Original Research Article

Pre- Harvest Foliar Spray of Zinc, Calcium, Chitosan, and Salicylic Acid on Quality Standards of Indian Ber (*Zizyphusmauritiana* Lamk.) cv. Gola

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ABSTRACT

Aim: The present experiment was designed to find out the effect of afoliar spray of zinc, calcium, chitosan and salicylic acid on thefruit quality of ber.
Place and Duration of Study: This experiment was conducted at Horticulture farm, SKN College of Agriculture, Jobner in the newly established orchard of Indian jujube cv. Gola during the two-consecutiveyears2022 and 2023.
Study Design and Methodology: The present experiment is laid out in factorial randomized block design with three replications. Factor A consists of 12 level of zinc, calcium, chitosan, and salicylic acid treatments along with the control, and factor B consists three foliar sprays i.e., single foliar spray at pea size stage, color turning stage of fruits and double foliar spray at pea size and color turning stage of fruits (green to yellow). Various quality parameters namely TSS, acidity, ascorbic acid, total, reducing and non-reducing sugars are observed as per standard procedures.
Results: Plants sprayed with $ZnSO_4$ @ 4g/L + $CaCl_2$ @ 2g/L + Chitosan @ 1.5g/L +Salicylic acid @ 1g/L recorded highest TSS (19.05°Brix), minimum acidity (0.415%) TSS: acid ratio (45.93%), ascorbic acid (89.08mg/100g), total sugars (10.25%), reducing sugars (6.68%) and non-reducing sugars (3.39%) were significantly more in the treated fruits in comparison to untreated fruits. These quality parameters were observed maximum with adouble foliar spray of nutrients and agrochemicals at thepea size stage and color turning stage (S_3).
Conclusion: It is concluded that $ZnSO_4$ @ 4g/L + $CaCl_2$ @ 2g/L + Chitosan @ 1.5g/L +Salicylic acid @ 1g/L is effective in improve the quality of ber fruits.

Keywords: Zinc; Calcium; Chitosan; Salicylic acid; Quality

1. INTRODUCTION

Ber (*Zizyphusmauritiana* Lamk.) is one of the most ancient and common fruits of India and it is cultivated all over the country. Being a hardy fruit, it can be grown even on inferior and marginal lands. Ber is indigenous to an area stretching from India to China and Malaysia. Because of good returns from ber, its cultivation is becoming increasingly popular in Gujarat and other states of India, especially in Punjab, Haryana, and Rajasthan. Gola is the most common cultivar being farmed (Surani *et al.,* 2018). The Gola variety is a well-liked early type. The fruit has a medium size and an oblong to spherical shape. Its color changes from green to golden yellow as it ripens. Fruit typically weighs between 16 and 20 g on average (Chattopadhyay, 2012). A huge loss of horticultural produce takes place during storage. Inadequate means of losses during storage due to poor handling and poor post-harvest management practices. Ber can be cultivated even under constraints of irrigation and fertilization. The essential element of fruit production isbioregulators. These regulators can be applied to fruits pre-harvest to improve their physical and biochemical characteristics and preservequality.

Zinc is an essential micro element for plants, being involved in many enzymatic reactions and is necessary for their good growth and development. It is also involved in regulating protein and carbohydrate metabolism. Its availability to plants is reduced in high-pH soils. Fruits generally have a considerable amount of Calcium in their tissues. The Ca application makes the middle lamella of the fruit cell wall thicker by increased deposition of calcium pectate and so, maintains the firmness of the fruit (Sudha *et al*. 2007). Calcium has long been associated with regulation of the ripening and post-harvest storage life of fruits. Specially, maintenance of relatively high ca concentrates in fruit tissue result in a slower rate of ripening, as seen in lower respiration rate, reduced ethylene production and slower softening of fruit flesh. Combined with pectin, the "glue" that holds plant cells together, calcium forms a pectate salt that helps to keep the cell wall sturdy and rigid. Chitosan applied topically at various phases of fruit development had a major impact on the postharvest life of jujube fruits during storage. Treatments with chitosan function as barriers, preventing the transfer of water, shielding fruit skin from mechanical damage, and sealing minor wounds to postpone dehydration (Ribeiro *et al.,* 2007). Salicylic acid is an additional phenolic endogenous growth regulator that helps control a number of physiological functions in plants, including transpiration, ion absorption, stomata closure, and the suppression of ethylene production (Shafiee *et al*., 2010). Keeping in mind the importance of nutrients and agrochemicals current study was planned to improve the quality of ber fruit by pre-harvest exogenous spray of different concentrations of zinc, calcium, chitosan and salicylic acid at various growth stages under semi-arid condition of Rajasthan.

2. MATERIAL AND METHODS

2.1 Experimental site and treatments detail

This experiment was conducted at Horticulture farm, SKN College of Agriculture, Jobner in the newly established orchard of Indian jujube (*Zizyphusmauritiana* Lamk.) cv. Gola during 2022 and 2023. Factor A consists of 12 level of zinc, calcium, chitosan, and salicylic acid treatments along with the control, and factor B consists ofthree foliar sprays i.e., single foliar spray at pea size stage, colorturning stage of fruits and double foliar spray at pea size and colour turning stage of fruits (green to yellow). The treatment details of zinc, calcium, chitosan and salicylic acid along with the control i.e., T_0 (Control), T_1 (Zinc sulfate @ 4 g / L), T_2 (Calcium chloride @ 2 g / L), T_3 (Chitosan @ 1.5 g / L, T_4 Salicylic acid @ 1 g / L), T_5 (Zinc sulphate @ 4 g / L + Calcium chloride @ 2 g / L), T_6 (Zinc sulfate@ 4 g / L + Chitosan @ 1.5 g / L), T_7 (Zinc sulfate@ 4 g / L + Salicylic acid @ 1 g / L), T_8 (Calcium chloride @ 2 g / L + Chitosan @ 1.5 g / L), T_9 (Calcium chloride @ 2 g / L + Salicylic acid @ 1 g / L), T_{10} (Chitosan @ 1.5 g / L + Salicylic acid @ 1 g / L) and T_{11} (Zinc sulfate @ 4 g / L + Calcium chloride @ 2 g / L + Chitosan @ 1.5 g / L + Salicylic acid @ 1 g / L) laid out in factorial randomized block design with three replications. The treatments were applied withsingle foliar spray at the pea size stage of fruits during first week of November and double foliar spray at pea size and color turning stage of fruits (green to yellow) applied last week of December, 2022-23 and 2023-24 after recording initial (base) quality and parameters of ber fruits.

2.2 Quality attributes of ber fruit

For determination of total soluble solids wasmeasured by placing a drop of juice on the prism of the hand refractometer. The reading against the light was noted and presented in degree brix. For estimation of ascorbic acid, well-homogenized 2 g of sample was taken in a beaker volume made up to 20 ml and 5 ml of HPO_3 is added and titrated with the standard dye solution to a pink end-point which should persist for 15 seconds. The same procedure was repeated in random samples of fruits in both the year of an experiment to draw an average value of ascorbic acid content. The ascorbic acid content of the sample was calculated by using the following formula (Ranganna 2000).

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre value x dye factor x volume made up}}{\text{Aliquot extract taken for estimation x weight of sample taken for Estimation}} \times 100$$

Total and reducing sugars were estimated by the lane and Eynon copper titration method and expressed in percentage (Ranganna, 1986). The percentage of non-reducing sugar was determined by subtracting the percent reducing sugar from the percent total sugar and multiplying the same with 0.95 as given below (Somogyi, 1952).

Non-reducing sugars (%) = (Per cent total sugar – per cent reducing sugar) × 0. 95

2.3 Statistical analysis

The data were statistically analyzed as per the analysis of variance technique as suggested by Panse *et al*. (1995). The significance of the treatments was tested through the F test at a 5 percent level of significance. The critical difference CD was calculated to assess the significance of differences among the different treatments.

3. RESULTS AND DISCUSSION

Pre- harvest foliar spray of zinc, calcium, chitosan, and salicylic acid on quality standards viz., TSS, titratable acidity, TSS: acid ratio and ascorbic acid of ber (*Zizyphusmauritiana*Lamk.) cv. Gola is presented in (Table 1).

The maximum TSS content in fruits (19.05%) was recorded with the application of treatment ($ZnSO_4$ @ 4g/L + $CaCl_2$ @ 2g/L + Chitosan @ 1.5g/L +Salicylic acid @ 1g/L) followed byT_9 ($CaCl_2$ @ 2g/L + Salicylic acid @ 1g/L 18.90%), T_7 ($ZnSo_4$ @ 4g/L +Salicylic acid @ 1g/L 18.83%), T_5 ($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L 18.69%) and minimum TSS content in fruits (16.80) was noted under control. The maximum total soluble solid content (18.05 °Brix) was observed with double foliar spray of nutrients and agrochemicals at the pea size stage and color turning stage (S_3) and it was found at par with foliar spray atthe S_1stage. The foliar spray of nutrients and agrochemicals at the color-turning stage (S_2) registered the lowest total soluble solid (17.38 °Brix).A significant decrease in titratable acidity was observed in $ZnSO_4$ @ 4g/L + $CaCl_2$ @ 2g/L + Chitosan @ 1.5g/L +Salicylic acid @ 1g/L (0.16%) followed by the T_9, T_7 and $T_5$and highest titratable acidity was observed in fruits of controlled treatment (0.469%).The application of nutrients and agrochemicals at different fruit development stages had not shown any significant effect on the titratable acidity in ber fruits.

The maximum TSS: acid ratio (45.93) was recorded with combined application of $ZnSO_4$ @ 4 g/l + $CaCl_2$ @ 2 g/l + Chitosan @ 1.5 g/l + Salicylic acid @ 1 g/l (T_{11}) followed by this treatment T_9, T_7 and T_5. However, a minimum TSS: acid ratio of (36.32) was recorded under control. Application of a double foliar spray of nutrients and agrochemicals exhibited maximum TSS: acid ratio (41.69) in fruits. However, this treatment (S_3) was found statistically at par with treatment S_1. The foliar spray at S_2 recorded the lowest TSS: acid ratio (38.90)during the experimentation.

$ZnSO_4$ @ 4g/L + $CaCl_2$ @ 2g/L + Chitosan @ 1.5g/L +Salicylic acid @ 1g/L significantly increasethe ascorbic acid content of ber fruits. Highest ascorbic acid content was observed in fruits treated with $ZnSO_4$ @ 4g/L + $CaCl_2$ @ 2g/L + Chitosan @ 1.5g/L

+Salicylic acid @ 1g/L that's 89.08 mg/100g followed by T_9 (85.77 mg/100g), T_7 (85.63 mg/100g) and T_5 (85.31 mg/100g). Thelowest contents were observed in control (74.63 mg/100g). However, the maximum ascorbic acid content (83.42 mg/100g) was observed with a double foliar spray of nutrients and agrochemicals at the pea size stage and color turning stage (S_3) and it was found statistically at par with S_1(82.75 mg/100g). The treatment combination S_2 recorded minimum ascorbic acid content (81.96 mg/100g)during the investigation.

Table 1 Pre- Harvest Foliar Spray of Zinc, Calcium, Chitosan and Salicylic Acid on TSS, titratable acidity, TSS: acid ratio and ascorbic acidofber fruit.

Treatments	TSS (^{0}Brix)	Titratable acidity (%)	TSS: acid ratio	Ascorbic acid (mg/100g)
Nutrients and agrochemicals				
T_0 Control	16.80	0.469	36.32	74.63
T_1 $ZnSO_4$	16.90	0.457	37.03	80.38
T_2 $CaCl_2$	16.94	0.457	37.15	80.72
T_3 Chitosan	16.83	0.465	36.26	76.44
T_4 Salicylic acid	16.94	0.447	37.96	81.15
T_5 $ZnSO_4$ + $CaCl_2$	18.69	0.421	44.47	88.07
T_6 $ZnSO_4$ + Chitosan	17.43	0.448	38.97	81.53
T_7 $ZnSO_4$ + Salicylic acid	18.83	0.418	45.05	88.32
T_8 $CaCl_2$ + Chitosan	17.77	0.450	39.57	81.65
T_9 $CaCl_2$ + Salicylic acid	18.90	0.417	45.36	88.80
T_{10} Chitosan+ Salicylic acid	17.94	0.434	41.55	81.77
T_{11} $ZnSO_4$ + $CaCl_2$ + Chitosan + SA	19.05	0.415	45.93	89.08
SEm$\pm$	**0.21**	**0.00**	**0.61**	**0.48**
CD (P = 0.05)	**0.59**	**NS**	**1.70**	**1.35**
Different Stage of Foliar Spray				
S_1	17.83	0.440	40.81	82.75
S_2	17.38	0.449	38.90	81.96
S_3	18.05	0.435	41.69	83.42
SEm$\pm$	**0.11**	**0.00**	0.30	0.24
CD (P = 0.05)	**0.29**	**NS**	**0.85**	**0.68**

It is evident from data presented in Table 2 related to the application of nutrients and agrochemicals showed a significanteffect on total, reducing and non-reducing sugars in fruits. Significantly higher total sugars was observed in $ZnSO_4$ @ 4g/L + $CaCl_2$ @ 2g/L + Chitosan @ 1.5g/L +Salicylic acid @ 1g/L treatment (10.25%). Controlled treatment shows minimum total sugars among other treatments (8.16%). However, the highest total sugars of (9.54 %) were observed with a double foliar spray of nutrients and agrochemicals at the pea size stage and colour turning stage (S3) and it was found statistically at par with treatment S1(9.32 %). The treatment combination S_2 recorded the lowest total sugars content(8.96 %) during the experimentation.

$ZnSO_4$ @ 4g/L + $CaCl_2$ @ 2g/L + Chitosan @ 1.5g/L +Salicylic acid @ 1g/L significantly increases reducing and non-reducing sugars (6.52%, 4.23% respectively) followed by the fruits treated with T_9, T_7 and T_5 and minimum values were observed in the control treatment. However, the maximum reducing (6.46%) and non-reducing (3.01%) sugars were observed with a double foliar spray of nutrients and agrochemicals at the pea size stage and color turning stage (S_3) and this treatment (S_3) was found statistically at par with treatment S_1. Whereas, minimum reducing (6.17%) and non-reducing (2.56%) sugars were recorded with a foliar spray of nutrients and agrochemicals done at the color-turning stage (S_2).

Table 2Pre- Harvest Foliar Spray of Zinc, Calcium, Chitosan and Salicylic Acid on total, reducing and non-reducing sugars ofber fruit.

Treatments	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
Nutrients and agrochemicals			
T_0 Control	8.16	5.92	2.13
T_1 $ZnSO_4$	8.84	6.15	2.56
T_2 $CaCl_2$	8.92	6.23	2.55
T_3 Chitosan	8.64	6.07	2.44
T_4 Salicylic acid	9.01	6.19	2.68
T_5 $ZnSO_4$ + $CaCl_2$	9.93	6.56	3.21
T_6 $ZnSO_4$ + Chitosan	9.01	6.24	2.64
T_7 $ZnSO_4$ + Salicylic acid	10.05	6.58	3.30
T_8 $CaCl_2$ + Chitosan	9.10	6.28	2.68
T_9 $CaCl_2$ + Salicylic acid	10.16	6.63	3.35
T_{10} Chitosan+ Salicylic acid	9.17	6.31	2.71
T_{11} $ZnSO_4$ + $CaCl_2$ + Chitosan + SA	10.25	6.68	3.39
SEm±	**0.17**	**0.10**	**0.17**
CD (P = 0.05)	**0.47**	**0.27**	**0.48**
Different Stage of Foliar Spray			
S_1	9.32	6.33	2.84
S_2	8.96	6.17	2.56
S_3	9.54	6.46	3.01
SEm±	**0.08**	**0.05**	**0.09**
CD (P = 0.05)	**0.23**	**0.13**	**0.24**

The application of zinc, $CaCl_2$, chitosan and SA increased TSS content in the fruits, which might be due to the enhancement of auxin synthesis. Auxin, in turn, enhances the synthesis of metabolites and their rapid translocation from one part of the plant to developing fruits (Alrawi *et al.,* 2012, Badway *et al.,* 2019 and Talat *et al*., 2024). The improvement in fruit quality might also be due to zinc's role in enzymatic reactions, such as hexokinase, and its involvement in carbohydrate formation and protein synthesis (Pamila *et al.,* 1992 and Wahab *et al*., 2021).The reason for decreased TA is due to the breakup of fermentation of acids into sugars during the respiration process. An increase in the TSS: acid ratio is likely due to an increase in TSS content and a decrease in acidity (Abdel Rhman*et al.,* 2017 and Yadav *et al*., 2022). Zinc, $CaCl_2$, chitosan and SA application also increased the ascorbic acid content, which appears to be due to increased growth and the availability of more metabolites for ascorbic acid synthesis. The possible reason for the increase in total sugar and reducing sugars in fruits from foliar sprays of minerals and agrochemicals might be the conversion of starch and acid into sugars, along with the continuous mobilization of sugars from leaves to fruits (Yadav *et al.,* 2018, Sharma*et al*., 2021 and Martínez *et al.,* 2022). Treatments that delayed the start of fruit senescence and the conversion of complex carbohydrates into simple sugars may have contributed to the greater non-reducing sugar levels in treated samples (Sajid *et al*. 2020, Shanbehpour*et al*., 2020, Shashi*et al.,* 2022 and Singh *et al*. 2023).

4. CONCLUSION

The findings of this study demonstrate that as compared with individual applications of zinc, calcium, chitosan, or salicylic acid, a combination of these elicitors had a much superior impact on fruit quality aspects of ber fruits. The present study is noteworthy because it offers evidence that a combination of these elicitors may enhance fruit quality both during the postharvest storage period and at the time of harvest. Future research should concentrate on optimizing the concentrations and combinations that might be used commercially on ber fruit from different crops or cultivars to increase the fruit's marketability.

Disclaimer (Artificial intelligence)

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

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