (gm) under different treatments combination

Table 2. Effect of Sodium potassium niobate nanoparticles on yield and yield attributes

Treatment	Plant height (cm) at different days after sowing				Bulb diameter (cm) at different days after sowing				Leaf fresh weight (gm) at different days after sowing			
	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days
T0	13.18 (±0.86)	25.04 (±0.88)	40.78 (±1.43)	51.40 (±0.84)	1.08 (±0.10)	2.85 (±0.21)	4.35 (±0.43)	10.36 (±0.92)	1.81 (±0.37)	45.08 (±8.82)	51.33 (±8.56)	54.57 (±4.31)
T1	15.53 (±1.48)	25.59 (±0.78)	41.22 (±0.59)	54.01 (±0.72)	1.22 (±0.09)	3.05 (±0.13)	5.12 (±0.46)	9.94 (±0.60)	2.11 (±0.25)	43.92 (±3.36)	50.25 (±2.80)	59.21 (±3.70)
T2	17.51 (±0.86)	29.65 (±0.73)	43.08 (±0.83)	56.30 (±0.84)	1.70 (±0.12)	3.70 (±0.17)	6.24 (±0.42)	13.02 (±0.66)	2.73 (±0.45)	45.20 (±5.58)	52.64 (±4.60)	56.25 (±2.58)
T3	14.00 (±1.40)	26.62 (±1.41)	41.80 (±1.09)	53.89 (±0.50)	1.45 (±0.11)	3.33 (±0.34)	4.79 (±0.57)	9.85 (±0.65)	1.97 (±0.58)	30.52 (±2.36)	36.94 (±1.71)	42.75 (±1.01)
T4	14.54 (±1.34)	25.40 (±1.13)	40.01 (±1.15)	52.51 (±1.36)	1.24 (±0.11)	2.93 (±0.21)	3.81 (±0.72)	9.90 (±0.65)	2.22 (±0.49)	36.64 (±4.36)	43.78 (±4.21)	52.43 (±1.49)
S.Em(±)	1.40	1.02	1.11	0.89	0.11	0.23	0.54	0.71	0.45	2.93	4.96	5.39
CD (p<0.05)	NS	3.09	3.35	2.68	NS	0.68	1.62	2.41	NS	8.82	14.96	16.24

Table 2. Effect of Sodium potassium niobate nanoparticles on yield and yield attributes (Contd.)

Treatment	Plant leaf dry weight (gm) at different days after sowing				Bulb fresh weight (gm) at different days after sowing				Bulb dry weight (gm) at different day after sowing			
	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days
T0	0.22 (±0.022)	2.94 (±0.28)	3.67 (±0.59)	4.34 (±0.99)	3.16 (±0.63)	16.50 (±0.62)	43.54 (±1.29)	82.50 (±12.5)	0.24 (±0.08)	1.38 (±0.40)	3.54 (±0.15)	6.86 (±0.65)
T1	0.24 (±0.031)	3.01 (±0.44)	3.31 (±0.35)	4.19 (±0.33)	3.50 (±0.25)	22.84 (±0.84)	44.87 (±1.44)	100.00 (±4.08)	0.35 (±0.025)	2.60 (±0.53)	5.07 (±0.36)	9.74 (±0.70)
T2	0.29 (±0.048)	2.14 (±0.15)	5.34 (±0.25)	6.46 (±0.71)	4.64 (±0.34)	35.82 (±2.86)	60.62 (±2.59)	130.00 (±10.80)	0.46 (±0.03)	5.25 (±0.87)	7.27 (±0.46)	11.03 (±0.80)
T3	0.26 (±0.025)	2.77 (±0.44)	4.21 (±0.27)	5.19 (±0.23)	3.43 (±0.50)	25.64 (±2.67)	50.81 (±1.09)	77.50 (±6.29)	0.34 (±0.05)	3.66 (±0.55)	4.74 (±0.32)	8.17 (±0.82)
T4	0.22 (±0.038)	3.41 (±0.44)	4.24 (±0.26)	4.56 (±0.50)	3.04 (±0.56)	21.21 (±1.79)	49.59 (±1.46)	65.00 (±6.45)	0.30 (±0.05)	3.00 (±0.96)	4.41 (±0.16)	6.91 (±0.89)
SEm±	0.03	0.37	0.37	0.62	0.49	1.98	1.66	8.61	0.05	0.70	0.32	0.78
CD (p <0.05)	NS	1.12	1.12	1.87	NS	5.98	5.01	25.96	NS	2.12	0.96	2.36

4. CONCLUSION

The Sodium potassium niobate nanoparticles significantly reduced nutrients loss in the root environment. The field experiment comprised of 5 treatments combination of (Sodium potassium Niobate Nanoparticles) KNN on crop yield and yield attributes. The different concentration (0.0, 200, 400, 600, and 800 ppm) of KNN with four replications were statistical analysed best result show 400 ppm in all treatment. These combination findings were analyzed standard statistical and concluded. We observed that even a half concentration of such eco-friendly nutrient complexes enhanced the bioavailability of potassium and sodium, enhancing crop growth and nutrient tool that will contribute to the alleviation of the pollution and waste generation arising from agriculture These nanoparticles were multi- nutrient complexes that bio-fortified the crops with minimum fertilizer, making agriculture less costly and safer for the environment. The present study thus establishes comprehensive experimental evidence for the one-crop cycle application of nano-fertilizers. It unlocks new paradigms for designing and applying climate-friendly smart fertilizers for sustainable agriculture. In case of yield parameter, the applications of KNN have positive effects on sugar beet crop.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

I hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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