

Effect of Foliar Application of Nano Urea and Micronutrients on Growth, Yield and Fruit Quality of Ber (*Ziziphus Mauritiana* L.)

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Abstract

A field experiment was conducted during the consecutive years 2022–23 and 2023–24 at Dr. B.R.C. Agricultural Research Station, Mandor, Jodhpur (Rajasthan) to evaluate the effect of foliar application of nano urea and micronutrient fertilizers on growth, yield and fruit quality of ber (*Ziziphus mauritiana* L.). The experiment was laid out in Randomized Block Design (RBD) with 13 treatments and 3 replications. The study aimed to assess the influence of nano urea, zinc sulfate (ZnSO_4), ferrous sulfate (FeSO_4) and boron on various morphological, yield and quality parameters of ber under arid agro-climatic conditions. The combined foliar application of Nano Urea 0.2% + ZnSO_4 0.5% + FeSO_4 0.5% + Boron 0.5% (T_{13}) resulted in the highest plant height (4.49 m), fruit retention (53.66%), fruit weight (24.58 g), TSS (17.3 °B) and fruit yield (14.97 t ha⁻¹). T_{13} also recorded the highest net return (₹1,52,314 ha⁻¹) and B:C ratio (3.11). The results underscore the synergistic effect of macro and micronutrients especially in nano form enhancing productivity and profitability of ber cultivation.

Keywords: ferrous, foliar application, growth, micronutrient, nano urea, yield, zinc

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Introduction

Ber (*Ziziphus mauritiana* L.) is one of the oldest and most prominent fruit crops cultivated in arid and semi-arid regions. *Ziziphus rotundifolia*, *Ziziphus rugosa*, *Ziziphus jujube* and *Ziziphus oenoplia* are other wild ber species found in India. Ber belongs to the family Rhamnaceae and possesses a tetraploid chromosome number of $2n = 4x = 48$. Often referred to as the "King of Desert Fruits" due to its summer deciduous nature and exceptional adaptability. Ber is also known as the "poor man's apple" because of its high nutritional value and affordability. Ber is widely appreciated for its excellent economic returns, low input requirements and adaptability to drought and marginal soils making it ideal for cultivation in tropical and subtropical climates. The fruit is rich in nutrients including ascorbic acid (65.8–76.0 mg/100 g), vitamin A (55 mg), thiamine (0.13 mg), riboflavin (0.19 mg), carotene (81 µg), protein (0.8 g), fat (0.3 g), carbohydrate (17 g), calcium (4 mg), phosphorus (9 mg) and iron (1.8 mg) [1].

Adequate and balanced supply of macro and micronutrients is essential for optimal plant growth which in turn leads to improved flowering, fruit set and yield. The enhancement in fruit quality is often attributed to the catalytic role of nutrients especially when applied at appropriate concentrations [2]. Given the increasing significance of micronutrients in sustainable agriculture, foliar application has emerged as an effective method to deliver nutrients directly to the plant canopy ensuring their timely availability during critical growth stages [3].

Nano-fertilizers have gained prominence due to their non-toxic nature, environmental safety and efficiency in improving soil fertility, crop productivity and quality. Compared to conventional fertilizers, nano-fertilizers can enhance crop yield by up to 30%, reduce input costs and increase profitability. Specifically nano nitrogen plays a vital role in promoting plant growth, improving nutrient uptake, enhancing photosynthesis and increasing water use efficiency [1]. Keeping this in mind the present study was conducted to study the response of foliar application of nano-urea and micronutrients on growth, yield and quality of ber at Dr. B.R.C. Agricultural Research Station, Mandor, Jodhpur (Rajasthan)

Material and Methods

The present field experiment was conducted over two consecutive years (2022–23 and 2023–24) to evaluate the effect of foliar application of nano urea, zinc sulphate (ZnSO_4), ferrous sulphate (FeSO_4) and boron on the growth, yield and fruit quality of ber (*Ziziphus mauritiana* L.) cv. Gola. The study was carried out at the Horticulture Research Block of

Dr. B.R. Choudhary Agricultural Research Station, Mandor, Jodhpur (Rajasthan). The experimental orchard consisted of five-year-old ber trees planted at a spacing of 8 × 8 meters (row × plant). Three trees were used for each treatment in the experiment. The soil of the experimental site is predominantly sandy in texture with moderate nutrient availability particularly in the surface layer. This sandy nature coupled with low organic matter and inherent fertility constraints necessitated the use of targeted nutrient management strategies to improve plant performance and fruit quality under arid condition. The study was laid out in a randomized block design (RBD) with three replication and thirteen treatments viz. T₁ - Control (Water Spray), T₂ - Nano Urea 0.2%, T₃ - ZnSO₄ 0.5%, T₄ - FeSO₄ 0.5%, T₅ - Boron 0.5%, T₆ - Nano Urea 0.2% + ZnSO₄ 0.5%, T₇ - Nano Urea 0.2% + FeSO₄ 0.5%, T₈ - Nano Urea 0.2% + Boron 0.5%, T₉ - Nano Urea 0.2% + ZnSO₄ 0.5% + FeSO₄ 0.5%, T₁₀ - Nano Urea 0.2% + ZnSO₄ 0.5%+ Boron 0.5%, T₁₁ - Nano Urea 0.2% + FeSO₄ 0.5% + Boron 0.5%, T₁₂ - ZnSO₄ 0.5% + FeSO₄ 0.5% + Boron 0.5% and T₁₃ - Nano Urea 0.2% + ZnSO₄ 0.5% + FeSO₄ 0.5% + Boron 0.5%. Nano urea developed by the IFFCO contains nitrogen nanoparticles with a size range of approximately 20-50 nm. Foliar sprays were applied twice each year, once during the first week of October and again during the second week of November. All recommended cultural practices including pest and disease management were uniformly followed across all experimental plots to ensure consistency. Each treatment was applied to a plot consisting of three ber trees. Observations were recorded on various growth, yield and quality parameters including plant height (m), fruit retention (%), fruit length (cm), fruit breadth (cm), fruit weight (g), total soluble solids (TSS in °Brix), fruit yield per tree (kg) and fruit yield (ton ha⁻¹). The total cumulative yield per tree was measured using a digital weighing balance and expressed in kilograms. The yield per hectare was then calculated by multiplying the yield per tree by the number of trees that could be accommodated in one hectare and the results were expressed in tons per hectare. Total soluble solids (TSS) were determined using a hand refractometer. The pooled data over two years were subjected to statistical analysis using analysis of variance (ANOVA). Treatment means were compared using the Critical Difference (CD) test at a 5% level of significance with the method suggested by Panse and Sukhatme (1989) [4].

Table 1 Effect of foliar spray of Nano Urea, ZnSO₄, FeSO₄ and Boron on plant growth, yield and fruit quality in ber cv. Gola (Pooled data of two years)

Treatments	Plant height (m)	Fruit retention (%)	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)	Total soluble solid (°B)
T ₁	3.20	24.67	3.08	2.48	16.79	12.80
T ₂	3.45	31.51	3.33	2.99	18.46	14.72
T ₃	3.57	34.40	3.37	3.17	19.27	15.08
T ₄	3.37	27.45	3.21	2.86	17.57	13.75
T ₅	3.52	32.66	3.36	3.13	18.87	15.02
T ₆	3.80	36.90	3.39	3.22	20.05	15.32
T ₇	3.68	35.50	3.39	3.14	19.77	15.18
T ₈	3.90	39.37	3.41	3.27	20.46	15.83
T ₉	4.27	46.74	3.55	3.39	21.27	16.50
T ₁₀	4.33	48.58	3.62	3.46	22.30	16.80
T ₁₁	4.03	44.40	3.50	3.36	20.93	16.32
T ₁₂	3.97	43.52	3.43	3.31	20.52	15.88
T ₁₃	4.49	53.66	3.78	3.77	24.58	17.30
SEm±	0.25	3.120	0.14	0.20	1.36	0.77
CD at 5%	0.71	8.871	0.40	0.58	3.88	2.18
CV (%)	11.40	14.068	7.06	10.97	11.77	8.61
T ₁ - Control (Water Spray), T ₂ - Nano Urea 0.2%, T ₃ - ZnSO ₄ 0.5%, T ₄ - FeSO ₄ 0.5%, T ₅ - Boron 0.5%, T ₆ - Nano Urea 0.2% + ZnSO ₄ 0.5%, T ₇ - Nano Urea 0.2% + FeSO ₄ 0.5%, T ₈ - Nano Urea 0.2% + Boron 0.5%, T ₉ - Nano Urea 0.2% + ZnSO ₄ 0.5% + FeSO ₄ 0.5%, T ₁₀ - Nano Urea 0.2% + ZnSO ₄ 0.5%+ Boron 0.5%, T ₁₁ - Nano Urea 0.2% + FeSO ₄ 0.5% + Boron 0.5%, T ₁₂ - ZnSO ₄ 0.5% + FeSO ₄ 0.5% + Boron 0.5% and T ₁₃ - Nano Urea 0.2% + ZnSO ₄ 0.5% + FeSO ₄ 0.5% + Boron 0.5%.						

Results and Discussion

The pooled data across two consecutive years revealed significant effects of foliar application of nano urea, zinc sulphate ($ZnSO_4$), ferrous sulphate ($FeSO_4$) and boron on growth, yield and fruit quality parameters of ber. The application of micronutrients and nano urea had a significant impact on vegetative growth as indicated by increased plant height. The tallest plants (4.49 m) were observed in T_{13} (Nano Urea 0.2% + $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% + Boron 0.5%) while the shortest plants (3.20 m) were recorded in the control (T_1). The synergistic effect of nitrogen, zinc, iron and boron likely enhanced photosynthetic efficiency, cell division and elongation contributing to greater vertical growth. These findings align with Drostkar *et al.*, (2016), who reported enhanced vegetative growth with the foliar application of macro and micronutrients. Similarly, Abd El-Rhman and Shadia (2012) [5] found that combined foliar application of urea and $ZnSO_4$ improved plant height in ber.

Fruit retention is a key determinant of final yield. T_{13} recorded the highest fruit retention (53.66%) significantly higher than the control (24.67%). Treatments such as T_{10} (48.58%), T_9 (46.74%) and T_{11} (44.40%) also showed substantial improvement. The improved retention may be attributed to reduced premature fruit drop due to boron's role in pollen germination and ovary development and iron's involvement in enzymatic activation. Similar results were reported by Chander *et al.*, (2017) [4] in guava where a combination of $ZnSO_4$, borax and urea significantly increased fruit retention.

Fruit length, breadth and weight were positively influenced by foliar applications. The largest fruit dimensions were obtained under T_{13} with fruit length (3.78 cm), breadth (3.77 cm), and fruit weight (24.58 g) reflecting a notable improvement over the control (3.08 cm, 2.48 cm, and 16.79 g respectively). This improvement is likely due to the enhancement of cell expansion and dry matter accumulation facilitated by the combined effect of N, Zn, Fe, and B. These findings correlate with the results of Abd El-Rhman and Shadia (2012) [5] who observed increased fruit size and weight in ber trees with the foliar application of urea and $ZnSO_4$. Meena *et al.*, (2008) [7] and Bhalerao and Patel (2015) [8] also reported similar gains in fruit morphology with micronutrient sprays in ber and Papaya, respectively.

Table 2 Effect of foliar spray of Nano Urea, $ZnSO_4$, $FeSO_4$ and Boron on yield and economics in ber cv. Gola (Pooled data of two years)

Treatments	Fruit yield per tree (kg)	Fruit yield per hectare (t)	Gross Return ha^{-1} (Rs)	Net Return ha^{-1} (Rs)	B : C ratio
T_1	60.30	9.41	141098	77873	2.23
T_2	65.03	10.14	152166	85141	2.27
T_3	68.55	10.69	160411	93936	2.41
T_4	63.77	9.95	149226	82551	2.24
T_5	67.15	10.47	157119	89344	2.32
T_6	75.19	11.73	175941	107666	2.58
T_7	71.88	11.21	168188	99713	2.46
T_8	76.55	11.94	179115	109540	2.57
T_9	87.28	13.61	204224	134499	2.93
T_{10}	90.57	14.13	211930	141105	2.99
T_{11}	83.47	13.02	195308	124283	2.75
T_{12}	80.61	12.58	188631	118156	2.68
T_{13}	95.98	14.97	224589	152314	3.11
SEm \pm	4.86	0.76	11365	11365	0.17
CD at 5%	13.81	2.15	32315	32315	0.47
CV (%)	11.09	11.09	11.09	18.07	11.13

T_1 - Control (Water Spray), T_2 - Nano Urea 0.2%, T_3 - $ZnSO_4$ 0.5%, T_4 - $FeSO_4$ 0.5%, T_5 - Boron 0.5%, T_6 - Nano Urea 0.2% + $ZnSO_4$ 0.5%, T_7 - Nano Urea 0.2% + $FeSO_4$ 0.5%, T_8 - Nano Urea 0.2% + Boron 0.5%, T_9 - Nano Urea 0.2% + $ZnSO_4$ 0.5% + $FeSO_4$ 0.5%, T_{10} - Nano Urea 0.2% + $ZnSO_4$ 0.5% + Boron 0.5%, T_{11} - Nano Urea 0.2% + $FeSO_4$ 0.5% + Boron 0.5%, T_{12} - $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% + Boron 0.5% and T_{13} - Nano Urea 0.2% + $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% + Boron 0.5%.

Total soluble solids is a indicator of sweetness and overall fruit quality showed significant enhancement with foliar treatments. T_{13} recorded the maximum TSS (17.3 °B) followed by T_{10} (16.80°B) and T_9 (16.50°B). The lowest TSS

(12.80°B) was recorded in the control. The results clearly illustrate the cumulative benefit of combining macro and micronutrients for improving the sugar content and palatability of ber fruits. The TSS enhancement can be attributed to improved photosynthate accumulation and translocation toward developing fruits under optimal nutrient supply. Boron plays a vital role in sugar metabolism and movement, while iron contributes to chloroplast integrity and photosynthetic enzyme activation. The present results on TSS are conformity with the findings of Jat and Kacha (2014) [9] in guava and Abhijith *et al.*, (2018) [10] in aonla.

Fruit yield per tree and per hectare followed a consistent pattern with other yield components. The highest yield per tree (95.98 kg) and per hectare (14.97 t) were obtained with T₁₃ which was significantly superior to all other treatments. The control recorded the lowest yield (60.30 kg/tree and 9.41 t ha⁻¹). Treatments T₁₀ (90.57 kg/tree), T₉ (87.28 kg/tree) and T₁₁ (83.47 kg/tree) also showed considerable improvements. The increased yield in T₁₃ can be attributed to better fruit retention and larger fruit size. The synergistic effects of foliar-applied nano urea and micronutrients likely maintained optimal plant health and reproductive efficiency allowing the plant to sustain higher fruit load without compromising quality. These results are in close conformity with Abd El-Rhman and Shadia (2012) [5] in ber, Chander *et al.*, (2017) [6] in guava and Sonkar *et al.*, (2024) [11] in strawberry.

The economic evaluation of treatments revealed that the most profitable option was T₁₃, with a gross return of ₹2,24,589/ha and a net return of ₹1,52,314 ha⁻¹ also giving the highest benefit-cost (B:C) ratio of 3.11. This was followed by T₁₀ (B:C ratio 2.99) and T₉ (B:C ratio 2.93). In contrast, the control treatment yielded a B:C ratio of 2.23. These results suggest that the micronutrient combinations slightly increase the input cost while the return on investment is also significantly higher due to the dramatic improvement in yield and quality. This aligns with Abhijith *et al.* (2018) [10] who also observed higher economic returns with ZnSO₄, FeSO₄ and borax combinations in aonla and reporting a B:C ratio of 3.60.

Conclusion

The results of this study conclusively demonstrate that foliar application of nano urea in combination with ZnSO₄, FeSO₄ and boron significantly improves the vegetative growth, fruit retention, yield attributes, biochemical quality and economic returns of ber cv. Gola. The treatment T₁₃ (Nano Urea 0.2% + ZnSO₄ 0.5% + FeSO₄ 0.5% + Boron 0.5%) consistently outperformed all other treatments and is recommended for adoption in Ber growing regions especially where soil fertility is a constraint. The findings of this study reinforce the concept that foliar fertilization especially with nano-forms and micronutrient combinations is a potent strategy for improving both the yield and quality of fruit crops. Due to its high surface area and efficient leaf absorption, nano-urea offers an edge over conventional urea in reducing nitrogen loss and enhancing nutrient use efficiency.

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