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Research Article

Influence of Pre-harvest spray of Calcium nitrate, Boric acid and Zinc sulphate on Quality and Storage life of Nagpur mandarin (*Citrus reticulata* Blanco)

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Abstract

A field experiment was conducted during winter season of 2014 -2015 to study the Influence of Pre-harvest spray of Calcium nitrate, Boric acid and Zinc sulphate on quality and storage life of Nagpur mandarin (*Citrus reticulata* Blanco) at Department of Fruit Science at College of Horticulture and Forestry, Jhalawar. Various doses of Calcium nitrate (1.0%, 2.0% and 3.0 %), Boric acid (0.2 %, 0.4 % and 0.6 %) and Zinc sulphate (0.2 %, 0.4 % and 0.6 %) were sprayed before harvesting and compared with untreated ones. The results obtained indicated that the trees sprayed with T_{27} i.e. (Calcium nitrate @ 3.0 % + Boric acid @ 0.6 % + Zinc sulphate @ 0.6 %) showed maximum increase non reducing sugar (2.58%), total sugar (9.02%), Juice per cent (46.89%), Sensory score (9.23/10.0) over control. Further, T_{24} treatment combination (calcium nitrate @ 3.0 % + boric acid @ 0.4 % + Zinc sulphate @ 0.6 %) has also significantly increased TSS (12.05 ^{0}B), TSS: Acid ratio (15.97), ascorbic acid (50.61 mg) and reduced acidity (0.73%) of fruits. Besides, T_{27} treatment combination also significantly recorded minimum physiological loss in weight (2.23%), (5.13%) and (10.09 %), decay percent (2.22 %), (5.13 %) and (11.34 %) and higher retention of juice percent (46.31 %), (44.31 %), (41.77%) and (39.12 and sensory score (8.83/ 10), (8.63/ 10) and (8.28/ 10) storage at 5th, 10th and 15th day of storage at ambient temperature.

Keywords: Boric acid, Calcium nitrate, Pre-harvest spray, Quality, Storage and Zinc sulphate

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Introduction

In India citrus fruits have a prominent place among popular and extensively grown tropical and subtropical fruits after mango and banana. Mandarin (*Citrus reticulata* Blanco) is considered to be one of the most important cultivated species among citrus and is being commercially grown in certain specific region of the country like Nagpur mandarin in Central India; this crop occupies the first position among the citrus in India with respect to area and production. Mandarin juice is refreshing and nutritious due to its ascorbic acid content, sweet acid taste and appealing colour. Nagpur mandarin is being commercially grown in specific region of the country like Nagpur mandarin in Central India, Khasi mandarin in North Eastern regions and Coorg mandarin in Southern regions. The total production of mandarin in India is 34.31 lakh tonnes from an area of 330.0 thousand hectares with the productivity of 10.4 MT/ha (Anonymous, 2015). In Rajasthan mandarin covers 11.20 thousand hectares area producing 229.90 thousand MT with the productivity of 20.5 MT/ha. In the state, In Jhalawar district mandarin where it is grown over 37,251 ha area, 11,323 ha of which are in the fruit bearing stage and the production is 2.5 Lac tonnes [1].

Nutrition is one of the most important aspects of fruit production and accounts for thirty per cent of the total cost of cultivation. The nutrient plays an important role in the development and growth of new cells in plant meristem. The Calcium salts are known to be involved in a number of physiological processes concerning membrane structure, function and enzymatic activity. The exact role of calcium, like that of all minerals, is still obscure, but it is important for cell wall development [2]. Zinc (Zn) is an essential micro element for plants, being involved in many enzymatic reactions and is necessary for their good growth and development. Zinc improves the auxins content and it also acts as catalyst in oxidation-reduction processes [3]. Boron is also a heavy metal micronutrient. It is absorbed by plant in the form of boric acid (H_3BO_3). It is essential for translocation of sugar; involved in reproduction of plants and germination of pollen grains [4].

Since the demand of fruit is increasing in the market, thereby to achieve higher yield of good quality fruit with longer storage life become the priority. The application of mineral nutrients like calcium nitrate, boric acid and zinc sulphate are known to play a crucial role in growth, development, quality and storage of fruits. The present study will contribute in understanding the biochemical and storability status of Nagpur mandarin fruits at harvest as influenced by pre-harvest spray of mineral nutrients, which may help in increasing the quality and storage life of Nagpur mandarin. Hence the present studies were undertaken under Rajasthan conditions especially in Jhalawar with the followings objectives: To study the influence of pre harvest spray of Calcium nitrate, Boric acid and Zinc sulphate on yield and storage life of Nagpur mandarin.

Materials and Methods

The present investigation was carried out on eight years old Nagpur mandarin (*C. reticulata* Blanco.) of uniform size and growth at the Fruit research farm, Department of Fruit Science, College of Horticulture and Forestry, Jhalawar during the year 2014-15. The selected plants were sprayed with Calcium nitrate (1.0, 2.0 and 3.0 per cent), Boric acid (0.2, 0.4 and 0.6 per cent) and Zinc sulphate (0.2, 0.4 and 0.6 per cent).This experiment was laid out in Factorial Randomized Block Design (RBD) with three replications. The factors of experimentation comprising of 28 treatment combinations to study the influence of pre-harvest spray of Calcium nitrate, Boric acid and Zinc sulphate on quality and storability of Nagpur mandarin (*C. reticulata* Blanco). The treatments were applied during second week of September, 2014 after selection of good uniform size and bearer plant. The chemical composition of Nagpur mandarin fruits with respect to total soluble solids (TSS), total sugar, titrable acidity, ascorbic acid contents were determined by A.O.A.C. (2007) [5] by taking the samples from extracted juice of fruits. The data generated during the experimentation were subjected to statistical analysis of variance. The significance of the treatments was tested through 'F' test at 5 per cent level of significance. The critical difference was calculated to assess the significance of difference among the different treatments as described by Fisher (1950) [6].

Result and Discussion

Quality characteristics of fruits

It is evident from the results that pre-harvest application of micronutrients on Nagpur mandarin had significantly improved the nutritional quality of fruits in terms of TSS, acidity content, TSS/Acid ratio, sugars contents, ascorbic acid content, juice per cent and sensory score of fruit as compared to control.

However, the highest TSS, (12.05 ^{0}B), lowest acidity (0.73 %) and maximum TSS/ Acid ratio (15.97) were recorded under T_{24} (calcium nitrate @ 3.0 per cent + boric acid @ 0.4 per cent + zinc sulphate @ 0.6 per cent) treatment and T_{27} was found second best treatment with regards to these parameters (**Table 1**).

Table: 1 Influence of pre-harvest spray of calcium nitrate, boric acid and zinc sulphate on quality characteristics of Nagpur mandarin

Treatments		TSS (^{0}B)	T. Acidity (%)	TSS/Acid ratio	Reducing sugar (%)	Non Reducing (%)	Total sugar (%)
T_0	$Ca_0 B_0 Zn_0$	8.14	0.98	8.31	4.50	1.72	6.31
T_1	$Ca_1 B_1 Zn_1$	8.34	0.96	8.69	4.60	1.77	6.46
T_2	$Ca_1 B_1 Zn_2$	9.00	0.96	9.38	4.67	1.78	6.54
T_3	$Ca_1 B_1 Zn_3$	9.27	0.94	9.86	4.77	1.85	6.72
T_4	$Ca_1 B_2 Zn_1$	9.14	0.95	9.62	4.85	1.87	6.82
T_5	$Ca_1 B_2 Zn_2$	9.34	0.93	10.04	4.77	2.06	6.94
T_6	$Ca_1 B_2 Zn_3$	10.13	0.90	11.26	4.89	2.13	7.13
T_7	$Ca_1 B_3 Zn_1$	9.74	0.88	11.07	4.98	2.22	7.32
T_8	$Ca_1 B_3 Zn_2$	10.24	0.88	11.64	5.02	2.15	7.28
T_9	$Ca_1 B_3 Zn_3$	10.27	0.85	12.08	5.11	2.10	7.32
T_{10}	$Ca_2 B_1 Zn_1$	10.34	0.89	11.62	5.20	2.11	7.42
T_{11}	$Ca_2 B_1 Zn_2$	10.62	0.86	12.35	5.30	2.25	7.67
T_{12}	$Ca_2 B_1 Zn_3$	10.76	0.85	12.66	5.46	2.14	7.71
T_{13}	$Ca_2 B_2 Zn_1$	10.84	0.82	13.22	5.50	2.30	7.92
T_{14}	$Ca_2 B_2 Zn_2$	11.11	0.82	13.55	5.61	2.31	8.04
T_{15}	$Ca_2 B_2 Zn_3$	11.37	0.80	14.21	5.56	2.26	7.94

T_{16}	**Ca_2 B_3 Zn_1**	11.67	0.78	14.96	5.67	2.32	8.11
T_{17}	**Ca_2 B_3 Zn_2**	11.67	0.79	14.77	5.77	2.34	8.23
T_{18}	**Ca_2 B_3 Zn_3**	11.78	0.77	15.30	5.81	2.38	8.31
T_{19}	**Ca_3 B_1 Zn_1**	11.05	0.80	13.81	6.11	2.26	8.49
T_{20}	**Ca_3 B_1 Zn_2**	11.78	0.79	14.91	6.20	2.35	8.67
T_{21}	**Ca_3 B_1 Zn_3**	11.85	0.77	15.39	6.11	2.54	8.78
T_{22}	**Ca_3 B_2 Zn_1**	11.78	0.78	15.10	6.24	2.44	8.81
T_{23}	**Ca_3 B_2 Zn_2**	11.85	0.76	15.59	6.29	2.52	8.94
T_{24}	**Ca_3 B_2 Zn_3**	12.05	0.73	15.97	6.23	2.54	8.90
T_{25}	**Ca_3 B_3 Zn_1**	11.90	0.77	15.56	6.22	2.51	8.86
T_{26}	**Ca_3 B_3 Zn_2**	11.98	0.76	15.65	6.28	2.57	8.98
T_{27}	**Ca_3 B_3 Zn_3**	12.00	0.74	15.78	6.30	2.58	9.02
CD at 5%		0.12	0.01	0.18	0.06	0.02	0.08
SEm±		0.26	NS	0.40	NS	0.08	0.16

Ca_1 – Calcium nitrate– 1% B_1 – Boric acid – 0.2% Zn_1 – Zinc sulphate – 0.2%
Ca_2 – Calcium nitrate –2% B_2 – Boric acid – 0.4% Zn_2 – Zinc sulphate – 0.4%
Ca_3 – Calcium nitrate – 3% B_3 – Boric acid – 0.6% Zn_3 – Zinc sulphate – 0.6%

The higher total soluble solids and TSS: Acid ratio might be due to the efficient translocation of photosynthates to the fruit by regulation of calcium, boron and zinc. Ullah *et al.* (2012) [7] revealed that acidity percentage of mandarin fruit might have been reduced due to higher synthesis of nucleic acids, on account of maximum availability of plant metabolism. The similar results of increase in TSS, reduction in acidity and there by increased TSS / acid ratio was observed by these micronutrient treatments by Dawood *et al*. (2002) [8] in ‘Balady’ mandarin, El-Rahman (2003) [9] in Naval orange.

The data presented in (**Table 2**) clearly indicates that the pre-harvest spray of calcium nitrate, boric acid and zinc sulphate had significantly increased the sugar content (Non-reducing and total sugar) of Nagpur mandarin fruits whereas, reducing sugar per cent was not observed significantly. In the present investigation of Nagpur mandarin, the highest reducing sugar (6.30 %), non-reducing (2.58 %) and total sugar content (9.02 %) were recorded with T_{27} (calcium nitrate @ 3 per cent + boric acid @ 0.6 per cent + zinc sulphate @ 0.6 per cent) treatment. Whereas, the minimum reducing sugar (4.50 %), non-reducing sugar (1.72%) and total sugar (6.31%) were recorded at control. The increase in sugars fraction by the foliar feeding of zinc and boron might be due to their involvement in photosynthesis of metabolites and rapid translocation of sugars from other part of the plants to developing fruits [10]. These results are in conformity with the findings of El-Rahman (2003) [9] in Naval Orange, and Rajkumar *et al*. (2014) [11] in Guava.

The data in (Table 2) reveal that interaction effect of calcium nitrate, boric acid and zinc sulphate was significant on ascorbic acid of fruits. The ascorbic acid of Nagpur mandarin fruits (50.61 mg/100 ml) was recorded maximum with treatment T_{24} (calcium nitrate @ 3.0 per cent + boric acid @ 0.4 per cent + zinc sulphate @ 0.6 per cent) which was closely followed by $T_{27,}$ $T_{23,}$ $T_{26,}$ $T_{18,}$ T_{20} and T_{21} treatments. However, minimum ascorbic acid of fruit (34.95 mg) was recorded in control. Augmentation of ascorbic acid per cent age of mandarin fruit might be due to higher synthesis of nucleic acid, on account of maximum availability of plant metabolism [12]. These results are in conformity with the findings of Dawood *et al*. (2002) [8] in ‘Balady’ mandarin and Sajid *et al.* (2012) [12] in Sweet orange.

The data in (Table 2) reveal that the juice percent of Nagpur mandarin fruits (46.89) was recorded maximum with treatment T_{27} (calcium nitrate @ 3.0 per cent + boric acid @ 0.6 per cent + Zinc sulphate @ 0.6 per cent) which was closely followed by $T_{24,}$ $T_{23,}$ $T_{25,}$ T_{26} and T_{21} treatments. However, the minimum juice percent of fruit (32.43 %) was recorded in control. These results are in close conformity with those of Malik *et al.* (2000) [13] in Kinnow, El-Rahman (2003) [9] in Naval orange, Prakash *et al.* (2014) [14] in pomegranate.

The data in (Table 2) reveal that interaction effect of calcium nitrate, boric acid and zinc sulphate was not significantly affected the sensory score of Mandarin fruits. However, the maximum sensory score (9.23/10.00) was recorded with treatment T_{27} (calcium nitrate @ 3 per cent + boric acid @ 0.6 per cent + Zinc sulphate @ 0.6 per cent).Whereas, the minimum sensory score of Mandarin (7.11/10.00) was recorded under control. The maximum organoleptic rating due to application of calcium, zinc and boron might be due to better sugar acid ratio and better electrolytic balance of juice and overall enhancement of fruit quality. These results are in close conformity with those of Malik *et al.* (2000) [13] in Kinnow and El-Rehman *et al*. (2003) [9] in Sweet Orange.

Table 2 Influence of pre-harvest spray of calcium nitrate, boric acid and zinc sulphate on ascorbic acid content, juice per cent and sensory score of Nagpur mandarin

Treatments		Ascorbic acid (mg/100g)	Juice per cent	Sensory Score
T_0	Ca_0 B_0 Zn_0	34.95	32.43	7.11
T_1	Ca_1 B_1 Zn_1	35.16	35.17	7.36
T_2	Ca_1 B_1 Zn_2	37.99	34.23	7.37
T_3	Ca_1 B_1 Zn_3	37.54	36.42	7.44
T_4	Ca_1 B_2 Zn_1	37.89	36.11	7.59
T_5	Ca_1 B_2 Zn_2	38.50	38.47	7.89
T_6	Ca_1 B_2 Zn_3	40.66	37.83	7.48
T_7	Ca_1 B_3 Zn_1	40.87	40.67	7.91
T_8	Ca_1 B_3 Zn_2	42.96	38.18	8.16
T_9	Ca_1 B_3 Zn_3	40.12	40.96	7.95
T_{10}	Ca_2 B_1 Zn_1	43.66	38.27	7.98
T_{11}	Ca_2 B_1 Zn_2	45.17	39.98	8.27
T_{12}	Ca_2 B_1 Zn_3	42.90	41.36	8.37
T_{13}	Ca_2 B_2 Zn_1	44.81	40.37	8.37
T_{14}	Ca_2 B_2 Zn_2	47.67	43.11	8.44
T_{15}	Ca_2 B_2 Zn_3	47.92	43.24	8.40
T_{16}	Ca_2 B_3 Zn_1	45.76	42.55	8.28
T_{17}	Ca_2 B_3 Zn_2	46.17	43.82	8.41
T_{18}	Ca_2 B_3 Zn_3	48.87	41.11	8.54
T_{19}	Ca_3 B_1 Zn_1	46.11	43.68	8.67
T_{20}	Ca_3 B_1 Zn_2	48.78	42.11	8.60
T_{21}	Ca_3 B_1 Zn_3	48.11	44.68	8.51
T_{22}	Ca_3 B_2 Zn_1	47.78	43.21	8.70
T_{23}	Ca_3 B_2 Zn_2	49.97	45.78	8.79
T_{24}	Ca_3 B_2 Zn_3	50.61	46.24	9.05
T_{25}	Ca_3 B_3 Zn_1	47.12	45.67	8.92
T_{26}	Ca_3 B_3 Zn_2	49.93	45.03	9.12
T_{27}	Ca_3 B_3 Zn_3	50.11	46.89	9.23
SEm ±		0.94	0.90	0.19
C.D. at 5%		2.65	2.55	NS

Ca_1 – Calcium nitrate– 1.0 % B_1 – Boric acid – 0.2 % Zn_1 – Zinc sulphate – 0.2 %
Ca_2 – Calcium nitrate –2.0 % B_2 – Boric acid – 0.4 % Zn_2 – Zinc sulphate – 0.4 %
Ca_3 – Calcium nitrate – 3.0 % B_3 – Boric acid – 0.6 % Zn_3 – Zinc sulphate – 0.6 %

Storability Parameters

From the investigation, it is evident that the physiological loss in weight increased continuously from inception of study till the end of storage period irrespectively of different treatments applied (**Table 3**). The PLW per cent of Nagpur mandarin fruits (1.24%), (4.17%) and (9.27 %) was recorded minimum with treatment T_{27} (calcium nitrate @ 3 per cent + boric acid @ 0.6 per cent + Zinc sulphate @ 0.6 per cent) at 5^{th}, 10^{th} and 15^{th} day of storage at ambient temperature respectively. However, the maximum PLW (3.12 %), (6.72 %) and (11.42 %) was recorded under control at 5^{th}, 10^{th} and 15^{th} day of storage, respectively. The losses during the study periods occurred as a result of moisture loss from fruit skin through respiration and transpiration [8]. The present finding and were also supported by Dawood *et al*. (2002) [8] in Balady Mandarin and Yang and Lee (2003) [14] in Satsuma Mandarin.

The data in (**Table 4)** further reveal that effect of calcium nitrate, boric acid and zinc sulphate was significant on decay per cent of Mandarin fruits. The decay per cent increased gradually with the increase in the storage period in all the treatments. The minimum decay per cent (15.23 %) was recorded with treatment T_{27} (calcium nitrate @ 3.0 % + boric acid @ 0.6 % + Zinc sulphate @ 0.6 %) at 15^{th} day of storage at ambient temperature respectively, which was closely followed by T_{26}, T_{24} and T_{23} treatments. However, the maximum decay per cent (28.44 %) was recorded under control at 15^{th} day of storage.

The decay loss of fruit increased with the advancement of storage period and calcium, zinc and boron treated fruits show the minimum deccay loss [8]. Spoilage due to disease incidence was higher at ambient temperature. These finding are in general agreement with earlier finding with Amir *et al*., (2003) [15] in Kinnow, Yang and Lee (2003) [14] in Satsuma mandarin and Chaturvedi *et al*., (2007) in guava [4].

Table 3 Influence of pre-harvest spray of calcium nitrate, boric acid and zinc sulphate on Physiological loss in weight at 0^{th}, 5^{th}, 10^{th} and 15^{th} day of storage of Nagpur mandarin

Treatments		Physiological Loss in Weight (PLW %)		
		5-days	10-days	15-days
T_0	$Ca_0\ B_0\ Zn_0$	3.12	6.72	11.42
T_1	$Ca_1\ B_1\ Zn_1$	3.10	6.62	11.39
T_2	$Ca_1\ B_1\ Zn_2$	3.02	6.41	11.27
T_3	$Ca_1\ B_1\ Zn_3$	2.97	6.28	11.04
T_4	$Ca_1\ B_2\ Zn_1$	3.05	6.34	11.14
T_5	$Ca_1\ B_2\ Zn_2$	3.12	6.21	11.14
T_6	$Ca_1\ B_2\ Zn_3$	2.91	6.11	10.97
T_7	$Ca_1\ B_3\ Zn_1$	2.82	6.02	10.84
T_8	$Ca_1\ B_3\ Zn_2$	2.74	5.91	10.78
T_9	$Ca_1\ B_3\ Zn_3$	2.62	5.84	10.67
T_{10}	$Ca_2\ B_1\ Zn_1$	2.52	5.63	10.78
T_{11}	$Ca_2\ B_1\ Zn_2$	2.34	5.27	10.45
T_{12}	$Ca_2\ B_1\ Zn_3$	2.43	5.55	10.23
T_{13}	$Ca_2\ B_2\ Zn_1$	2.23	5.21	10.34
T_{14}	$Ca_2\ B_2\ Zn_2$	2.18	5.08	10.14
T_{15}	$Ca_2\ B_2\ Zn_3$	2.04	4.94	9.82
T_{16}	$Ca_2\ B_3\ Zn_1$	2.13	5.05	10.04
T_{17}	$Ca_2\ B_3\ Zn_2$	2.02	4.88	9.92
T_{18}	$Ca_2\ B_3\ Zn_3$	1.94	4.81	9.87
T_{19}	$Ca_3\ B_1\ Zn_1$	1.81	4.78	9.81
T_{20}	$Ca_3\ B_1\ Zn_2$	1.67	4.54	9.74
T_{21}	$Ca_3\ B_1\ Zn_3$	1.72	4.47	9.55
T_{22}	$Ca_3\ B_2\ Zn_1$	1.64	4.51	9.77
T_{23}	$Ca_3\ B_2\ Zn_2$	1.55	4.42	9.61
T_{24}	$Ca_3\ B_2\ Zn_3$	1.34	4.23	9.41
T_{25}	$Ca_3\ B_3\ Zn_1$	1.52	4.40	9.52
T_{26}	$Ca_3\ B_3\ Zn_2$	1.37	4.36	9.49
T_{27}	$Ca_3\ B_3\ Zn_3$	1.24	4.17	9.27
SEm ±		0.05	0.06	0.08
C.D. at 5%		0.14	0.16	0.20

Ca_1 – Calcium nitrate– 1%	B_1 – Boric acid – 0.2%	Zn_1 – Zinc sulphate – 0.2%,
Ca_2 – Calcium nitrate –2%	B_2 – Boric acid – 0.4%	Zn_2 – Zinc sulphate – 0.4%,
Ca_3 – Calcium nitrate – 3%	B_3 – Boric acid – 0.6%	Zn_3 – Zinc sulphate – 0.6%

The juice percent of Nagpur mandarin during storage reduced with the advancement of storage periods at room temperature (**Table 5**).The Fruit treated with (calcium nitrate @ 3.0 % + boric acid @ 0.6 % + Zinc sulphate @ 0.6 %) retained maximum juice per cent at the end of storage period. Higher retention of juice per cent of mandarin fruits (46.31 %), (44.52 %), (41.77%) and (39.12 %) were recorded maximum with treatment T_{27} (calcium nitrate @ 3 per cent + boric acid @ 0.6 per cent + Zinc sulphate @ 0.6 per cent) at 0^{th}, 5^{th},10^{th} and 15^{th} day of storage at ambient temperature, respectively. while, minimum juice per cent (35.20%), (31.83 %), (27.40 %) and (25.90%) was recorded under control at 0^{th}, 5^{th}, 10^{th} and 15^{th} day of storage, respectively.

It was probably due to moisture loss from the rind of epidermal cells during storage and also drying of juice vesicles indicating that the fruit juice contents decreased with increasing storage durations irrespective of foliar spray. The increase in fruit juice contents of plant sprayed with micronutrients might be due to active absorption of micronutrients mobilizing them to the active sites of fruit development. The present results are in conformity with the findings of Amir *et al.* (2003) in Kinnow [15], Yang and Lee (2003) [14] in Satsuma mandarin, Sajid *et al.* (2012) [12] in sweet Orange.

Table 4 Influence of pre-harvest spray of calcium nitrate, boric acid and zinc sulphate on decay per cent at 0th, 5th, 10th and 15th day of storage of Nagpur mandarin

Treatments		Decay per cent %		
		5th –day	**10th –day**	**15th –day**
T_0	**Ca_0 B_0 Zn_0**	7.72	16.89	28.44
T_1	**Ca_1 B_1 Zn_1**	7.11	16.34	28.33
T_2	**Ca_1 B_1 Zn_2**	6.67	16.34	27.78
T_3	**Ca_1 B_1 Zn_3**	6.67	16.00	27.34
T_4	**Ca_1 B_2 Zn_1**	7.23	15.56	27.78
T_5	**Ca_1 B_2 Zn_2**	6.34	15.56	26.89
T_6	**Ca_1 B_2 Zn_3**	6.34	14.24	26.50
T_7	**Ca_1 B_3 Zn_1**	5.67	14.24	27.34
T_8	**Ca_1 B_3 Zn_2**	6.12	13.89	24.50
T_9	**Ca_1 B_3 Zn_3**	5.00	13.33	24.89
T_{10}	**Ca_2 B_1 Zn_1**	5.33	12.68	24.34
T_{11}	**Ca_2 B_1 Zn_2**	5.50	12.34	22.23
T_{12}	**Ca_2 B_1 Zn_3**	4.67	12.50	23.50
T_{13}	**Ca_2 B_2 Zn_1**	4.44	13.23	22.23
T_{14}	**Ca_2 B_2 Zn_2**	4.11	11.11	20.77
T_{15}	**Ca_2 B_2 Zn_3**	3.89	10.34	20.34
T_{16}	**Ca_2 B_3 Zn_1**	3.33	11.44	20.77
T_{17}	**Ca_2 B_3 Zn_2**	2.23	10.34	18.44
T_{18}	**Ca_2 B_3 Zn_3**	3.33	10.27	20.11
T_{19}	**Ca_3 B_1 Zn_1**	2.23	10.11	18.23
T_{20}	**Ca_3 B_1 Zn_2**	1.92	10.34	20.34
T_{21}	**Ca_3 B_1 Zn_3**	1.92	10.11	20.67
T_{22}	**Ca_3 B_2 Zn_1**	2.23	9.45	18.44
T_{23}	**Ca_3 B_2 Zn_2**	0.00	8.72	17.11
T_{24}	**Ca_3 B_2 Zn_3**	0.00	8.45	15.78
T_{25}	**Ca_3 B_3 Zn_1**	1.67	9.11	17.34
T_{26}	**Ca_3 B_3 Zn_2**	0.00	8.45	15.56
T_{27}	**Ca_3 B_3 Zn_3**	0.00	8.22	15.23
SEm ±		0.17	0.24	0.45
C.D. at 5%		0.55	0.62	1.26

Ca_1 – Calcium nitrate– 1% B_1 – Boric acid – 0.2% Zn_1 – Zinc sulphate – 0.2%
Ca_2 – Calcium nitrate –2% B_2 – Boric acid – 0.4% Zn_2 – Zinc sulphate – 0.4%
Ca_3 – Calcium nitrate – 3% B_3 – Boric acid – 0.6% Zn_3 – Zinc sulphate – 0.6%

Table 5 Influence of pre-harvest spray of calcium nitrate, boric acid and zinc sulphate on juice per cent at 0th, 5th, 10th and 15th day of storage of Nagpur mandarin

Treatments		Juice percent during storage			
		On the day of Storage	**At 5th day**	**At 10th day**	**At 15th day**
T_0	**Ca_0 B_0 Zn_0**	35.20	31.83	27.40	25.90
T_1	**Ca_1 B_1 Zn_1**	36.46	32.51	28.63	25.04
T_2	**Ca_1 B_1 Zn_2**	36.75	32.91	29.68	26.98
T_3	**Ca_1 B_1 Zn_3**	37.95	33.28	29.11	26.21
T_4	**Ca_1 B_2 Zn_1**	39.28	36.08	32.66	29.10
T_5	**Ca_1 B_2 Zn_2**	37.64	34.44	31.02	27.46
T_6	**Ca_1 B_2 Zn_3**	38.07	34.87	31.45	27.89
T_7	**Ca_1 B_3 Zn_1**	40.63	37.43	34.01	30.45
T_8	**Ca_1 B_3 Zn_2**	41.62	38.42	35.00	31.44
T_9	**Ca_1 B_3 Zn_3**	39.36	36.16	32.74	29.18
T_{10}	**Ca_2 B_1 Zn_1**	40.54	37.34	33.92	30.36
T_{11}	**Ca_2 B_1 Zn_2**	41.67	38.47	35.05	31.49

T_{12}	**Ca_2 B_1 Zn_3**	42.93	39.93	36.80	33.53
T_{13}	**Ca_2 B_2 Zn_1**	40.51	37.51	34.38	31.11
T_{14}	**Ca_2 B_2 Zn_2**	43.03	39.51	35.82	28.16
T_{15}	**Ca_2 B_2 Zn_3**	40.23	37.51	31.63	27.64
T_{16}	**Ca_2 B_3 Zn_1**	40.23	37.51	31.63	27.64
T_{17}	**Ca_2 B_3 Zn_2**	43.03	38.61	34.68	30.98
T_{18}	**Ca_2 B_3 Zn_3**	40.23	38.03	35.22	32.22
T_{19}	**Ca_3 B_1 Zn_1**	43.38	41.18	38.37	35.37
T_{20}	**Ca_3 B_1 Zn_2**	42.89	40.69	37.88	34.88
T_{21}	**Ca_3 B_1 Zn_3**	44.49	41.41	36.30	31.78
T_{22}	**Ca_3 B_2 Zn_1**	42.61	40.41	37.60	34.60
T_{23}	**Ca_3 B_2 Zn_2**	45.77	43.17	40.93	38.28
T_{24}	**Ca_3 B_2 Zn_3**	46.12	44.14	41.58	38.93
T_{25}	**Ca_3 B_3 Zn_1**	44.80	42.80	40.26	37.67
T_{26}	**Ca_3 B_3 Zn_2**	45.82	43.77	41.28	38.63
T_{27}	**Ca_3 B_3 Zn_3**	46.31	44.52	41.77	39.12
SEm ±		0.95	0.40	0.40	0.32
C.D. at 5%		2.70	1.15	1.15	0.91

Ca_1 – Calcium nitrate– 1% | B_1 – Boric acid – 0.2% | Zn_1 – Zinc sulphate – 0.2%
Ca_2 – Calcium nitrate –2% | B_2 – Boric acid – 0.4% | Zn_2 – Zinc sulphate – 0.4%
Ca_3 – Calcium nitrate – 3% | B_3 – Boric acid – 0.6% | Zn_3 – Zinc sulphate – 0.6%

The data in (**Table 6**) reveal that the overall sensory score based on colour, aroma and test of mandarin fruit decreased with the advancing period of storage at room temperature. The highest score (9.15/ 10), (9.05/ 10), (8.81/ 10) and (8.41/ 10) were recorded with treatments T_{27} (calcium nitrate @ 3.0 % + boric acid @ 0.6 % + Zinc sulphate @ 0.6 %) at 0^{th}, 5^{th}, 10^{th} and 15^{th} day of storage, respectively which was closely followed by T_{24} and T_{26} treatments. However, minimum sensory score (7.58/ 10), (7.23/ 10) (6.76 /10) and (6.39/ 10) were recorded under control at 0^{th}, 5^{th}, 10^{th} and 15^{th} day of storage at ambient temperature, respectively.

It was probably due to delayed ripening in fruits, retardation of moisture loss, rotting and shrinkage. It may be assumed that higher rate of losses in weight during storage might have been due to raised energy requirement during storage. The present results are in conformity with the findings of Robson *et al*. [16] in peach and Patel and Tiwari [17] in Guava.

Table 6 Influence of pre-harvest spray of calcium nitrate, boric acid and zinc sulphate on sensory score at 0^{th}, 5^{th}, 10^{th} and 15^{th} day of storage of Nagpur mandarin

Treatments		**Sensory score**			
		On the day of storage	**5-days**	**10-days**	**15-days**
T_0	Ca_0 B_0 Zn_0	7.58	7.23	6.76	6.39
T_1	Ca_1 B_1 Zn_1	7.64	7.34	6.96	6.46
T_2	Ca_1 B_1 Zn_2	7.67	7.47	7.05	6.55
T_3	Ca_1 B_1 Zn_3	7.70	7.52	7.08	6.58
T_4	Ca_1 B_2 Zn_1	7.80	7.61	7.18	6.68
T_5	Ca_1 B_2 Zn_2	7.82	7.62	7.22	6.72
T_6	Ca_1 B_2 Zn_3	7.98	7.79	7.39	6.89
T_7	Ca_1 B_3 Zn_1	7.50	7.31	6.91	6.42
T_8	Ca_1 B_3 Zn_2	7.98	7.79	7.36	6.86
T_9	Ca_1 B_3 Zn_3	8.07	7.88	7.50	7.00
T_{10}	Ca_2 B_1 Zn_1	8.02	7.84	7.46	6.96
T_{11}	Ca_2 B_1 Zn_2	7.88	7.72	7.32	6.84
T_{12}	Ca_2 B_1 Zn_3	8.08	7.90	7.56	7.08
T_{13}	Ca_2 B_2 Zn_1	7.58	7.43	7.10	6.62
T_{14}	Ca_2 B_2 Zn_2	8.13	7.97	7.67	7.23
T_{15}	Ca_2 B_2 Zn_3	8.17	8.01	7.71	7.27
T_{16}	Ca_2 B_3 Zn_1	8.49	8.33	8.03	7.59

T_{17}	$Ca_2 B_3 Zn_2$	8.26	8.10	7.82	7.38
T_{18}	$Ca_2 B_3 Zn_3$	8.75	8.59	8.31	7.89
T_{19}	$Ca_3 B_1 Zn_1$	8.63	8.47	8.19	7.77
T_{20}	$Ca_3 B_1 Zn_2$	8.25	8.11	7.85	7.43
T_{21}	$Ca_3 B_1 Zn_3$	8.76	8.62	8.36	7.94
T_{22}	$Ca_3 B_2 Zn_1$	8.45	8.32	8.06	7.64
T_{23}	$Ca_3 B_2 Zn_2$	8.80	8.67	8.42	8.00
T_{24}	$Ca_3 B_2 Zn_3$	9.10	8.98	8.73	8.33
T_{25}	$Ca_3 B_3 Zn_1$	8.84	8.72	8.46	8.04
T_{26}	$Ca_3 B_3 Zn_2$	9.04	8.94	8.69	8.29
T_{27}	$Ca_3 B_3 Zn_3$	9.15	9.05	8.81	8.41
SEm ±		0.18	0.11	0.08	0.07
C.D. at 5%		0.52	0.34	0.23	0.22

Ca_1 – Calcium nitrate– 1% B_1 – Boric acid – 0.2% Zn_1 – Zinc sulphate – 0.2%
Ca_2 – Calcium nitrate –2% B_2 – Boric acid – 0.4% Zn_2 – Zinc sulphate – 0.4%
Ca_3 – Calcium nitrate – 3% B_3 – Boric acid – 0.6% Zn_3 – Zinc sulphate – 0.6%

Conclusion

On the basis of results obtained from the field experiment, it may be concluded that the pre-harvest spray of different micronutrients was found beneficial for quality and storability of Nagpur mandarin especially under Agro-climatic zone-V of Rajasthan i.e. in Jhalawar condition. However, among different interaction treatments, T_{27} treatment (calcium nitrate @ 3 % + boric acid @ 0.6 % + Zinc sulphate @ 0.6 %) has given significantly maximum increase reducing sugar, non reducing sugar, total sugar, juice per cent, sensory score over control. This treatment combination also significantly reduced physiological loss in weight, decay percent and higher retention of juice percent and sensory score till end of storage period. Further, T_{24} treatment combination (calcium nitrate @ 3 % + boric acid @ 0.4 % + Zinc sulphate @ 0.6 %) has also significantly increased TSS, TSS: Acid ratio, ascorbic acid content, and reduced number of seeds per fruit and acidity percent of fruits.

References

[1] Anonymous (2015) Indian Horticulture Database, 2014. Published From National Horticulture Board, Gurgaon, pp.118-121.

[2] Katiyar, P. N., Singh, J.P and Singh, P.C. 2008. Effect of Zinc sulphate, Borax and Calcium nitrate on flowering, yield and quality of Litchi cv. Dehradun Journal of Rural and Agricultural Research, 8 (2): 49-51

[3] Razzaq, K., Khan, A.S., Malik, A.U., Shahid, M. and Ullah, S. 2013. Influences of foliar application of zinc on growth, yield and quality of Kinnow mandarin. Journal of Plant Nutrition, 36 (10): 1479-1495.

[4] Chaturvedi, R.S., Gaur, O. P. and Singh, G. 2007.Effect of Pre-harvest sprays of zinc, calcium and boron on the storage behaviour of guava (Psidium guajava L.) cv. Allahabad Safeda. Acta Horticulturae; 7 (35): 633-638

[5] A.O.A.C. 2007. Official Method of Analysis. 15th Ed.Vol II. Association of Official Analytical Chemists. Washington, D.C.

[6] Fisher, R.A., 1950. Statistical methods for research workers. Oliver and Boyd, Edinburgh.

[7] Ullah, S., Khan, A.S., Malik, A.U., Afzal, I., Shahid, M. and Razzaq, K. 2012. Foliar application of boron influences the leaf mineral status, growth, yield and quality of Kinnow mandarin (Citrus reticulata Blanco). Journal of Plant Nutrition, 35 (13): 2067-2079.

[8] Dawood, S. A., Meligy, M. S. and El-Hamady, M. M. 2002. Influence of pre harvest spray of calcium nitrate, zinc sulphate and boric acid on quality and shelf life of Balady mandarin. Annals of Agricultural Science, 39(1): 433-447

[9] El-Rahman, A.M.A. (2003) Effects of some nutrients and growth substances application on fruiting, yield and fruit quality of Navel orange trees. Bulletin of Faculty of Agriculture, Cairo University, 54 (2): 175-187

[10] Singh, P. C. Gangwar, R. S. and Singh, V. K. 2012. Effect of micronutrients spray on fruit drop, yield and quality of Aonla cv. Banarasi. Hort Flora Research Spectrum, 1(1):73-76

[11] Rajkumar, Tiwari, J.P. and Shant, Lal. 2014. Effect of foliar spray of zinc and boron on yield and quality of Guava cv. Pant Prabhat. Annals of Agric. Biol. Res. 19 (1): 105-108.

[12] Sajid, M., Rab, A., Tanveer, S., Iqbal, A., Zamin, M. and Shakur, M. 2012.Pre-harvest treatment of Zn & B affects the fruit quality and storability of sweet orange. J. Agric. Sci. and Technol., 2 (2):1224-1233
[13] Malik, R.P., Ahlawat, V.P. and Nain, A.S. 2000.Effect of foliar spray of urea and zinc sulphate on yield and quality of Kinnow mandarin. Haryana Journal of Horticultural Science, 29 (12): 37-38.
[14] Yang, Y. J. and Lee, K. A. 2003.Postharvest quality of Satsuma mandarin fruit affected by pre harvest spray of micronutrients. Acta Horticulturae; 41 (600): 775-779
[15] Amir, M., Chaturvedi, O.P. and Tripathi, V.K. 2003. Effect of pre-harvest application of gibberellic acid and calcium nitrate on the fruit maturity and storage quality of Kinnow Mandarin. Farm Science Journal, 12 (2): 148-149.
[16] Robson, M.G., Hopfinger, J. and. Eck, P. 1999. Postharvest sensory evaluation of calcium and zinc treated peach fruit. Acta Hort. 25 (4) :173–177.
[17] Patel, V. and Tiwari, R. 2014. Effect of pre-harvest spray of nutrients on delayed ripening and prolonged storability of guava fruits. Annals of Plant and Soil Research 16(4): 327-329.

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