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Chemical Quality Parameters of Mandarin (*Citrus reticulata* Blanco.) Fruits Influenced by different Organic Sources

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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 carried out during the year 2021-22 and 2022-23 on 12 years old mandarin plants at the Instructional Farm, Department of Fruit Science, College of Horticulture and Forestry, Jhalawar. The experiment was consisting of 21 treatments of different organic source of NPK *viz*., vermicompost, cotton fortified vermicompost, neem cake, cotton cake, mustard cake and bio fertilizers such as PSB and VAM with three levels of recommendation dose of fertilizers. The experiment was laid out in randomized block design with three replications. Among different treatments, treatment T_9 (75 % RDF + 10 kg Vermicompost + 7.5 kg Neem cake + 50 g PSB) was

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found best with regards to maximum pooled TSS (11.74 ^{0}B), reducing sugar (6.30%) non-reducing sugar (2.62%), total sugar (8.92%) per cent, sugar/acid ratio (14.40), ascorbic acid (53.08mg/100g) and juice (46.57%). Therefore, based on two years experimentation, use of organic source of nutrients with bio-fertilizers favoured biochemical compounds of Nagpur Mandarin fruits.

Keywords: Juice; mandarin; neem cake; nitrogen; TSS; sugars.

1. INTRODUCTION

Mandarin (*Citrus reticulata* Blanco.) is considered to be one of the most important cultivated species among citrus fruits. It belongs to the family Rutaceae and sub-family Aurantioideae. In the genus of citrus, there are 162 species which is extensively grown in the tropical and sub-tropical regions of the worldand most of the species are originated from South East Asia, mainly India and China.

The authentication of the Nagpur mandarin variety, a geographically distinct and economically significant citrus variety from India, requires a multidimensional approach combining morphological, biochemical, and molecular techniques. Morphologically, the Nagpur mandarin is characterized by its medium-sized fruit, thin peel, and distinctive deep orange color. These physical features are supplemented by organoleptic properties, such as its balanced sweet-acidic flavor profile, juicy pulp, and high aroma content, distinguishing it from other mandarin varieties. Biochemical assays focusing on its unique phytochemical composition—particularly its high levels of carotenoids, flavonoids, and essential oils—further confirm its identity. HPLC analysis of flavonoid content, coupled with quantification of limonene and linalool in the essential oil fraction, serves as critical biochemical markers. Additionally, molecular techniques such as DNA fingerprinting, based on simple sequence repeats (SSR) and sequence-related amplified polymorphism (SRAP) markers, provide high specificity in distinguishing the Nagpur mandarin at the genetic level. These DNA markers offer reliable, reproducible results, confirming genetic purity and geographical origin. Combined, these morphological, biochemical, and molecular tools ensure the accurate authentication of the Nagpur mandarin, facilitating its protection under geographical indication (GI) status and supporting quality control measures in the marketplace.

Vermicompost is an eco-friendly natural fertilizer prepared from biodegradable organic wastes, rich in macro and micronutrients, vital plant promoting substances, humus farming substances, N-fixers and humus forming microorganism (Bhandari et al., 2018). It is a stable fine granular organic matter, which loosens the soil and provides passage for entry of air. It grows plants extremely well and can also be used as structural additives for poorer soils to provide nutrients and minimize erosion. Biofertilizers are microbial preparations containing living cells of different microorganisms which have the ability to mobilize plant nutrients in soil from unusable to usable form through biological process. They are environmental friendly and play significant role in crop production. The use of organic manure along with biofertilizers and inorganic fertilizers has resulted in beneficial effects on growth, yield and quality of various fruit crops (Bhandari et al., 2018). Biofertilizers have gone a long way and are accepted as important nutrient inputs under both integrated nutrient management strategy and organic management approach.

The efficiency of phosphate fertilizer is very low in soil and it is mostly unavailable to the crop because of its low solubility. Phosphate Solubilizing Bacteria (*PSB*) is another important biofertilizers which has capacity to solubilize the native phosphorus due to secretion of organic acid. It also produces plant growth promoting substances like vitamin B12 and auxin.*PSB* is also produce growth promoting substances which might enhance the crop growth. These hormones from *PSB* might have increased the various endogenous hormonal levels in plant tissue, that may enhance pollen germination and tube growth, which ultimately increased the fruit set. The oil-cakes such as *neem*, mustard, cotton, castor, *karanj*, groundnut, *mahua etc.* are the natural fertilizers which are used for the control of phytonematodes and as soil amendments. Oil-cakes are the best option against phytoparasitic nematodes not only because of its ease of availability but also the economic feasibility for the growers/farmers. Neem cake also decreases the pH of soil because it produces organic acids so it is used to reduce the alkalinity of the soil Krishnaraj et al., (2018). Cotton seed oilcake and mustard oilcake are highly valued because both of them contain high amount of macro and micro nutrients which released slowly in soil. Cotton seed in oilcakes and mustard oilcake are the residues that remain after extracting the oil from the seeds of cotton and mustard, respectively. Both CSOC and MOC are beneficial for soil health and safe for the environment (Yasmin et al*.,* 2020).

2. MATERIALS AND METHODS

2.1 Location

Jhalawar district is located at 23^0 4' to 24^0 52' N-Latitude and 75^0 29' to 76^0 56' E-Longitude in South-Eastern, Rajasthan. Agro-climatically, the district falls in Zone V, known as Humid South Eastern Plain. About 84.22 per cent population of the district is rural whose main occupation is agriculture. Average rainfall in the region is 954.7 mm. Maximum temperature range in the summer is 43 ^{0}C-48 ^{0}C and minimum 3 ^{0}C-5 ^{0}C during winter. Agriculture and forest lands occupy 73.5 per cent area respectively, in the district.

2.2 Plant Material

For the present investigation of study, "Nagpur Mandarin" planting materials were obtained from the Central Citrus Research Institute, Nagpur, Maharashtra, ensuring the authenticity and genetic purity of the variety. The plants were selected for their health, uniform growth and vigor at the time of transplanting to establish a reliable experimental baseline. The plants were free from any visible signs of disease or pest infestation and they exhibited consistent morphology typical of the Nagpur Mandarin variety.

The planting layout followed a 6 x 6 meter spacing to provide adequate room for root development and canopy expansion, promoting healthy plant growth and reducing competition for water, nutrients and sunlight. This spacing is standard for mandarin orchards, facilitating ease of management practices such as pruning, irrigation and pest control. At the Instructional Farm of the College of Horticulture and Forestry, Jhalawar, a block of 126 Nagpur Mandarin plants of uniform size and growth was selected for the experiment. These plants were evaluated over two consecutive years (2021-22 and 2022-23) for study of quality and physiological responses under local agro-climatic conditions. The careful selection of planting materials was critical in ensuring the success of the experiment, as healthy and uniform plants are essential for producing reliable and reproducible results in horticultural research.

2.3 Experimental Details

The field experiment was laid out in simple Randomized Block Design (RBD) with three replications. The experimentation comprising of 21 treatment combinations (T_0- Control (100 % RDF), T_1-75 % RDF, T_2-75 % RDF + 10 kg VC, T_3- 75 % RDF + 10 kg CFV, T_4- 75 % RDF + 7.5 kg NC, T_5- 75 % RDF + 7.5 kg CC, T_6- 75 % RDF + 7.5 kg MC, T_7- 75 % RDF + 50 g PSB, T_8- 75 % RDF + 50 g VAM, T_9- 75 % RDF + 10 kg VC + 7.5 kg NC + 50 g PSB, T_{10}- 50 % RDF + 50 g PSB, T_{11}- 50 % RDF + 50 g VAM, T_{12}- 50 % RDF + 10 kg VC + 50 g PSB, T_{13}- 50 % RDF + 10 kg VC + 50 g VAM, T_{14}- 50 % RDF + 7.5 kg NC + 50 g PSB, T_{15}- 50 % RDF + 7.5 kg NC + 50 g VAM, T_{16}- 50 % RDF + 7.5 kg CC + 50 g PSB, T_{17}- 50 % RDF + 7.5 kg CC + 50 g VAM, T_{18}- 50 % RDF + 7.5 kg MC + 50 g PSB, T_{19}- 50 % RDF + 7.5 kg MC + 50 g VAM, T_{20}- 50 % RDF + 10 kg VC + 7.5 kg NC + 50 g PSB). The treatments consisted of different organic source namely vermicompost, cotton fortified vermicompost, *neem* cake, cotton cake, mustard cake and bio fertilizers such as PSB and VAM with three levels of recommendation dose of fertilizers. For application of manure the top soil around the tree (equal to the leaf canopy of the tree) is dug up to 30 cm and the fertilizers were uniformly mixed into the soil, then which was leveled. Irrigation is supplied immediately after manures application. The whole amounts of the organic manure were applied as a basal dose during the month of June. The required quantity of organic manures @ 300: 200: 250 NPK g / plant were applied during the month of June under the spread of trees, 30 cm away from the trunk and mixed with soil. The required quantity of oilcakes were powdered and applied to the treatment plant. Bio fertilizers such as VAM and PSB were applied through soil inoculation on the onset of Monsoon.

2.4 Total Soluble Solids

Total soluble solids content of the fruit was determined by using a hand refractometer of 0-30 per cent range. In this case one drop of fruit juice was put on the prism of the refractometer and per cent TSS was recorded directly. The values were corrected at 20 ˚C and expressed as per cent total soluble solids of the fruits A.O.A.C. (1990).

2.5 Total Acidity (%)

The acidity was determined by diluting the known volume of clean juice with distilled water and titrating the same against standard $^{N}/_{10}$ NaOH solution using phenolphthalein as in indicator until faint pink colour was appeared. The result was expressed in terms of per cent acidity of the fruit juice A.O.A.C. (1990).

2.6 Total Sugars

Total sugars were estimated by taking 25 grams of clean juice, which were thoroughly homogenized with distilled water in warring blender and the volume was made to 250 ml. To this 250 ml solution, 2 ml of saturated lead acetate was added and kept as such for ten minutes. Thereafter, 2 ml of potassium oxalate was added to remove the excess of lead. The solution was kept as such for another ten minutes and then filtered. Hundred ml of this filtered solution was hydrolysed by adding two ml of concentrated HCl, allowing it to stand overnight for completing the inversion of sucrose. The excess of HCl was neutralized with saturated NaOH after the completion of hydrolysis in the next morning. The solution so obtained was titrated against 10 ml of the boiling Fehling's solution (5 ml each of Fehling solution A and B) in a conical flask, using methylene blue as an indicator. The end point was indicated by the appearance of brick red colour. The total sugars content was expressed as percentage of juice weight as per the method of A.O.A.C. (1990), using formula as:

$$\text{Total sugar (\%)} = \frac{\text{Fehling factor x Dilution}}{\text{Titre value x weight of sample taken}} \text{ x } 100$$

2.7 Reducing Sugar

The clarified solution of juice was titrated against 10 ml of boiling Fehling solutions (5 ml each of Fehling A and B) using methylene blue as an indicator, as per the method ascribed in A.O.A.C. (1990). The reducing sugars content was expressed as percentage.

$$\text{Reducing sugar (\%)} = \frac{\text{Fehling factor x Dilution}}{\text{Titre value x weight of sample taken}} \text{ x } 100$$

2.8 Non-Reducing Sugar

The amount of non-reducing sugar was obtained by subtracting reducing sugar from the amount of total sugar and multiplying the resultant by factor 0.95.

Non-reducing Sugar % = (Total Sugar % – Reducing Sugar %) × 0.95

2.9 Ascorbic Acid (mg/100 g)

Ascorbic acid content of juice was determined by diluting the known volume of clean juice with 3 per cent metaphosphoric acid to appropriate volume. A 10 ml of aliquot was taken and titrated against 2, 6 dichlorophenol indophenol solution after standardization (AOAC 1990) until light pink colour appeared. The result was expressed as mg ascorbic acid / 100 ml juice.

2.10 Juice Percentage

The fruits of mandarin were cut into equal halves and their juice was extracted with simple juice extractor. The juice was weighed with the help of balance and the percentage of juice was worked out on the basis of total weight of fruit and weight of juice.

2.11 Juice pH

The pH of juice was recorded by electrode pH meter.

3. RESULTS

3.1 Total Soluble Solids (^{0}B)

From the Table 1 the data indicated that total soluble solid (^{0}B) of Nagpur Mandarin was significantly increased by the application of different organic sources of NPK during the year 2021-22 and 2022-23. The maximum TSS (^{0}B) of fruits (11.6), (11.9) and (11.7) was observed under the treatment T_9 (75 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) which was closely followed by T_{20} (50 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) having values of (11.5), (11.8) and (11.7) during both the years 2021-22, 2022-23 and in pooled analysis respectively. However, the minimum TSS (^{0}B) of fruits (9.3), (9.4) and (9.4) was observed under T_1 (75 % RDF) during 2021-22, 2022-23 and in pooled analysis respectively.

3.2 Acidity Per Cent

From the Table 1 the data indicated that acidity per cent of Nagpur Mandarin was significantly reduced by the application of different organic sources of NPK during the year 2021-22 and 2022-23. The minimum acidity per cent of fruit

(0.63 %), (0.61 %) and (0.62 %) was observed under the treatment T_9 (75 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) which was closely followed by T_{20}(50 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) having values of (0.65 %), (0.62 %) and (0.63 %) during both the years 2021-22, 2022-23 and in pooled analysis respectively. However, the maximum acidity per cent of fruits (0.92), (0.91 %) and (0.91 %) was observed under T_1 (75 % RDF) during 2021-22, 2022-23 and in pooled analysis respectively.

3.3 Reducing Sugar Per Cent

From the Table 2 the data indicated that reducing sugar per cent of Nagpur Mandarin was significantly increased by the application of different organic sources of NPK during the year 2021-22 and 2022-23. The maximum reducing sugar per cent of fruit (6.23 %), (6.36 %) and (6.30 %) was observed under the treatment T_9 (75 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) which was closely followed by T_{20} (50 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) having values of (6.20 %), (6.33 %) and (6.27 %) during both the years 2021-22, 2022-23 and in pooled analysis respectively. However, the minimum reducing sugar per cent of fruits (4.87 %), (4.88 %) and (4.87 %) was observed under T_1 (75 % RDF) during 2021-22, 2022-23 and in pooled analysis respectively.

3.4 Non-Reducing Sugar Per Cent

From the Table 2 the data indicated that non-reducing sugar per cent of Nagpur Mandarin was significantly increased by the application of different organic sources of NPK during the year 2021-22 and 2022-23. The maximum non-reducing sugar per cent of fruit (2.60 %), (2.65 %) and (2.62 %) was observed under the treatment T_9 (75 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) which was closely followed by T_{20} (50 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) having values of (2.58 %), (2.64 %) and (2.61 %) during both the years 2021-22, 2022-23 and in pooled analysis respectively. However, the minimum non-reducing sugar per cent of fruits (2.01 %), (2.02 %) and (2.02 %) was observed under T_1 (75 % RDF) during 2021-22, 2022-23 and in pooled analysis respectively.

Table 1. Effect of different organic sources on total soluble solids (^{0}Brix) and acidity per cent of mandarin (*Citrus reticulata* Blanco.) cv. Nagpur Mandarin

Treatments	Total soluble solids (^{0}Brix)			Acidity per cent		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_0	9.43	9.51	9.47	0.91	0.90	0.90
T_1	9.33	9.43	9.38	0.92	0.91	0.91
T_2	9.97	10.16	10.06	0.82	0.79	0.80
T_3	9.90	10.09	9.99	0.85	0.83	0.84
T_4	10.13	10.33	10.23	0.79	0.76	0.78
T_5	10.23	10.43	10.33	0.78	0.75	0.77
T_6	10.03	10.22	10.13	0.81	0.78	0.79
T_7	9.87	10.13	10.00	0.86	0.84	0.85
T_8	9.80	9.99	9.89	0.87	0.85	0.86
T_9	11.57	11.92	11.74	0.63	0.61	0.62
T_{10}	9.73	10.01	9.87	0.88	0.86	0.87
T_{11}	9.53	9.71	9.62	0.89	0.87	0.88
T_{12}	10.53	10.73	10.63	0.76	0.73	0.75
T_{13}	10.70	10.90	10.80	0.75	0.72	0.74
T_{14}	11.13	11.34	11.24	0.68	0.65	0.66
T_{15}	11.00	11.21	11.10	0.69	0.66	0.68
T_{16}	11.27	11.59	11.43	0.66	0.63	0.64
T_{17}	11.23	11.45	11.34	0.67	0.64	0.66
T_{18}	10.90	11.11	11.00	0.70	0.67	0.69
T_{19}	10.83	11.04	10.94	0.71	0.68	0.70
T_{20}	11.50	11.83	11.66	0.65	0.62	0.63
SE (m) ±	0.11	0.26	0.16	0.05	0.02	0.01
C.D. at 5%	0.31	0.74	0.47	0.16	0.07	0.05

Table 2. Effect of different organic sources on reducing sugar, non-reducing sugar and total sugar per cent of mandarin (*Citrus reticulata* Blanco.) cv. Nagpur Mandarin

Treatments	Reducing sugar per cent			Non-reducing sugar per cent			Total sugar per cent		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_0	4.90	4.92	4.91	2.03	2.05	2.04	6.93	6.98	6.95
T_1	4.87	4.88	4.87	2.01	2.02	2.02	6.88	6.90	6.89
T_2	5.50	5.62	5.56	2.29	2.34	2.31	7.79	7.95	7.87
T_3	5.43	5.55	5.49	2.26	2.30	2.28	7.69	7.85	7.77
T_4	5.53	5.65	5.59	2.37	2.41	2.39	7.90	8.06	7.98
T_5	5.60	5.72	5.66	2.43	2.48	2.46	8.03	8.20	8.11
T_6	5.53	5.65	5.59	2.31	2.36	2.33	7.84	8.01	7.92
T_7	5.40	5.51	5.46	2.25	2.29	2.27	7.65	7.81	7.73
T_8	5.30	5.41	5.36	2.21	2.26	2.23	7.51	7.67	7.59
T_9	6.23	6.36	6.30	2.60	2.65	2.62	8.83	9.02	8.92
T_{10}	5.17	5.28	5.22	2.15	2.20	2.18	7.32	7.47	7.40
T_{11}	5.03	5.14	5.09	2.07	2.11	2.09	7.10	7.25	7.17
T_{12}	5.83	5.96	5.89	2.45	2.50	2.47	8.28	8.46	8.37
T_{13}	5.90	6.02	5.96	2.46	2.51	2.48	8.36	8.53	8.44
T_{14}	6.10	6.23	6.16	2.55	2.61	2.58	8.65	8.84	8.74
T_{15}	6.07	6.19	6.13	2.54	2.60	2.57	8.61	8.79	8.70
T_{16}	6.17	6.30	6.23	2.58	2.63	2.60	8.74	8.93	8.83
T_{17}	6.17	6.30	6.23	2.57	2.62	2.60	8.74	8.92	8.83
T_{18}	6.07	6.19	6.13	2.53	2.59	2.56	8.60	8.78	8.69
T_{19}	5.97	6.09	6.03	2.49	2.54	2.51	8.45	8.63	8.54
T_{20}	6.20	6.33	6.27	2.58	2.64	2.61	8.78	8.97	8.88
SE (m) ±	0.15	0.07	0.14	0.14	0.12	0.13	0.10	0.17	0.17
C.D. at 5%	0.45	0.22	0.40	0.40	0.37	0.37	0.30	0.51	0.50

3.5 Total Sugar Per Cent

From the Table 2 the data indicated that total sugar per cent of Nagpur Mandarin was significantly increased by the application of different organic sources of NPK during the year 2021-22 and 2022-23. The maximum total sugar per cent of fruit (8.83 %), (9.02 %) and (8.92 %) was observed under the treatment T_9 (75 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) which was closely followed by T_{20} (50 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) having values of (8.78%), (8.97 %) and (8.88 %) during both the years 2021-22, 2022-23 and in pooled analysis respectively. However, the minimum total sugar per cent of fruits (6.88 %), (6.90 %) and (6.89 %) was observed under T_1 (75 % RDF) during 2021-22, 2022-23 and in pooled analysis respectively.

3.6 Sugar/Acid Ratio

From the Table 3 the data indicated that sugar/acid ratio of Nagpur Mandarin was significantly increased by the application of different organic sources of NPK during the year 2021-22 and 2022-23. The maximum sugar/acid ratio (14.00), (14.8) and (14.4) was observed under the treatment T_9 (75 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) which was closely followed by T_{20} (50 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) having values of (13.6), (14.5) and (14.1) during both the years 2021-22, 2022-23 and in pooled analysis respectively. Treatment T_{16} (50 % RDF + 7.5 kg Cotton Cake + 50 g PSB), T_{17} (50 % RDF + 7.5 kg Cotton Cake + 50 g VAM), T_{14} (50 % RDF + 7.5 kg *Neem* Cake + 50 g PSB) and T_{15} (50 % RDF + 7.5 kg *Neem* Cake + 50 g VAM) were also found at par. However, the minimum sugar/acid ratio (7.5), (7.6) and (7.6) was observed under T_1 (75 % RDF) during 2021-22, 2022-23 and in pooled analysis respectively.

3.7 Ascorbic Acid (mg/100 g)

From the Table 3 the data indicated that Ascorbic acid (mg/100 g) of Nagpur Mandarinwas significantly increased by the application of different organic sources of NPK during the year 2021-22 and 2022-23. The maximum Ascorbic acid (52.50 mg), (53.66 mg) and (53.08 mg) per 100 g was observed under the treatment T_9 (75 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) which was closely followed by T_{20} (50 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) having values of (50.83 mg), (51.95 mg) and (51.39 mg) during both the years 2021-22, 2022-23 and in pooled analysis respectively. However, the minimum Ascorbic acid (mg/100 g) (41.00 mg), (41.60 mg) and (41.30 mg) was observed under T_1 (75 % RDF) during 2021-22, 2022-23 and in pooled analysis respectively.

3.8 Juice Per Cent

From the Table 4 the data indicated that juice per cent of Nagpur Mandarin was significantly increased by the application of different organic sources of NPK during the year 2021-22 and 2022-23. The maximum juice per cent (46.20 %), (46.94 %) and (46.57 %) was observed under the treatment T_9 (75 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) which was closely followed by T_{20} (50 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) having values of (45.87 %), (46.60 %) and (46.23 %) during both the years 2021-22, 2022-23 and in pooled analysis respectively. Treatment T_{16} (50 % RDF + 7.5 kg Cotton Cake + 50 g PSB), T_{17} (50 % RDF + 7.5 kg Cotton Cake + 50 g VAM), T_{14} (50 % RDF + 7.5 kg *Neem* Cake + 50 g PSB) and T_{15} (50 % RDF + 7.5 kg *Neem* Cake + 50 g VAM) were also found at par. However, the minimum juice per cent (35.30 %), (35.63 %) and (35.47 %) was observed under T_1 (75 % RDF) during 2021-22, 2022-23 and in pooled analysis respectively.

3.9 Juice pH

From the Table 4 the data indicated that juice pH of Nagpur Mandarin was significantly increased by the application of different organic sources of NPK during the year 2021-22 and 2022-23. The minimum juice pH (3.38), (3.42) and (3.40) was observed under the treatment T_9 (75 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) which was closely followed by T_{20} (50 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) having values of (3.36), (3.41) and (3.39) during both the years 2021-22, 2022-23 and in pooled analysis respectively. However, the maximum juice pH (3.09), (3.13) and (3.11) was observed under T_1 (75 % RDF) during 2021-22, 2022-23 and in pooled analysis respectively.

4. DISCUSSION

The integrated nutrient management increased TSS and total sugars due to gradual supply of nutrients and organic manures throughout the growth period which increased the metabolites in improvement in soil moisture availability, organic carbon, and nutrient status of the soil and decrease acidity of fruits may be attributed to their conversion into sugars and their derivatives by the reactions involving reversal of glycolytic pathway or might be used in respiration or both observed by Bhandari (2018). Similar findings were also reported by Dwivedi (2013). Vadak et al*.,* (2014) reported that VAM converts the unavailable nutrient from rhizosphere soil to available forms resulting increased uptake of nutrient. Besides increased nutrient absorbing area of root, so increase in the chemical quality of fruits may be due to beneficial and stimulatory effect of nitrogen and other nutrient Reddy et al*,* (2022).

Table 3. Effect of different organic sources on sugar/acid ratio and ascorbic acid of mandarin (*Citrus reticulata* Blanco.) cv. Nagpur Mandarin

Treatments	Sugar/acid ratio			Ascorbic acid (mg/100 g)		
	2021-22	**2022-23**	**Pooled**	**2021-22**	**2022-23**	**Pooled**
T_0	7.6	7.8	7.7	41.17	41.77	41.47
T_1	7.5	7.6	7.6	41.00	41.60	41.30
T_2	9.5	10.1	9.8	42.50	43.44	42.97
T_3	9.0	9.5	9.3	42.33	43.26	42.80
T_4	10.0	10.6	10.3	43.17	44.12	43.64
T_5	10.3	10.9	10.6	43.33	44.29	43.81
T_6	9.7	10.3	10.0	42.67	43.61	43.14
T_7	8.9	9.3	9.1	42.33	43.05	42.69
T_8	8.6	9.1	8.9	42.00	42.77	42.38
T_9	14.0	14.8	14.4	52.50	53.66	53.08
T_{10}	8.3	8.7	8.5	41.83	42.57	42.20
T_{11}	8.0	8.4	8.2	41.67	42.37	42.02
T_{12}	10.9	11.6	11.2	45.10	46.09	45.60
T_{13}	11.1	11.8	11.5	46.37	47.39	46.88
T_{14}	12.8	13.7	13.2	49.17	50.25	49.71
T_{15}	12.5	13.3	12.9	49.00	50.08	49.54
T_{16}	13.4	14.3	13.8	50.07	51.17	50.62
T_{17}	13.1	13.9	13.5	49.63	50.73	50.18
T_{18}	12.3	13.1	12.7	48.67	49.74	49.20
T_{19}	11.9	12.7	12.3	47.17	48.20	47.69
T_{20}	13.6	14.5	14.1	50.83	51.95	51.39
SE (m) ±	0.32	0.33	0.44	2.52	1.40	1.26
C.D. at 5%	0.93	0.95	1.27	7.22	4.02	3.60

Table 4. Effect of different organic sources on juice per cent and juice pH of mandarin (*Citrus reticulata* Blanco.) cv. Nagpur Mandarin

Treatments	Juice per cent			Juice pH		
	2021-22	**2022-23**	**Pooled**	**2021-22**	**2022-23**	**Pooled**
T_0	35.87	36.44	36.15	3.10	3.14	3.12
T_1	35.30	35.63	35.47	3.09	3.13	3.11
T_2	39.70	40.34	40.02	3.19	3.23	3.21
T_3	38.37	38.98	38.67	3.16	3.20	3.18
T_4	40.87	41.52	41.19	3.22	3.26	3.24
T_5	41.40	42.06	41.73	3.23	3.27	3.25
T_6	40.50	41.15	40.82	3.20	3.24	3.22
T_7	37.83	38.44	38.14	3.15	3.19	3.17
T_8	37.13	37.73	37.43	3.14	3.18	3.16
T_9	46.20	46.94	46.57	3.38	3.42	3.40
T_{10}	36.77	37.35	37.06	3.13	3.17	3.15
T_{11}	36.40	36.98	36.69	3.12	3.16	3.14
T_{12}	41.80	42.47	42.13	3.25	3.29	3.27
T_{13}	42.43	43.11	42.77	3.26	3.30	3.28

Treatments	Juice per cent			Juice pH		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_{14}	44.77	45.48	45.12	3.33	3.38	3.36
T_{15}	44.07	44.77	44.42	3.32	3.36	3.34
T_{16}	45.30	46.02	45.66	3.36	3.40	3.38
T_{17}	45.03	45.75	45.39	3.34	3.38	3.36
T_{18}	43.50	44.20	43.85	3.31	3.35	3.33
T_{19}	42.83	43.52	43.18	3.30	3.34	3.32
T_{20}	45.87	46.60	46.23	3.36	3.41	3.39
SE (m) ±	0.20	0.57	0.69	0.02	0.02	0.01
C.D. at 5%	0.58	1.65	1.99	0.07	0.06	0.05

The improvement in ascorbic acid in Nagpur mandarin fruits might be due to enhanced catalytic activity of multiple enzymes which participate in bio- synthesis of ascorbic acid and its precursor from sugars. The similar results are in accordance with the findings of Binepal et al*.,* (2013) in guava, Khera and Bal (2014) in lemon and Debbarma and Hazarika (2016) in acid lime.

The maximum juice recovery per cent of fruits could be attributed to synergistic combination of, organic inorganic and bio fertilizer sources (PSB and VAM) which might be resulted in improvement of soil structure, enhanced availability of nutrients, root proliferation, augmentation of favorable soil micro-organism in a holistic manner. Water is the main component of juice vesicles and juice recovery output, its increased availability in clayey vertisols within some limits was apt to increase juice content percentage favorably. The results of present investigations are elaborated by similar results in sweet orange by Singh et al*.,* (2000) Jain and Choudhary (2023).

Organic amendments impact the pH of mandarin juice by improving nutrient balance, soil health, and the plant's resilience to environmental stress. The inclusion of organic amendments and balanced nutrient application reduces the accumulation of organic acids in the fruit, leading to higher juice pH. This increase in juice pH not only improves flavor by reducing sourness but also contributes to better consumer acceptance and extended shelf life. Same results were found by Ramesh, et al*.,* (2021), Verma et al*.,* (2022) and Sharma et al*.,* (2020).

5. CONCLUSION

From the investigations, it was observed that the maximum fruit TSS, sugar per cent (reducing, non-reducing and total sugar), sugar/acid ratio, ascorbic acid and juice per cent were recorded under treatment T_9 (75 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB) which was closely followed by T_{20} (50 % RDF + 10 kg Vermicompost + 7.5 kg *Neem* Cake + 50 g PSB). Therefore, based on two year experimentation, it may be concluded that the organic use of source of nutrients with bio-fertilizers favoured quality of Nagpur Mandarin.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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